DEPARTMENT OF OCCUPATIONAL SAFETY AND HEALTH MALAYSIA
MINISTRY OF HUMAN RESOURCES, MALAYSIA

GUIDELINES ON OCCUPATIONAL SAFETY AND HEALTH IN CONSTRUCTION, OPERATION AND MAINTENANCE OF BIOGAS PLANT

2016

FOREWORD

The Guidelines on Occupational Safety and Health in Construction, Operation & Maintenance of Biogas Plant has been developed to provide information and recommendations on the safe design, construction, operation and maintenance of biogas plant.

Decomposition of organic waste such as Palm Oil Mill Effluent (POME), food waste, animal waste, sewage etc. via anaerobic process produces biogas that contains methane. The biogas can be captured by using the closed anaerobic digester (tank/pond) and can be used as a source of renewable energy (RE). By capturing methane, which is a greenhouse gas (GHG), this step can reduce the GHG emissions which cause global warming, reduce dependency on fossil fuel and generate economic returns. Since POME is the biggest biogas feedstock, therefore under the Entry Point Project Number 5 (EPP 5) - National Key Economic Area (NKEA) for oil palm sector, the government is targeting all palm oil mills to install biogas plants entrapment by 2020.

These guidelines are intended to assist industry in designing and building a biogas plant in a safe manner, and also aim to reduce employee exposure to hazards that exist when operating and maintaining the biogas plant. These guidelines use a risk-based approach, identifying risks associated with biogas plant as well as potential options to mitigate those risks.

I would like to thank and acknowledge those who have assisted in the development of these guidelines.

Thank you.

Director General
Department of Occupational Safety and Health
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Malaysia
2016

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ABBREVIATIONS

ABS	Acrylonitrile-Butadiene-Styrene
AD	Anaerobic Digestion
Bio-CNG	Bio-Compressed Natural Gas
CA	Covered Anaerobic
CHP	Combined Heat and Power
COD	Chemical Oxygen Demand
DOE	Department of Environment
DOSH	Department of Occupational Safety and Health
FGV	Felda Global Ventures Holdings Berhad
GHG	Greenhouse Gas(es)
HDPE	High-Density Polyethylene
HRT	Hydraulic Retention Time
ICE	Internal Combustion Engine
IEC	International Electrotechnical Commission
IPCC	Intergovermental Panel on Climate Change
LPG	Liquefied Petroleum Gas
MS	Malaysian Standards
MPOB	Malaysian Palm Oil Board
NIOSH	National Institute of Occupational Safety and Health
NSWMD	National Solid Waste Management Department
POME	Palm Oil Mill Effluent
PPE	Personal Protective Equipment
PVC	Polyvinyl chloride
SDR	Sime Darby Research Sdn Bhd
SEDA	Sustainable Energy Development Authority
SPD	Surge Protection Device
TAN	Total Acid Number
UV	Ultraviolet

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1. INTRODUCTION

1.1 What is biogas?

Biogas is a gas mixture obtained from the decomposition of organic matter by bacteria in anaerobic conditions. The gas mixture consists of CH_4, CO_2, H, N_2, H_2O, and H_2S. The proportion of these gases can be seen in the Table 1 below. Methane (CH_4) is the main component in the fuel, and it is flammable. Methane content in biogas is over 50%.

1.2 Biogas properties

The composition and properties of biogas varies to some degree depending on feedstock types, digestion systems, temperature, retention time etc. Table 1 contains average biogas composition values, found in most of the literature.

Table 1: Composition of Biogas

CONSTITUENT	SYMBOL	CONCENTRATION
Methane	CH_4	50-75%
Carbon Dioxide	CO_2	25-45%
Hydrogen	H	< 1%
Nitrogen	N_2	< 2%
Water	H_2O	2-7% (20-40°C)
Hydrogen Sulphide	H_2S	20-20,000 ppm
Oxygen	O_2	< 2%

(Source: Guide to Biogas from production to use, 2010)

1.3 How it works?

Biogas is produced in a biological process. In the absence of oxygen (anaerobic process), organic matter is broken down in a digester to form a gas mixture known as biogas. The organic matter is converted almost entirely to biogas by a range of different microorganisms. Energy (heat) and new biomass are also generated.

1.4 Methanogen bacteria

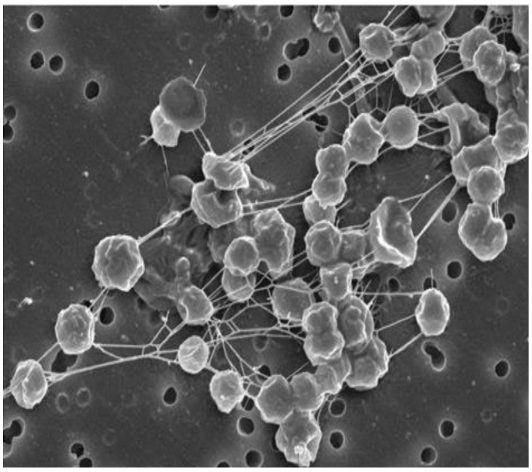


Figure 1: Methanogen bacteria (Source: Diversity of Plants)

In order to produce the biogas, there are 4 main process involve, which is Hydrolysis, Acidogenesis, Acetogenesis and Methanogenesis. The methanogen bacteria will convert the intermediate product (hydrolysis, acidogenesis & acetogenesis) into methane (CH_4) and carbon dioxide (CO_2). 70% of the formed methane originates from acetate, while the remaining 30% is produced from conversion of hydrogen (H) and carbon dioxide (CO_2) as following figure:

Acetic acid —*Methanogenic bacteria*→ *Methane+ Carbon Dioxide*

Hydrogen + Carbon Dioxide —*Methanogenic bacteria*→ *Methane + water*

Figure 2: Methanogenesis process

1.5 How much to be gained from a biogas entrapment activities?

The total quantity of biogas obtained from organic waste will depend on the nature of the organic waste used, design of digester system and the entrapment infrastructure. Some digesters are capable of producing 20m^3 per Metric Tons and the number can be much higher depending on the digester capacity. The quantity of gas produced also depends on the quality of organic waste used in the digester, digester design and operation systems.

1.6 Why is it important to capture methane gas?

Biogas is a gaseous fuel high in calorific value (CV), 20MJ/m^3. Its energy potential is huge although not as good as natural gas (38MJ/m^3) and Liquefied Petroleum Gas or LPG, (100MJ/m^3). The energy released makes biogas perfect for use as a fuel in a gas engine to convert the energy in the gas into electricity and heat.

Methane in the biogas emitted into atmosphere is a greenhouse gas (GHG) and is 25 times more potent than CO_2 in its global warming potential (IPCC 2007). Methane together with CO_2, water vapour and nitrogen oxides contribute towards climate change by containing the heat within the globe's atmosphere, causing temperatures to rise and forming a blanket to prevent heat radiation from the earth at night. As a result, biogas causes detrimental effects to the environment.

With biogas capture, the GHG can greatly be reduced and the biogas can be used as renewable energy to replace fossil fuel for steam or electricity generation. The excess electricity generated can also be supplied to the national grid through a proper mechanism allowed by the government.

1.7 The composition of biogas, bio-methane and natural gas

Table 2: Composition of biogas, bio-methane and natural gas

GAS COMPOSITION	BIOGAS	BIO-METHANE	NATURAL GAS
Methane (CH_4)	50-75%	94-99.9%	93-98%
Carbon Dioxide (CO_2)	25-45%	0.1-4%	1%
Nitrogen (N_2)	<2%	<3%	1%
Oxygen (O_2)	<2%	<1%	-
Hydrogen (H_2)	<1%	Traces	-
Hydrogen Sulphide (H_2S)	20-20,000ppm	<10 ppm	-
Ammonia (NH_3)	Traces	Traces	-
Ethane (C_2H_6)	-	-	<3%
Propane (C_3H_8)	-	-	<2%
Siloxane	'Traces'	-	-
Water	2-7% (20-40°C)	-	-

1.8 Glossary of terms

1.8.1 *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).

1.8.2 *Biogas*

A gas generally composed of approximately one-half to two-thirds methane and approximately one-third carbon dioxide that is produced from organic residues with a heating value averaging approximately 20 MJ/m^3 to 26 MJ/m^3. By the nature of the biological process under anaerobic conditions, its production and constituents are considered flammable, corrosive, and potentially hazardous.

1.8.3 *Biogas plant*

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

1.8.4 *Biogas scrubbing*

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.

1.8.5 *CHP unit*

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

1.8.6 *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.

1.8.7 *Collection*

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

1.8.8 *Contaminant*

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

1.8.9 Covered Anaerobic (CA) Pond/Tank

Is an Anaerobic Pond/Tank 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.

1.8.9 Desludging

Removing settled solids from an effluent pond.

1.8.10 Digestate

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

1.8.11 Digester

Covered Anaerobic (CA) pond/tank where microbial breakdown of the feedstock occurs.

1.8.12 Feedstock

The feedstock (sometimes also known as substrate or input) for anaerobic digestion consists of (a mix of) digestible organic materials such as POME (Palm Oil Mill Effluent), animal waste (manure) or agricultural waste.

1.8.13 Flares

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

1.8.14 Flame arrester

A device to quench and stop migration and propagation of flame into a combustible gas system.

1.8.15 Gas storage

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

1.8.16 GHG

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

1.8.17 IEC

The International Electrotechnical 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 Malaysia.

1.8.18 May

Indicates the existence of an option.

1.8.19 Nutrient

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

1.8.20 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.

1.8.21 Setbacks

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.

1.8.22 Shall

Indicates that an action is mandatory.

1.8.23 Should

Indicates a recommendation.

1.8.24 Sludge

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

1.8.25 Supernatant

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

1.8.26 Waste discharges

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

1.8.27 Zones

Potentially explosive areas are classified into zones according to the probability of the occurrence of a potentially explosive atmosphere according to IEC definitions for classifying zones.

1.9 Main components and functions

1.9.1 Main components in Covered Anaerobic Tank/Pond digester

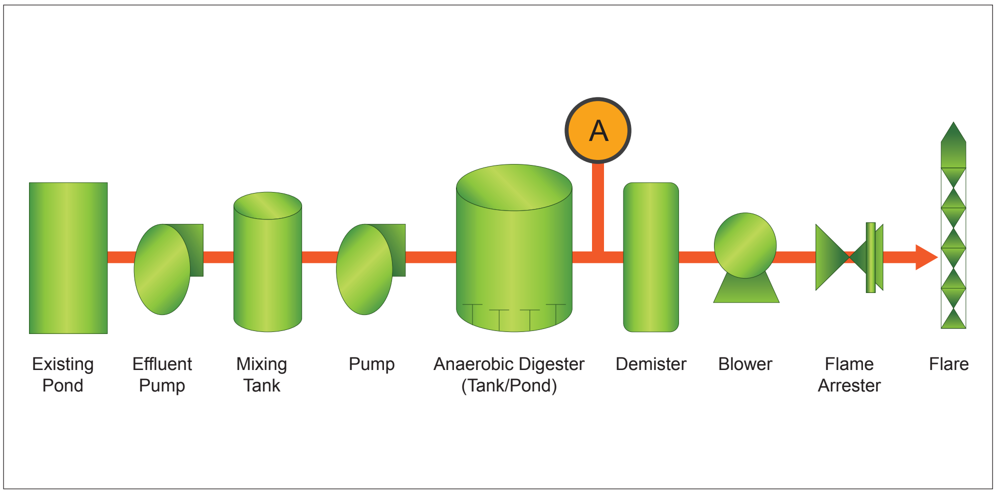


Figure 3: Main components in covered anaerobic tank/pond digester

Note: Option of biogas utilisation, continues from point ‘A’, see 1.10

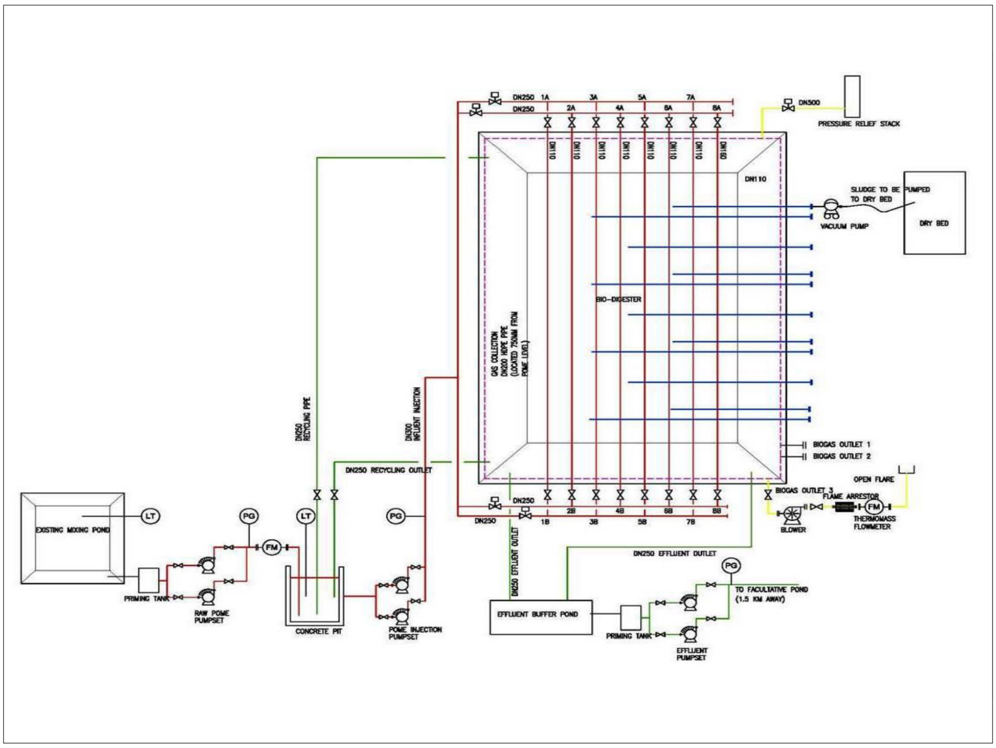


Figure 4: Example of schematic diagram for CA pond (Source: FGV)

1.9.1.1 *Existing Pond*

Serves as a collection point for sewage sludge or waste from the plant.

Figure 5: Sewage Pond (Source: Layfield Group)

1.9.1.2 *Mixing Pit*

To mix the sewage sludge from the plant and the excess wastewater from the digester before re-entering the biogas digester.

Figure 6: Above ground mixing pit (Source: FGV)

Figure 7: Under Ground Mixing Pit (Source: FGV)

1.9.1.3 Effluent Pump

To transfer the feedstock/substrate to the digester or the digestate from digester to the sludge tank.

Figure 8: Pump station (Source: FGV)

Figure 9: Centrifugal pump (Source: Process Industry Forum)

1.9.1.4 Digester

Where the decomposition of feedstock takes place, in absence of oxygen, and where biogas is produced. The components contained in digester are:-

Table 3: Digester components

COMPONENT	FUNCTIONS
Inlet Pipe	To channel effluent from existing pond into the digester.
Membrane	To collect biogas.
Liner & Skirting	To hold the membrane and prevent sewage sludge from seeping into the ground.
Desludging pipe	To dispose digestate inside the digester
Relief Valve/Emergency Stack	To remove the excess biogas pressure in the digester.
Outlet pipe/Overflow pipe	To discharge the excess sewage sludge in the digester into the concrete pit.
Biogas Outlet pipe	To transport the biogas from digester

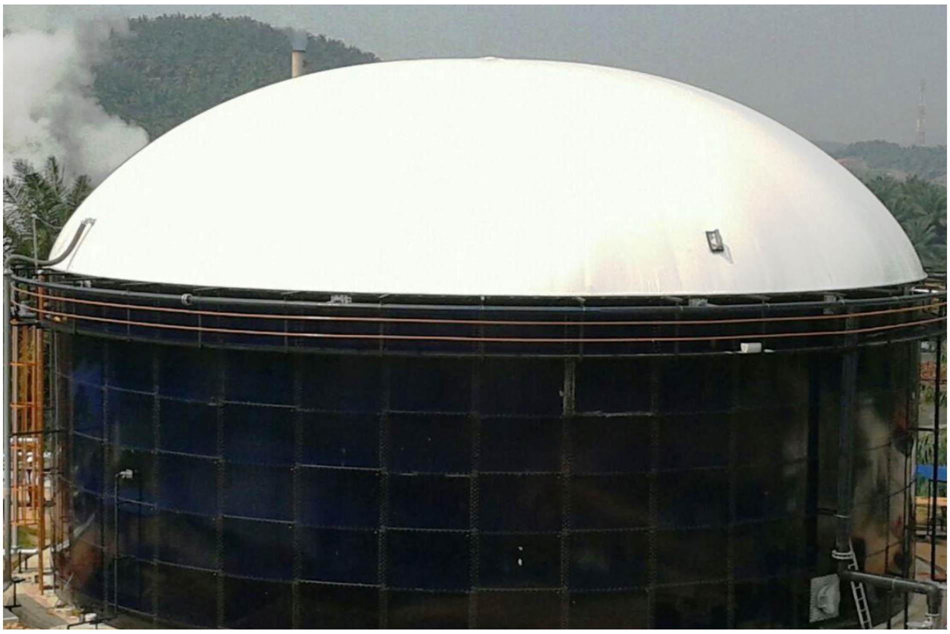


Figure 10: CA digester tank (Source: FGV)

Figure 11: CA digester pond (Source: FGV)

1.9.1.5 Demister

To separate gas and moisture before the gas is supplied to the blower.

Figure 12: Demister - Moisture Separator (Source: BKE Combustion Control)

1.9.1.6 Blower

To transfer the biogas from the digester to the flare.

Figure 13: Blower piping system (Source: BKE Combustion Control)

1.9.1.7 Flame Arrester

To prevent combustion in the flare going back into the biogas piping system.

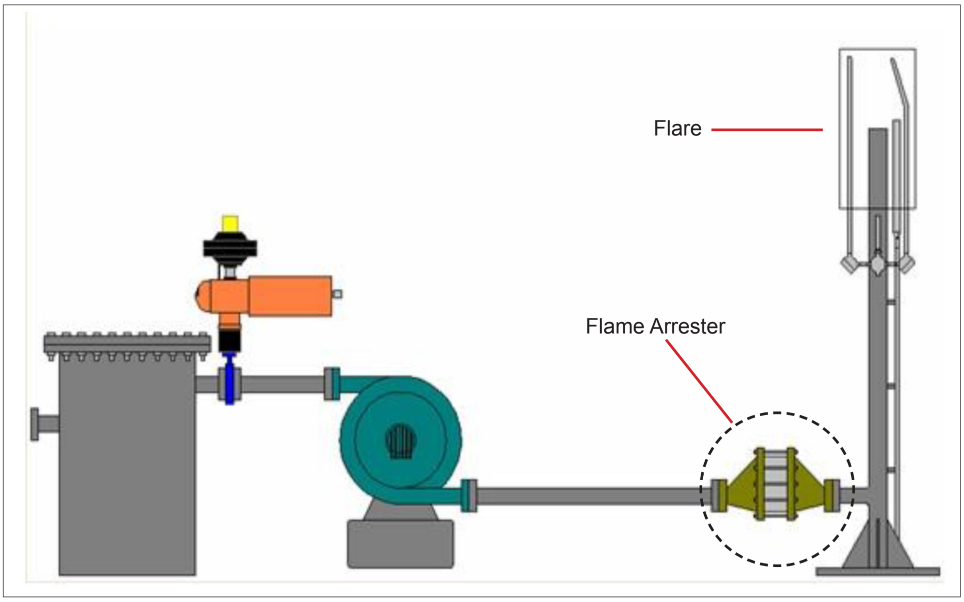


Figure 14: Flame arrester and flare stack (Source: Flare Guys)

Figure 15: Flame Arrester (Source: Pentair)

1.9.1.8 Flare

In normal condition, gas is conditioned to run combined heat and power (CHP). During shut down or maintenance, if there is no storage tank available the gas is burned off using flare system. Flare is divided into two types; Open Flares and Enclosed Flares.

Figure 16: Open Flare (Source: FGV)

Figure 17: Enclosed Flare (Source: FGV)

In choosing the right flare, one must consider few elements that will meet the need and objective of a system. Amongst others are shown in Table 4 below.

Table 4: Types of flares

OPEN FLARE	ENCLOSED FLARE
Cannot meet performance or emission standards	Meet performance and emission standards
May be skid mounted and collapsed for transport	Permanent system, 10 metre to 15 metre height
Costs are 20% to 75% of equivalent enclosed flares	Capable of operation over a wide range of combustion conditions
Suitable for temporary or test uses only	Can be further engineered to meet specific site

(Source: Investing in Bioenergy solutions, 2012)

1.9.1.9 *Piping*

As part of conveyance, piping is used to transfer biogas. It has to be safe, economic and should allow the required gas-flow for the specific gas appliance. The piping system has to be reliably gas-tight during the life-span of the biogas unit. In the past, faulty piping systems were the most frequent reason for gas losses in biogas units.

Biogas piping shall:

(a) take the most direct route or minimum route necessary to provide biogas cooling;
(b) contain as few elbows, drops, and risers as practicable;
(c) be of sufficient size to accommodate the maximum load requirements.

For isolation and purging purposes, the piping system shall be divided into separate trains or lines and shall be provided with a manual shut-off valve at each end, with the exception of the line supplying the waste gas burner, which shall have a valve only at the take-off point.

Figure 18: Digester pipeline (Source: FGV)

1.9.1.10 Lightning & surge protection device

Lightning protection system consists of an external and internal lightning protection system. The external lightning protection system will intercept the lightning strikes and conduct and disperse the lightning current to the ground without causing damage to the protected structures.

Meanwhile, for the internal lightning protection, a surge protection device (SPD) is used to protect the electrical equipment from over-voltage transients caused by lightning strikes.

Since an explosive mixture of gas and air is formed in the vicinity of digesters and gas tanks, these parts are classified as potentially explosive atmospheres. As a result, the biogas plant should be installed with the lightning protection systems according to the requirements of the MS IEC 62305 (Protection against Lightning) and also can be referred to the handbook “Guide on Lightning Protection System for Building” by Energy Commission, to ensure permanent availability and safe operation.

1.10 Biogas utilisation

Biogas has many energy utilisations, depending on the nature of the biogas source and the demand. The simplest way of utilising biogas is direct burning in boilers or burners. Generally, biogas can be used for heat production by direct combustion, electricity production by fuel cells or micro-turbines, CHP generation or on any machinery that used CNG, such as vehicles.

However, biogas needs to undergo 'conditioning process' such as condensation and particulate removal, compression, cooling and drying on which will remain outside the scope of this guideline. Nevertheless, for information, below are schematic diagram on typical utilisation of biogas;

(a) Main components for biogas utilisation from digester to Bio-CNG
(b) Main components for biogas utilisation from digester to boiler
(c) Main components for biogas utilisation from digester to gas engine

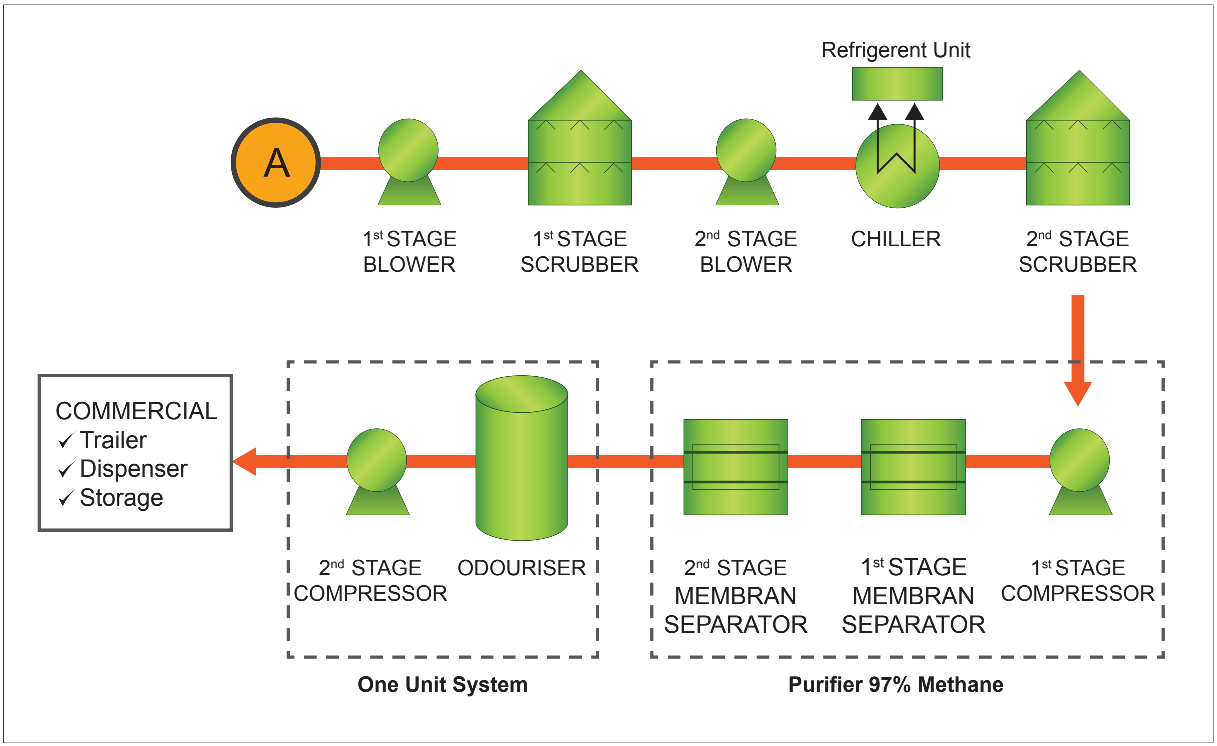


Figure 19: Main components for biogas utilisation from digester to Bio-CNG (The system for compressed natural gas (CNG) starting from 'A' of Figure 2)

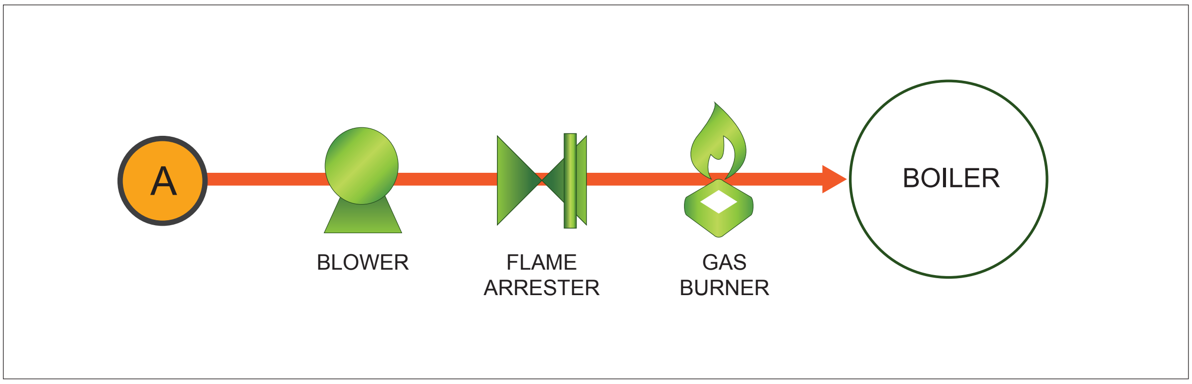


Figure 20: Main components for biogas utilisation from digester to burner
(The system for compressed natural gas (CNG) starting from 'A' of Figure 2)

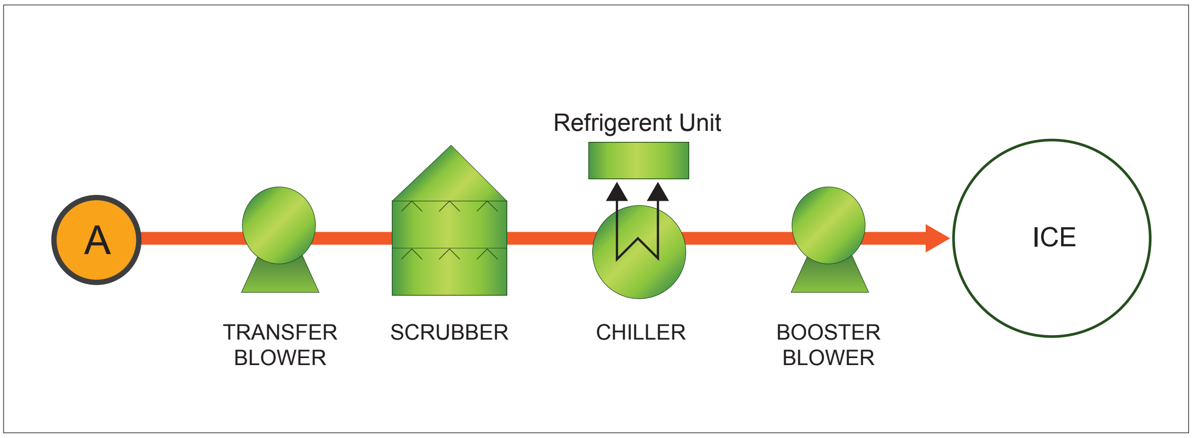


Figure 21: Main components for biogas utilisation from digester to gas engine
(The system for compressed natural gas (CNG) starting from 'A' of Figure 2)

2. PLANNING AND DESIGN

2.1 General

Any area selected for biogas plant should be large enough to minimize the risk of combustible biogas to any people around. Biogas trapping system (Covered Anaerobic (CA) Tank/Pond), flares, pipeline, gas compressors and buildings should be designed to make it easy for people to escape in case of fire or other hazard events, and it should be avoided from being close to any sources of ignition.

2.2 Design and construction

2.2.1 Definitions

Biogas installation in the meaning of this guideline is 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.

2.2.2 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

Biogas plants may be planned based on the available feedstock (volume, composition, location, seasonality of production), that will determine the layout of the biogas plants. There are numerous 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.

(a) Feedstock evaluation:

Feedstock evaluation and management which involves handling the feedstock and preparing it for digestion is the major consideration of the biogas project. In Malaysia, the majority of projects, biogas feedstock management will simply an extension of farm manure or by-product waste management such as Palm Oil Mill Effluent (POME), while digestion facilities will be an extension of waste management facilities.

The management of digestate will similarly be integrated with existing farm waste management. As covered anaerobic (CA) pond/tank biogas plants do not alter the quantities and flows of waste nutrients, questions regarding digestate nutrient value, nutrient re-use and nutrient land application limits will remain outside the scope of this guideline.

(b) Biogas technology selection

Selection should be seen as linked, but planning should be focus on independent parts of a biogas project as much as possible.

(i) Digester configuration:
- Digester technology selection should be as simple as possible. Various digester designs are available for agricultural operations. In most cases CA pond/tank offer the best value for money and are attractive for POME due to their low maintenance requirements and cost.

(ii) Biogas uses:
- Biogas utilisation should target on-site needs, high value application over low value applications and use of biogas in a CHP unit.

(iii) Biogas technology selection – Biogas conveyance and conditioning:
- Biogas conveyance and conditioning operations should be a consequence of the decisions made on preceding steps (i) and (ii).

The potential discharges from flares, boilers and biogas upgrading or from cogeneration equipment, shall be considered during the planning of a biogas project.

Refer Appendix C for a good biogas plant design considerations checklist.

2.2.3 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

2.2.3.1 *Plant layout*

A biogas plant generally will not be in a public place, so consideration to access to dangerous area is controlled, however closeness to the farm boundary may be a consideration. For specification details please refer local authorities and relevant authorities' requirement.

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.

2.2.3.2 *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 for easy maintenance. 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 holding tank before entering digester can eliminate Zone 1 environment (see Table 5 for zone definitions). Similarly, the use of open skids or well-ventilated shelters with no more than three walls (Appendix A: Example of Adequately Vented Shelter) housing biogas use equipment can reduce the extent, rating or occurrence of hazardous zones associated with the biogas plant.

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 based on 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 5: Hazardous Zone Definition

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)

Detailed zone classification examples for various parts of an agricultural biogas plant can be found in Appendix B: Examples of Zone Classification. However, for a typical 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 m around any gas carrying part of the plant (i.e. tightly sealed CA pond/tank 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 m vertically above the ground or structure (shelter roof, CA pond/tank cover etc) are classified as Zone 1 internally, Zone 1 in a spherical space 1 m around the outlet point as well as classified as Zone 2 for 2 m around all Zone 1 spaces.

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 CA pond/tank, 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 m (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.

2.2.4 Anaerobic digester

2.2.4.1 Feedstock and storage

What risks does this section aim to manage/avoid:

a) 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/substrate liquid

(i) 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:

- CA pond/tank can cope with relatively dilute wastes, although benefit from moderately high solids concentrations (smaller footprint). Highly concentrated wastes with pH number between 5-7 can lead to acidification and hydraulic problems with digesters.

(ii) Wastes 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

(i) Department of Environment (DoE) recommends the collection and transfer of effluent from shed/retention pond/holding tank 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.

(ii) 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

(i) 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.

2.2.4.2 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 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. Therefore, all materials used for a biogas plant need to be selected carefully.

Components of the biogas plant that are in contact with substrate, digestate or biogas (e.g. pond cover) should be corrosion resistant. Below are recommended material that can be used:

Table 6: Materials in contact with substrate

MATERIAL STATUS	MATERIAL LISTS
Recommended	HDPE, PVC with coating can be used as cover for CA tank, Stainless Steel, Clay, Concrete, Mild steel with corrosion coating
Not recommended	ABS, Copper, Non-coated steel, (PVC piping shall not be used)

2.2.4.3 *Digester design*

What risks does this section aim to manage/avoid:

a) Digesters being built inappropriate for feedstock and situation
b) Digesters being built which is 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 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. 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 CA pond/tank, 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 desludging. 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.

CA pond/tank accumulate rainwater on the cover surface that needs to be managed. An array of rainwater guidance pipes directing rainwater to a removal pump is a practical means of managing rainwater. Where CA pond/tank 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 corrective measures.

The point of drawing off gas from the holding space of the digester shall be above the highest point of the liquid overflow. The gas draw-off piping shall be corrosion resistant, external to the digester, and accessible for repair without entering the holding space of the digester.

All CA pond/tank, digestate storage structures and effluent collections systems need to be tightly sealed to avoid effluent seepage.

Furthermore all structures need to be structurally sound and place no environmental risk in accordance with Environmental Quality Act 1974, Environmental Quality (Industrial Effluent) Regulations 2009. 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.

2.2.4.4 Typical CA Pond system

The Covered Anaerobic (CA) pond design concept is based on the continuous/batch homogeneous mixing and uniform feeding of the POME/waste into the biodigester to ensure that there is maximum degradation of the Chemical Oxygen Demand (COD) in the POME/waste, hence producing the amount of biogas which can be put to gainful use. The influent POME/waste is taken from the mixing pond, whereby a Raw POME/waste pit is constructed to regulate the level and flow before being channelled via a pump to the POME/waste Mixing Pit. In the Mixing Pit, the recycled POME/waste from the biodigester is mixed with Raw POME, and together, is pumped to the bottom of biodigester for uniform and homogeneous feeding (Figure 22).

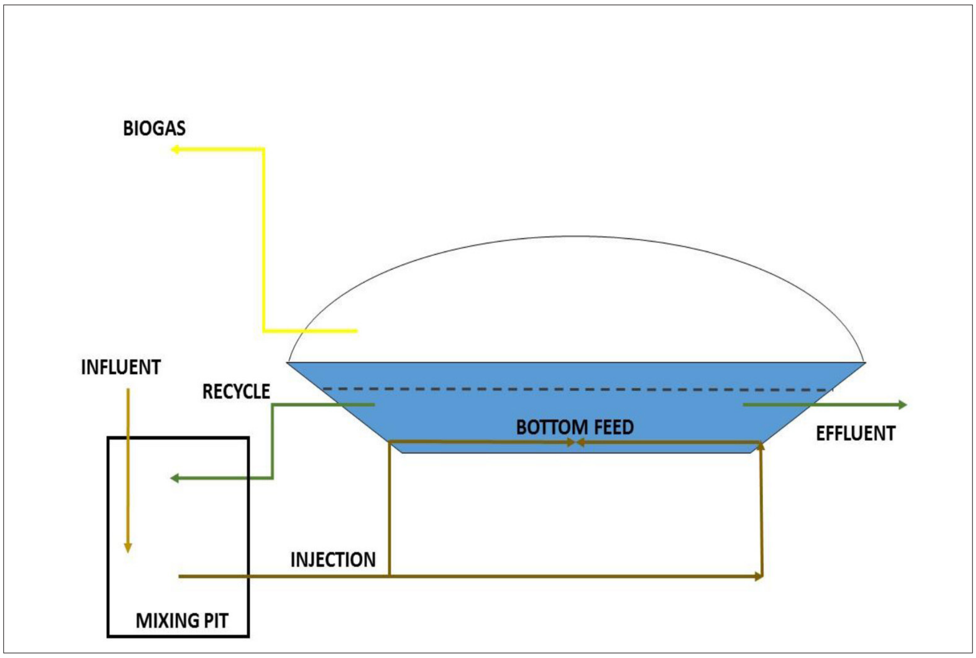


Figure 22: Process Flow Diagram for CA Pond (Source: FGV)

Liner of the CA pond material is made by HDPE geomembrane with 1.5 mm thickness. The membrane is anchored with rebar 300 mm and 1.5 m depth to withstand pressure built-up from biogas in the pond which is 0.5 mbar - 0.8 mbar. Then, earth compacted with monkey jump rammer at every 300 mm along the pond area. See Figure 23, 24 and 25 for typical conctruction detail of a CA pond.

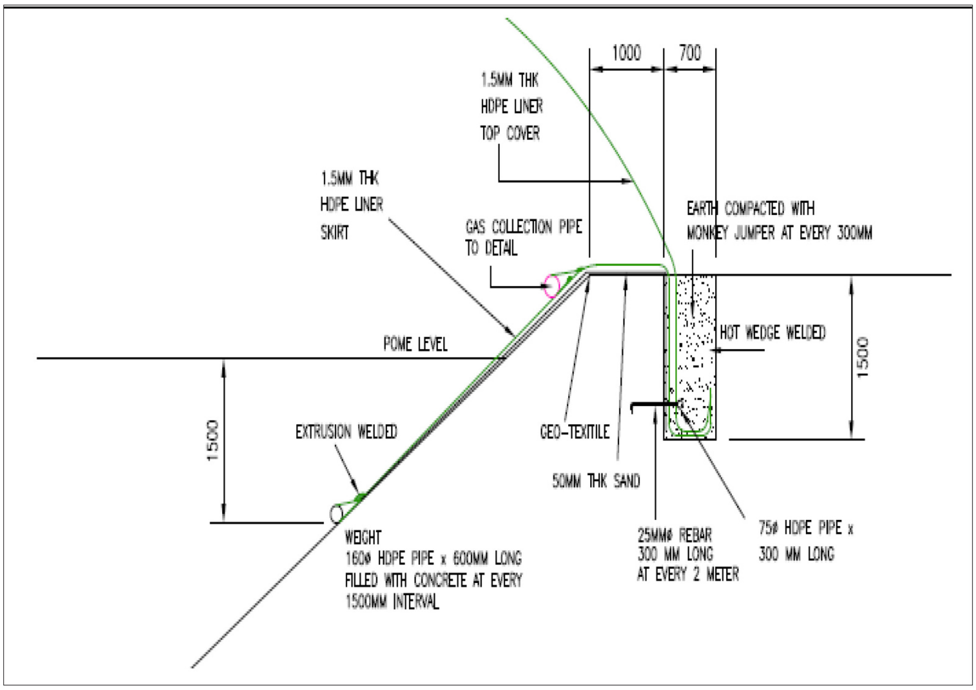


Figure 23: Detail of Typical HDPE Skirt and Top Cover Installation (Source: FGV)

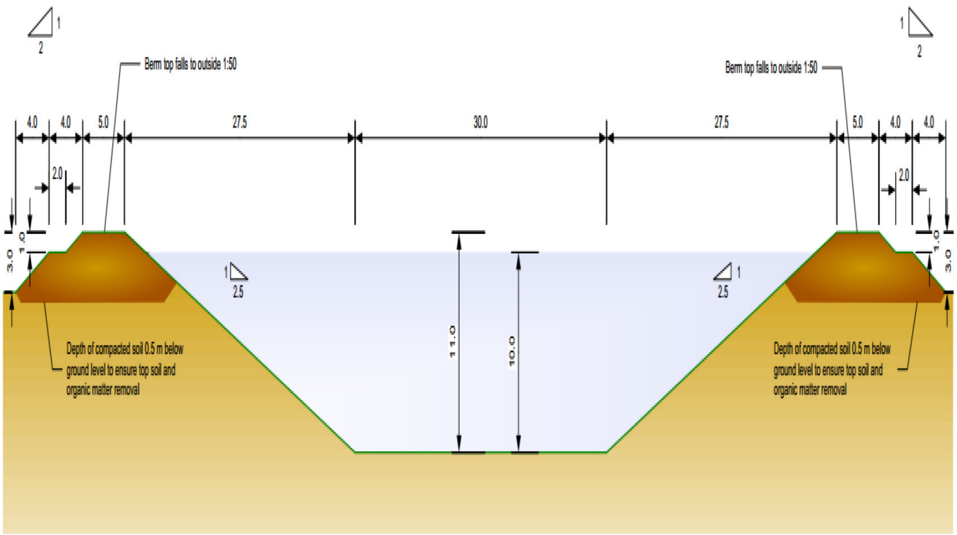


Figure 24: Detail of Typical CA Pond Cross Section diagram (Source: FGV)

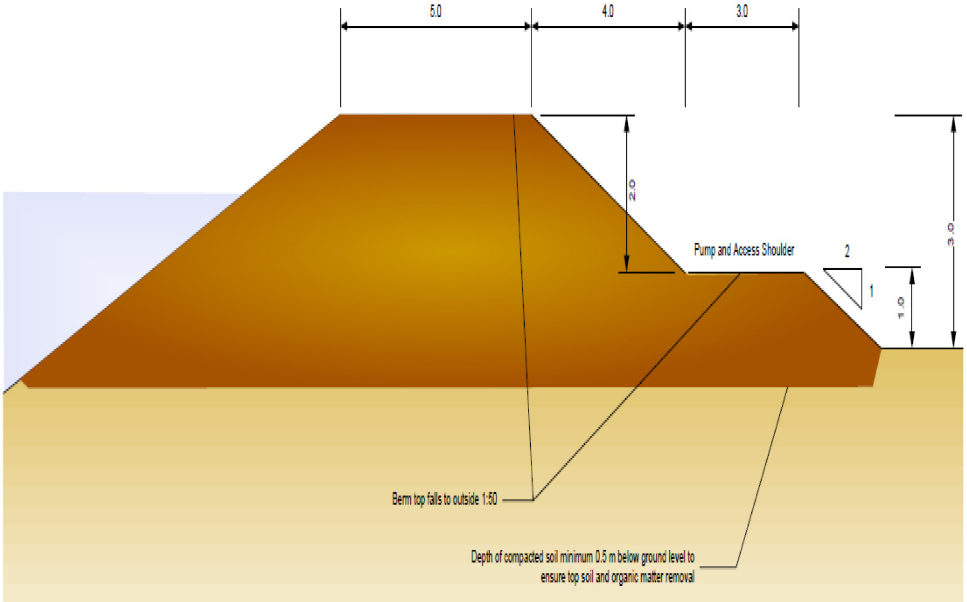


Figure 25: Detail of Typical Berm diagram (Source: FGV)

The typical CA pond membrane fitted with pressure relief valve (PRV) using a HDPE pipe install upper of membrane base on minimum elongation of membrane characteristic and capacity of storage requirement (Figure 26). The numbers and various length of HDPE pipe is depend on the capacity of biogas storage. The CA pond pressure relief valve should be integrated with emergency stack control by the pnuematic valve (Figure 27). Function of this equipment is to add value of safety features in the Biogas Plant.

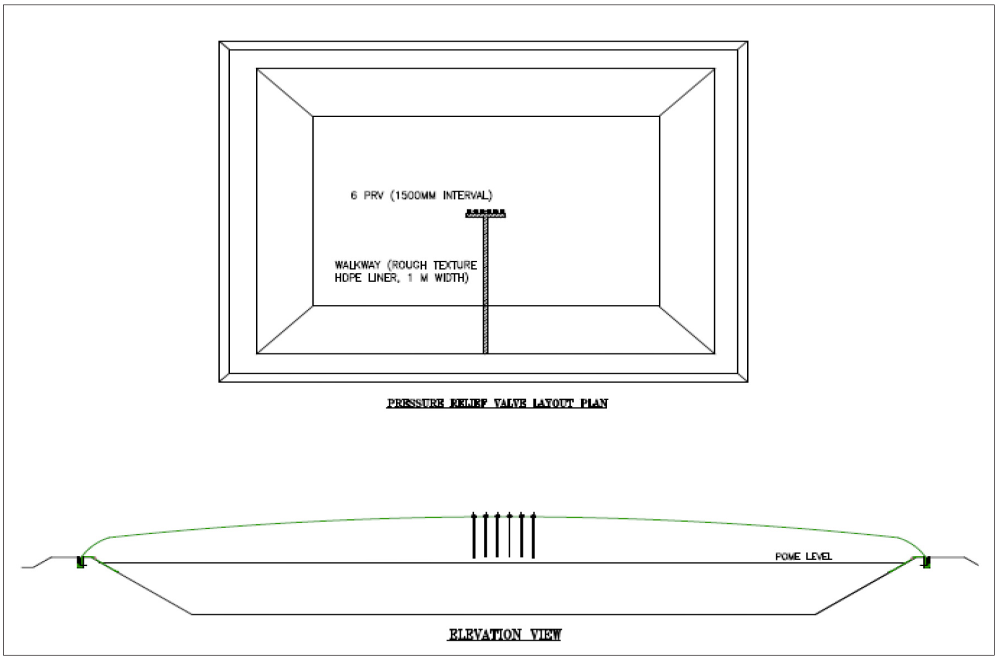


Figure 26: Detail of Typical Pressure Relief Valve in CA Pond system (Source: FGV)

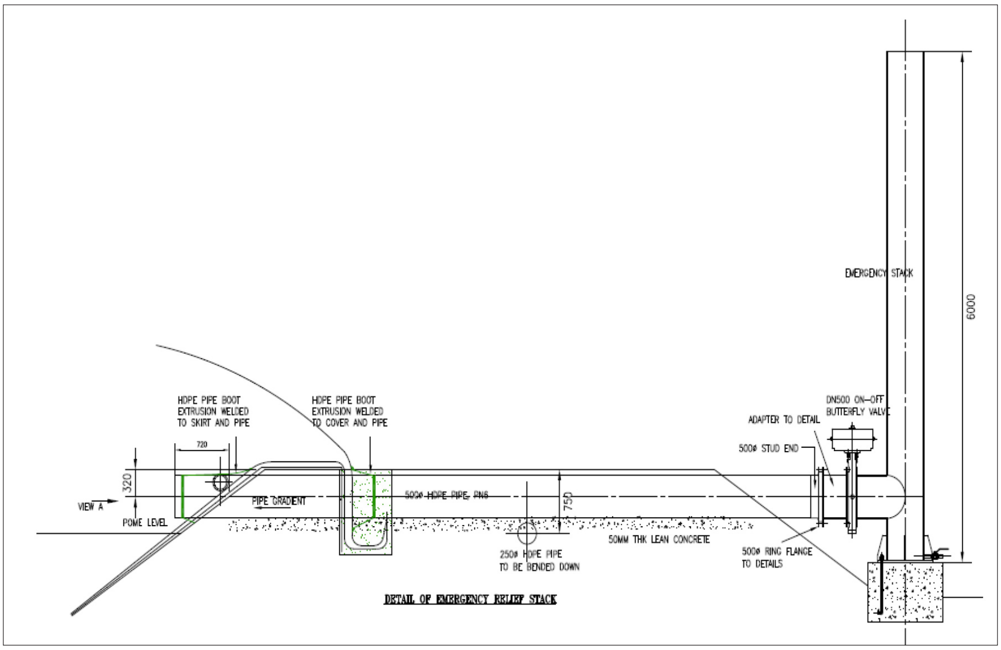


Figure 27: Detail of Typical Emergency Relief Stack (Source: FGV)

2.2.4.5 Typical CA Tank System

The Covered Anaerobic (CA) tank design concept is based on the continuous/batch homogeneous mixing and uniform feeding of the POME/waste into the biodigester to ensure that there is maximum degradation of the COD in the POME/waste, hence producing the amount of biogas which can be put to gainful use. The influent POME/waste is taken from the mixing pond, whereby a Raw POME/waste Pit is constructed to regulate the level and flow before being channelled via a pump to the POME/waste Mixing Pit. In the Mixing Pit, the recycled POME/waste from the biodigester is mixed with Raw POME, and together, is pumped from top to the bottom of biodigester for uniform and homogeneous feeding. The tank should be designed and constructed to the international code such as ANSI/AWWA D103 or any recognised standards acceptable to the authority having jurisdiction (Figure 32 and Figure 33).

Typical top cover of the CA tank material is made by PVC double membrane with 0.9 mm thickness. The membrane is clamped with bolt and nut to withstand pressure built-up from biogas in the tank which is 10 mbar - 15 mbar (Figure 28 & 30). There have two layer of membrane which is the first layer (inner) for storing/holding the biogas and the outer layer is fill up with air from air blower between the two membranes due to maintain the shape of inner membrane (Figure 31).

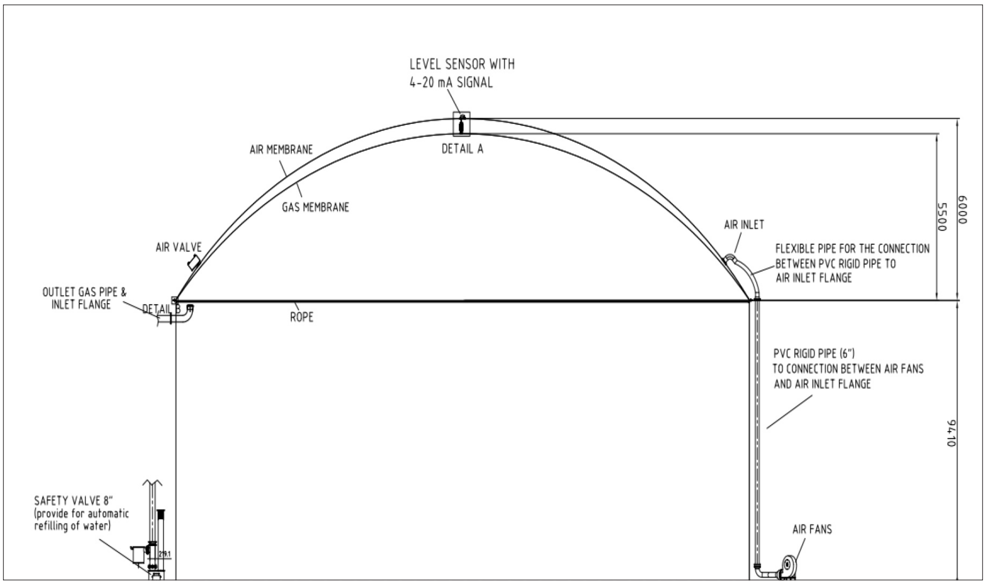
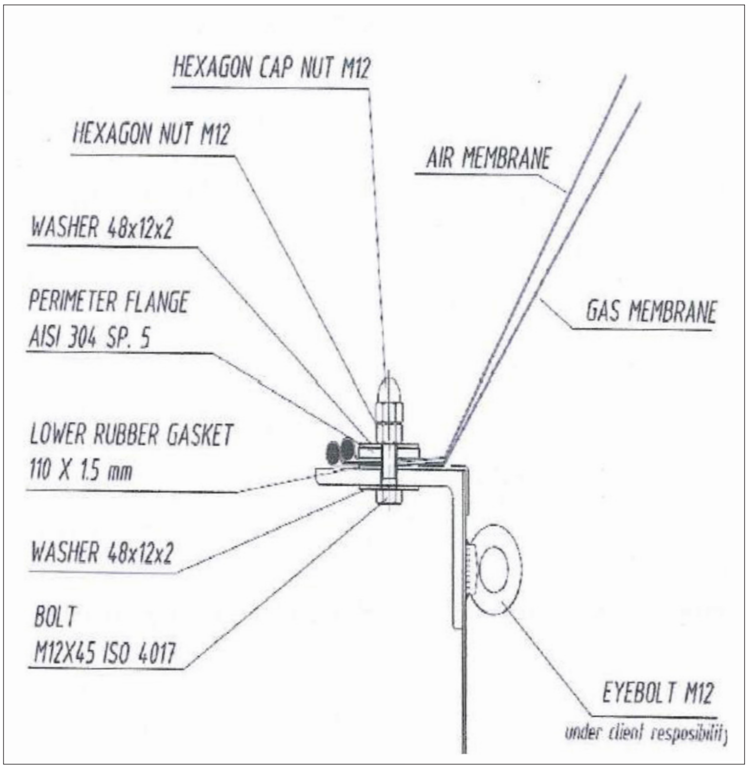


Figure 28: Detail of Typical Double Membrane Installation
(Source: FGV)

The membrane is installed with Relief Valve to release excess biogas when the biogas build-up pressure between 10 mbar – 15 mbar base on the membrane storage capacity (Figure 29).

Figure 29: Pressure Relief Valve (Source: FGV)



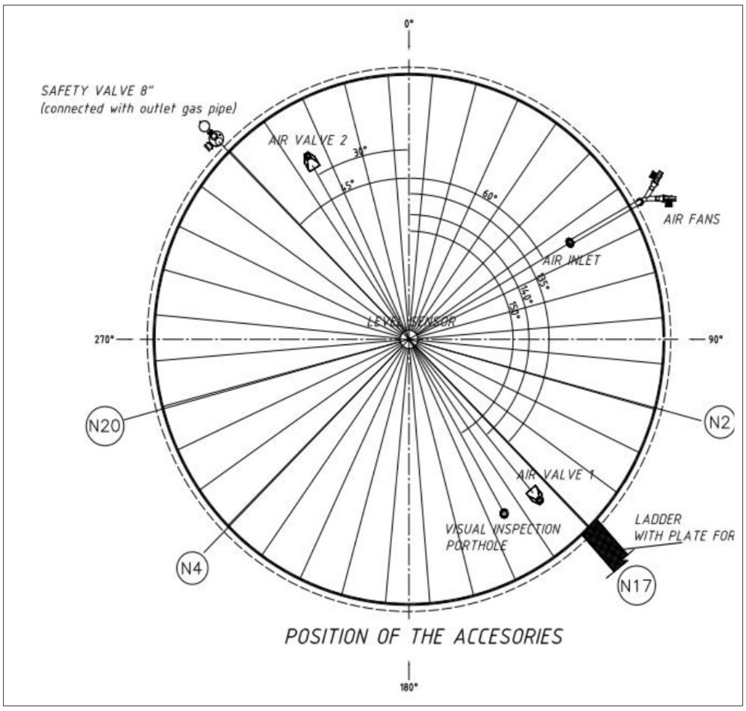


Figure 30: Detail of Typical Double Membrane Installation
(Source: FGV)

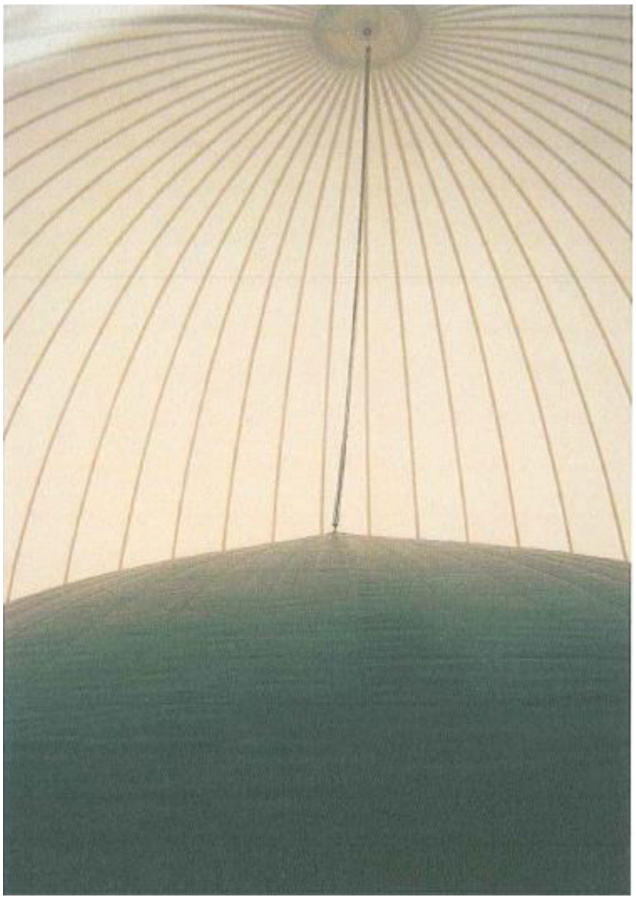


Figure 31: Double Membrane Installation (Source: FGV)

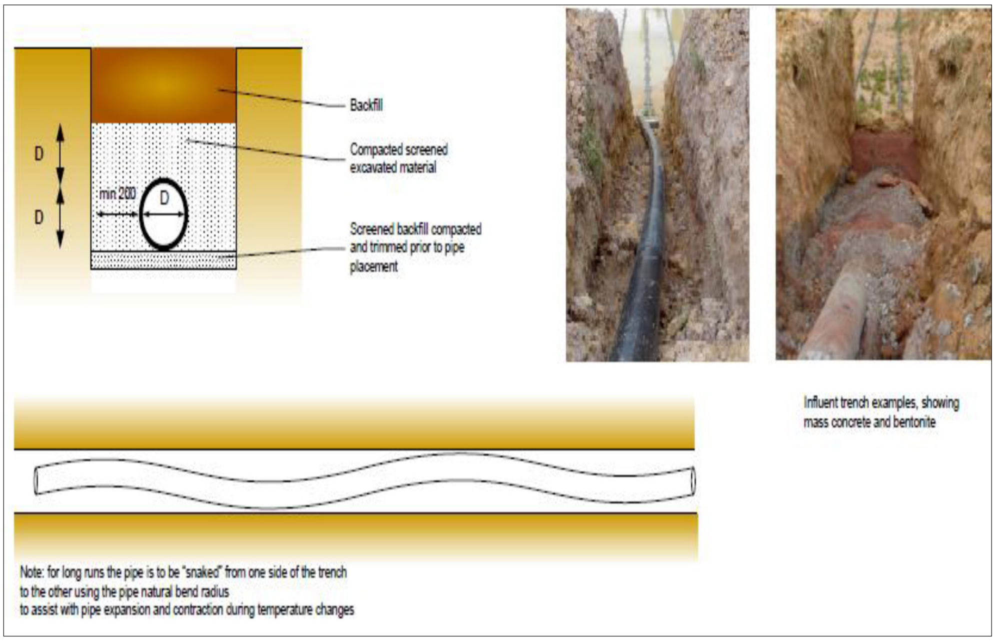


Figure 32: HDPE pipe installation (Source: FGV)

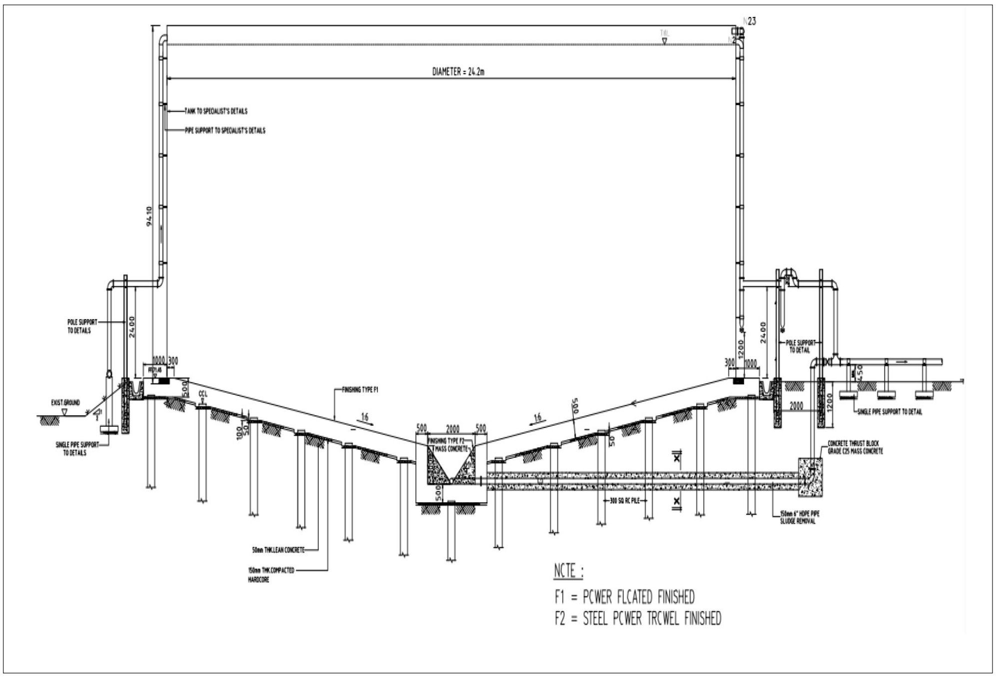


Figure 33: Detail of Typical CA Tank Cross Section (Source: FGV)

2.2.5 Biogas utilisation

2.2.5.1 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 recognize standards, the manufacturer's specifications and applicable legislation to meet regulatory requirements.

A shut-off valves: A shut-off 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 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 labeled 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 labeled. The same requirements apply also to electrically-operated shutoff valves.

2.2.5.2 Flares

What risks does this section aim to manage/avoid:

Direct venting of biogas into the atmosphere

All biogas plants should include flare 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 over a combustion period, an emergency situation and maintenance period. By routing the biogas through a flare, it is combusted and the risk of adverse odour and GHG impact is greatly reduced.

Biogas 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 (LPG) for ignition or flame stabilization.

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 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 employee safety. On the other hand, enclosed flares may be beneficial for fire safety.

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 Department of Environment regarding biogas flare requirements (e.g. diameter, stack height, etc.), inspections and approvals.

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 un-burnt gas being vented, it will not cause a hazard;
(b) To minimize 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 7.5 m from any building or potentially flammable structure (i.e. grain silo) as well as any gas carrying part of the biogas plant (other than the biogas transfer pipeline);

Table 7: Distance of Open and Enclosed Flares to Building and Digester

DISTANCE OF OPEN AND ENCLOSED FLARES	
From Digester	15 metre
From Building	7.5 metre
FLARE HEIGHT	
10 metre	

(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 Energy Commission 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 CA pond/tank 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 unauthorized persons and animals, the installation of a security fence is recommended. However shut off valves and other safety features need to remain easily accessible.

2.2.6 Biogas conveyance

2.2.6.1 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 labeled as carrying a fuel gas and color coded yellow.

Table 8: Biogas resistant materials

MATERIAL STATUS	MATERIAL LIST
Recommended	HDPE
Not recommended	ABS, 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 biogas pipeline installations is therefore on HDPE pipelines.

2.2.6.1.1 Biogas piping:

a) Biogas pipeline installations shall:

i. be operated at pressures no more than 100 kPa (1bar) for transfer distances of less than 4,000 m;
ii. take the most direct route or minimum route necessary to provide biogas cooling and contain as few elbows, drops, and risers as practicable;
iii. 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;
iv. be installed by a person who is aware of the risks associated with the facility and the precautions required;
v. 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.

b) Piping, tubing and fittings shall carry the manufacturer's identification as to the material. 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

c) Gas piping shall:
i. be painted or colour coded with high visibility yellow-orange paint;
ii. be labelled at least every linear 3 m, with the name of the gas being transported and the direction of flow.

Where piping is installed with a protective covering, the markings shall be transferred to the covering.

d) Sediment traps shall:
i. be installed at low points in the system.
ii. be equipped with a manual-type or continuous-flow-type drip trap or have another means of draining that will maintain a reliable gas seal.

e) Blowers used for biogas conveyance need to have an appropriate safety rating (e.g. IEC/MS category – if available) for the zone in which they are installed.

2.2.6.1.2 Buried piping:

a) Buried piping shall:

i. be protected against corrosion by any recognised method acceptable to the authority having jurisdiction, e.g., coating, the use of protective materials, or the application of cathodic protection;
ii. have a minimum of 150 mm of tamped sand all round before backfilling;
iii. be placed in a casing of not less than 50 mm larger diameter and the casing shall be of a material acceptable for the application when the piping is intended to be located under areas used for vehicular traffic, the pipe;
iv. be installed with a minimum 2% slope and the low end located in the building, at which point a drip tap shall be installed. When a long run of buried pipe makes it impractical to have a continuous 2% slope, the pipe may be installed with the required slope in two or more directions, provided that a drip trap is located inside the building or buildings at each low point or is otherwise freeze-protected;
v. not be installed with threaded fittings;

b) The ends of the casing pipe shall be sealed to the carrier pipe. Venting of the sealed casing shall not be required when the casing seals are of a type that will retain more than 35 kPa pressure between the casing and carrier pipes. If vents are not used, provisions shall be made to relieve the internal pressure before carrying out any maintenance work:

i. When used, vents shall:-
   - not be less than one-third of Nominal Pipe Size;
   - be installed one at each end of the casing;

ii. The termination of each vent shall:-
   - not be less than 600 mm above grade level;
   - be provided with a 180° bend and bug screen or equivalent; and
   - be protected against physical damage.

c) The casing material used with buried pipe shall have a smooth interior so as to prevent damage to the pipe;

d) When piping passes through walls and partitions, it shall be protected from direct contact with the wall or partition construction material. The wrapper or coating shall not restrain the longitudinal movement of the pipe;

e) When a metal sleeve is used to protect piping that passes through an inside wall or partition, the metal shall be of a material resistant to corrosion action from the construction material used in the wall or partition, or the outside surface of the sleeve shall be coated or wrapped with a corrosion-resistant material;

f) When piping passes through an exterior wall of masonry or concrete, a watertight seal shall be provided and the portion of pipe passing through the wall shall be coated or wrapped;

g) When piping passes through a sleeve, the sleeve shall be made of a material and installed in a way that protects the pipe from damage and maintains a watertight seal.

2.2.6.2 Biogas storage

What risks does this section aim to manage/avoid:

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

CA pond/tank generally provides 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. 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.

If tank is required, refer to 2.2.4.2 Construction Material.

3. OPERATION AND MAINTENANCE

3.1 Commissioning and start-up

What risks does this section aim to manage/avoid:

a) In-completed / untested biogas plants commencing operation
b) Start-up issues leading to bacteria community collapse and acidic condition
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 of membrane for tightness;
(b) Checking of all biogas carrying pipelines and other treatments facilities including connection pieces for gas tightness (e.g. pressure test by trained 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 tanks and pond covers.

Parts or components are considered tight when no leaks can be detected with a tightness test suitable for the application, or tightness monitoring or tightness inspection, e.g. with foam forming agent or with leak detection devices or leak detector device.

Prior to feedstock being introduced, CA pond/tank digesters need to be filled with start-up liquid for acclimatization to fulfill 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.

Operators 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 minimized 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 non-combustible gas, such as CO_2 or inert gas 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.

3.2 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.) favor the species of microbes and the synergistic effect that maximizes 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- 7.3.

3.3 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 μm to 5 μm 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 pressurized 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.

3.4 Biogas utilisation

3.4.1 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 and meets DOSH requirements.

3.4.2 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 (H_2S), 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) 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;
(c) 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);
(d) 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;

(e) 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;

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).

Air filters need to be changed within the manufacturer‘s recommended 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).

3.5 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 3.2, for biogas conditioning, see Section 3.3, for biogas utilisation see Section 3.4) and to evaluate these records as a routine exercise.

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

4. SAFETY AND HEALTH

4.1 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 2.2.3), management practices, protective equipment and training can be employed to minimize these biogas-specific risks and make biogas production and use a safe and low risk undertaking.

4.2 Workplace safety and health

What risks does this section aim to manage/avoid:

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

Occupational Safety and Health Act 1994 provides a workplace framework which has been adopted in this section.

4.2.1 Managing risks

Anaerobic digestion involves hazards that can negatively impact to 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 situation and maintenance works.

(a) Open flames shall not be permitted within 6 m of the biogas plant. Operators shall ensure that appropriate signage is in place (e.g. no smoking, no unauthorised entry).

(b) The use of an open flame, spark-producing tools, or any other source of ignition on or adjacent to within 6 m of a working digester or a digester or sludge holding tank not in use but containing any amount of sludge of any age, or in a hazardous area, shall be prohibited except by special permission in writing (e.g. Permit-to-Work).

(c) The operator of the plant should perform a weekly inspection that includes checking for cracks, tears, or points of distress on the equipment such as the digester, the presence of an odour, and gas leakage.

(d) A match, candle, flame, or other source of ignition shall not be used to check for a gas leak.

(e) A light (including a flashlight) used in connection with a search for gas leakage shall be restricted to the explosion proof type. Sources of ignition in or adjacent to the area of leakage shall be prohibited.

(f) Preventive maintenance should be conducted in accordance with the component manufacturer's recommendations.

(g) 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.

(h) 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.

(i) Isolating or rendering inoperative a safety shut-off valve, safety limit control, or relief valve shall be prohibited.

(j) The use of appliances, accessories, components, equipment, and materials shall be prohibited where such items have deteriorated to the extent that a hazardous condition could be created.

(k) Operators should comply with the safety precautions regarding to confined space entry (Refer to Industry Code of Practice for Safe Working in a Confined Space 2010).

(l) The risk assessment should be carried out for hazardous materials stored or handled at the plant site. It aims to protect to those who are close to the biogas plant from the risks.

(m) To address the movement of vehicles at the plant site, the layout of the plant should be designed for the safe route of vehicles through the biogas plant.

(n) Fire extinguisher should be located at the highly visible places.

(o) The use of warning signs that are clearly visible can help increase the level of safety; to provide clear information, warning and the action to be taken in case of emergency.
(p) Windsock should be installed at easily visible place.

4.2.2 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.

4.2.3 General working environment

Guidelines for general working environment identifies hazards specific to biogas plants:-

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

4.2.3.1 Electrical system

Work on the electrical systems shall be performed only by a qualified person with reference to Energy Commission.

4.2.3.2 Mechanical system

In the event of a mechanical failure, employees 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 person 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 preventive 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.

4.2.3.3 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 CA pond, 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; refer to Industry Code of Practice for Safe Working in a Confined Space 2010

(d) Operating equipment (e.g. pumps and agitators) shall be secured to prevent being switched on (lock-out/tag-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.

4.2.3.4 Safety signage

Safety 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. The safety signage also should be designed to be easily understood by local or foreign employees.

4.2.3.5 Fall prevention

When possible, employees should perform maintenance work at ground level. Fall protection, such as guardrails, a body harness, and self-retracting lifelines, should be used when an employee is above the 10 feet (Factories and Machinery (Safety, Health and Welfare) Regulations 1970). 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.

4.2.3.6 Drowning

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

Although the covers are often rigid enough to support the weight of an adult, but it 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 unauthorized persons‘ entry to the hazardous zone (see 0) around gas carrying parts of the biogas plant (3 m distance), can often serve the dual purpose of reducing drowning risk for humans and animals.

4.2.3.7 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. Please refer to Factories and Machinery (Safety, Health and Welfare) Regulations 1970.

4.2.4 Emergency plans

The employer 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 (such as an ambulance, fire and rescue department, police or other emergency service) at the earliest opportunity;
(d) medical treatment and assistance; and
(e) effective communication between the person authorized by the employer or undertaking to co-ordinate the emergency response and all persons at the workplace.

4.2.5 Personal protective equipment

The provision of appropriate personal protective equipment (PPE) is recommended together with employee training 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. Safety signage 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 material.

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. Encourage the use of PPE to minimize dust inhalation, absorption through the skin and thorough washing of exposed areas.

5. ENVIRONMENTAL PROTECTION

5.1 Definitions

Most biogas plants will be add-ons to existing waste 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.

5.2 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 bio-security 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 bio-security risks, as well as the potential for contaminant imports, including heavy metals and organic contaminants.

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

(a) The feedstock does not pose a bio-security 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 biogas feedstock, the key outcomes to good practice of waste management in Environmental Quality Act 1974 – Environmental Quality (Industrial Effluent) Regulations 2009 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.

5.3 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 under utilisation of the nutrient value in digestate or follow up problems where digestate (components) have been applied excessively

Please refer to Environmental Quality Act 1974-Environmental Quality (Industrial Effluent) Regulations 2009. This provides an overview of Effluent Management (collection and treatment), Solids Separation Systems, Solid By-products Storage and Treatment Areas and Reuse Areas.

5.4 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 minimize 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 CHP 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 CHP method. Stack tests from comparable units is the preferred method, otherwise manufacturer information, emission factors or mass balance, could also be used as appropriate with justification for rationale.

5.4.1 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 2.2.5.2 for guidance on avoiding venting of biogas into the atmosphere.

5.4.2 Noise

What risks does this section aim to manage/avoid:

Minimize the impact of noise into the immediate environment

Careful siting and separation from sensitive land uses will minimize 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.

5.4.3 Odour control

What risks does this section aim to manage/avoid:

Odours becoming a nuisance

The H_2S 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.

5.5 Solid waste discharge (Additional Info)

What risks does this section aim to manage/avoid:

That potentially hazardous material 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 DOE.

Management of spent biogas filter media:

(a) Some biogas filter media can be recycled (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.

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APPENDIX A: EXAMPLE OF ADEQUATELY VENTED SHELTER

Table A1: Ventilation criteria

	ADEQUATE VENTILATION	INADEQUATE VENTILATION
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/s 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.
Sheltered structures (Note 2)	(a) Within a structure having no more than 3 walls (figure A2) and where all walls have 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.	-
*Typical 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 on order to achieve adequate ventilation.		
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.		

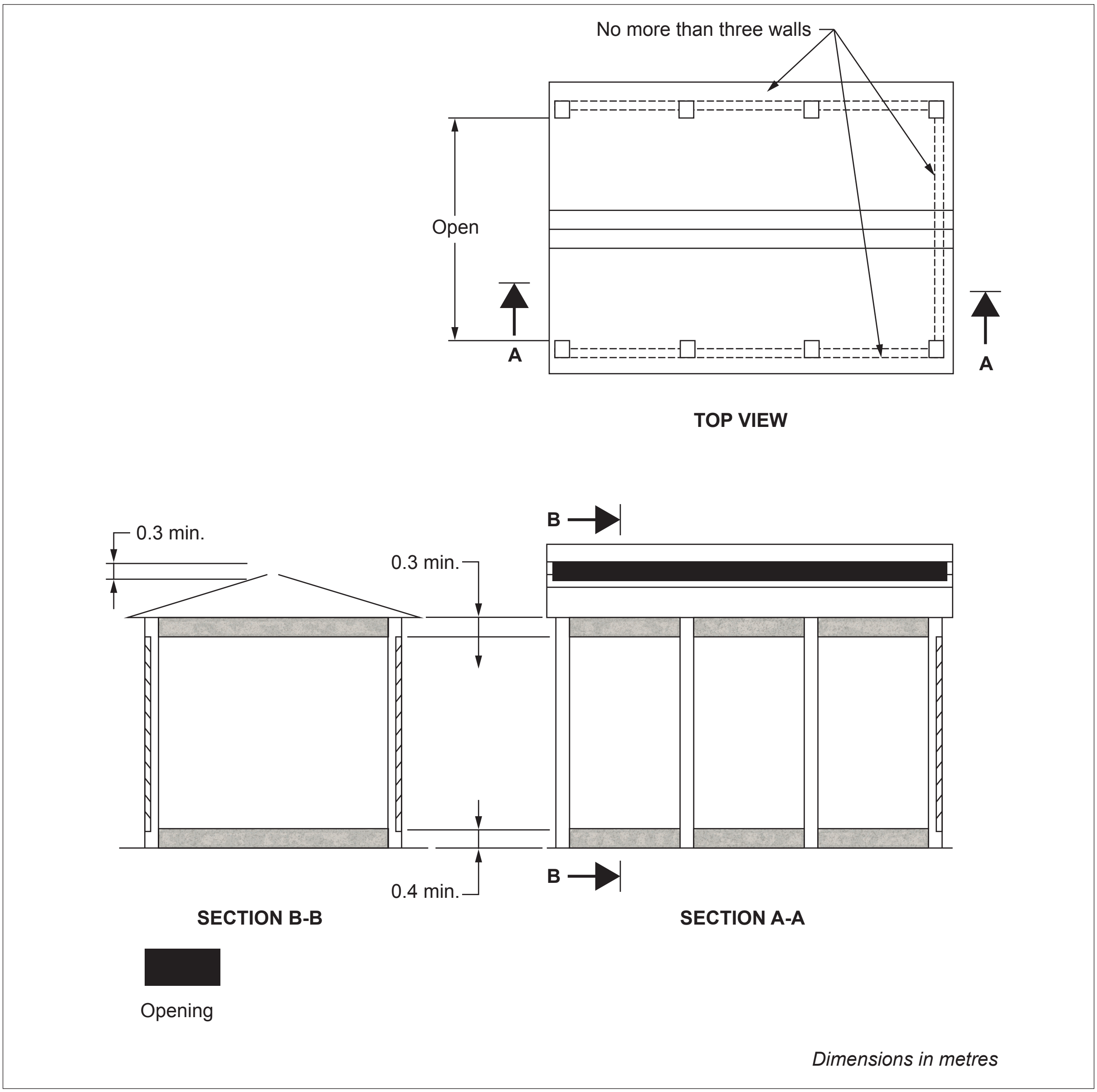


Figure A2: Example of shelter which may be treated as an adequately ventilated location

APPENDIX B: EXAMPLES OF 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.		-	-

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 faluty operation:			
(a) with the discharge in closed rooms without ventilation – **Zone 0 in the entire room.**		Entire room	1 m around openings of the enclosed room
(b) with the discharge in closed rooms with natural ventilation.		-	-
(c) closed drainage system, locks with double locking devices or automatic drainage. For the total space, 1m around openings of the enclosed room.			
Solid Subtance Dosing Around: 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 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 avoid. If possible, the entire room is Zone 1.

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.

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.

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

- Brickwork walls with trim
- Concrete walls
- Wall whose coating consists of non-combustible and spackled plates
- Standardized containers with metal walls

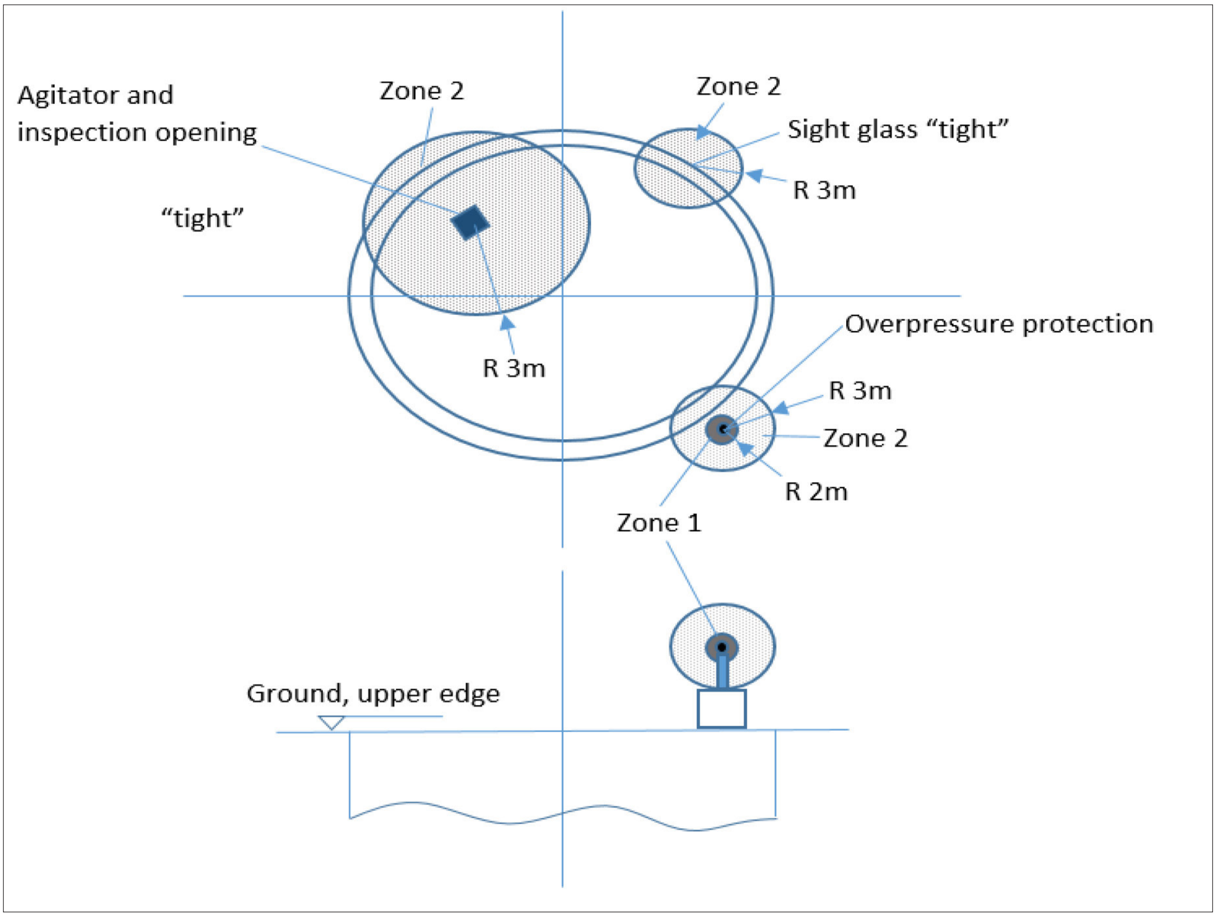
Double Membrane

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).

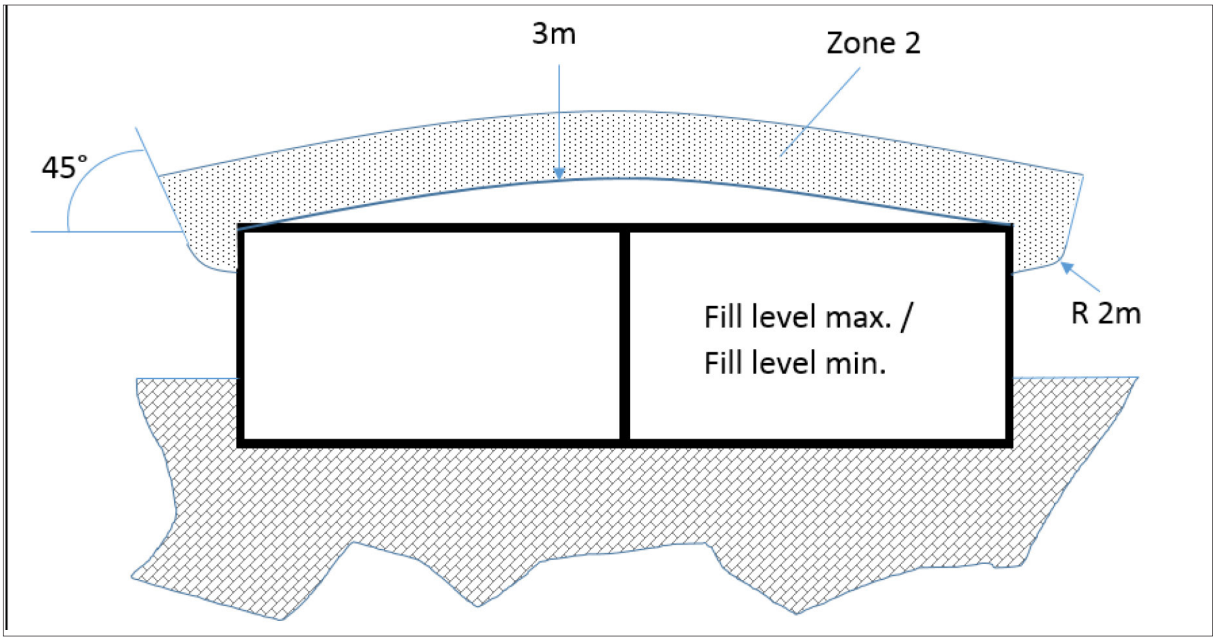
A ring-shaped potentially explosive atmosphere can occur around the transition to the digester if the connection is not implemented in a permanently impermeable manner.

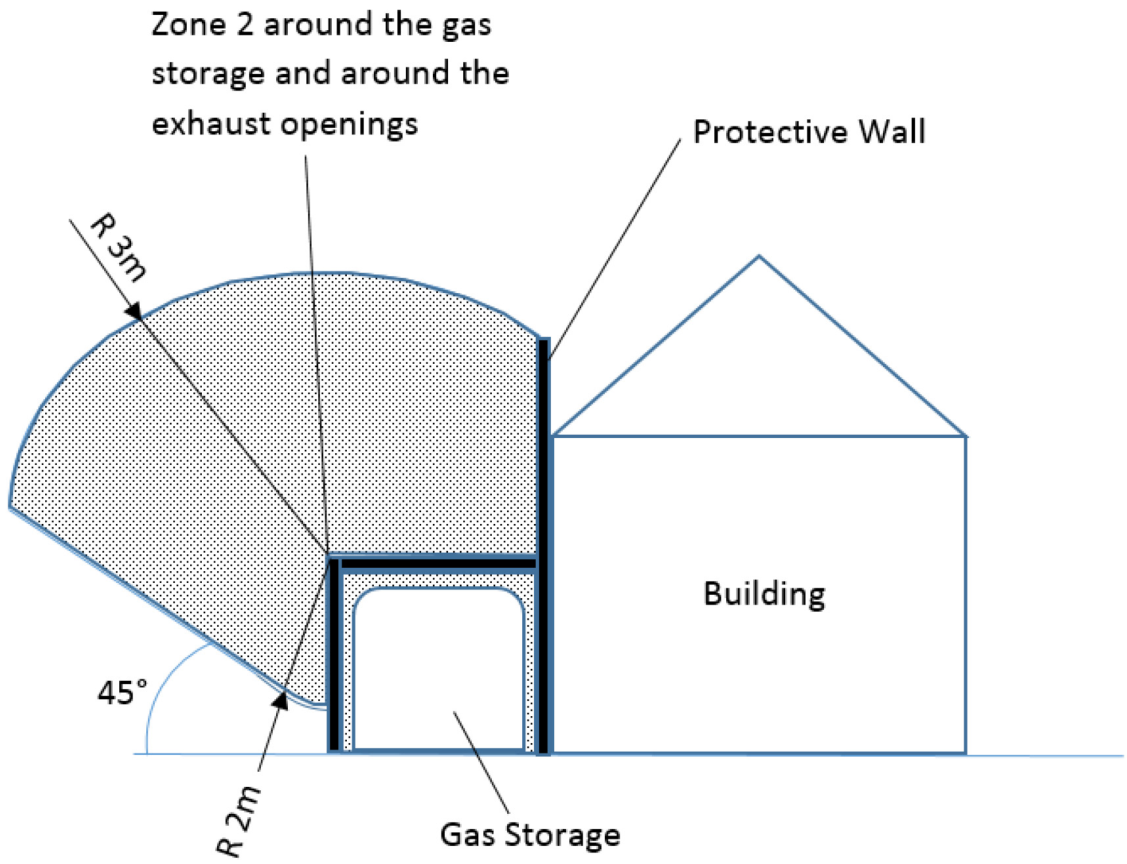
If it is not possible to prevent backflows into the support air blower, these are to be implemented according to 94/9/EU.

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

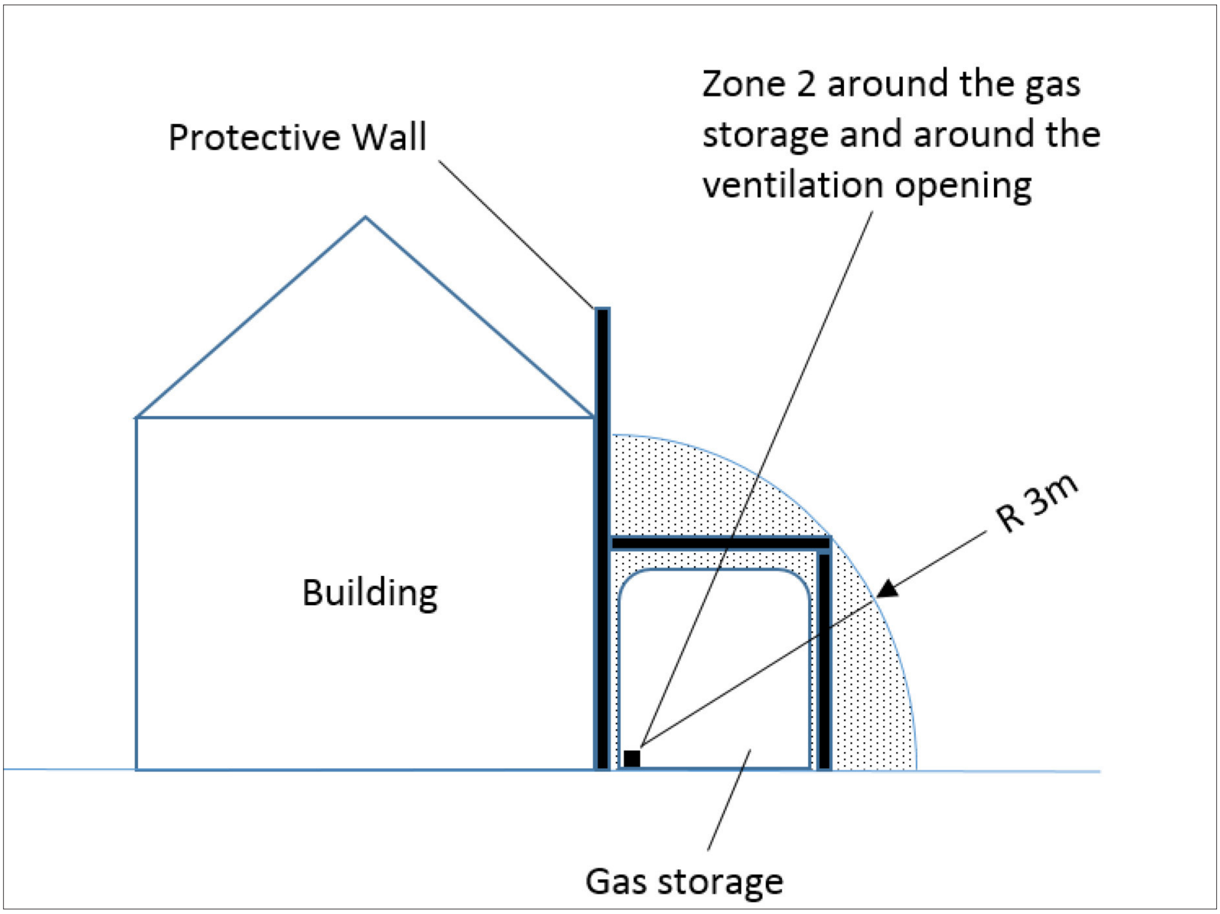


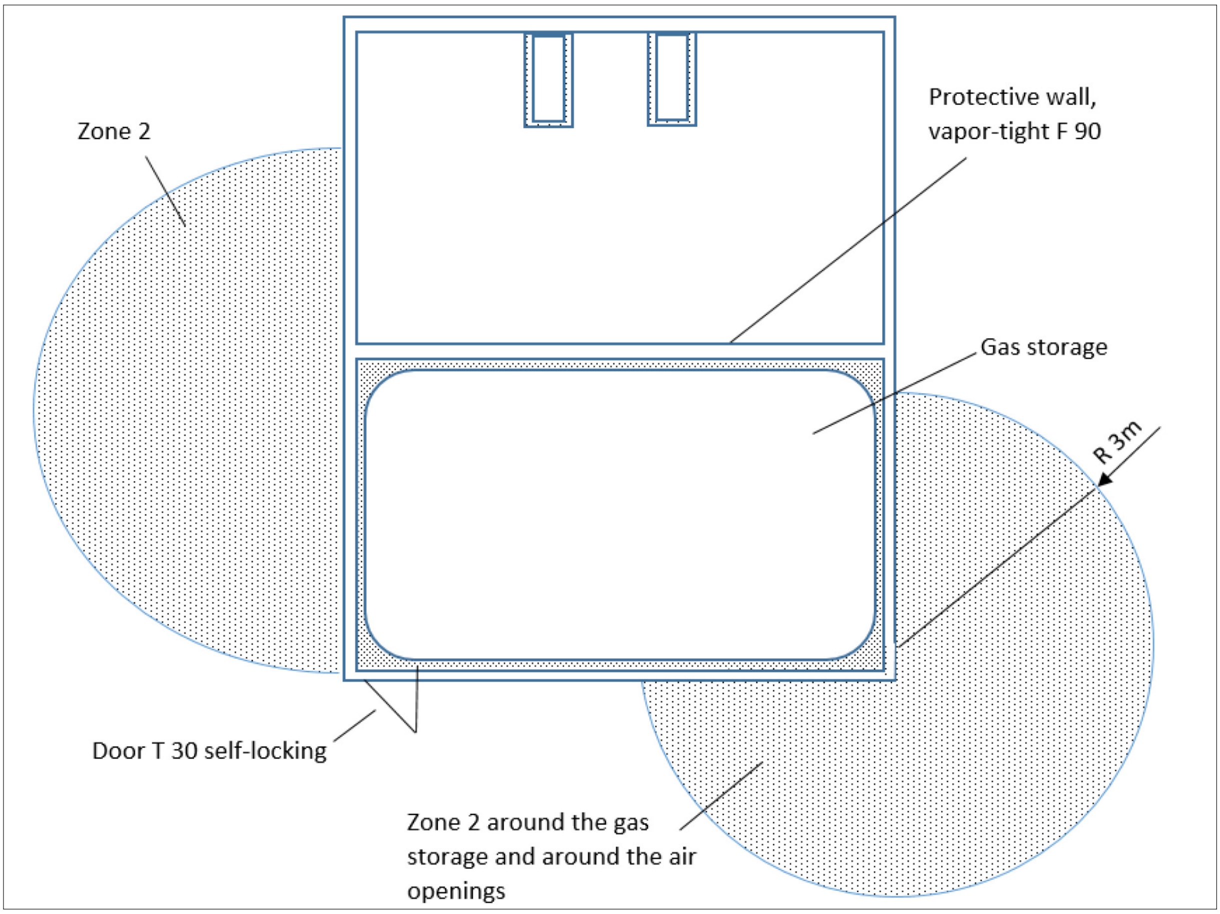
Example: Housed Gas Storage (Storage Room without Further Technical Measures)

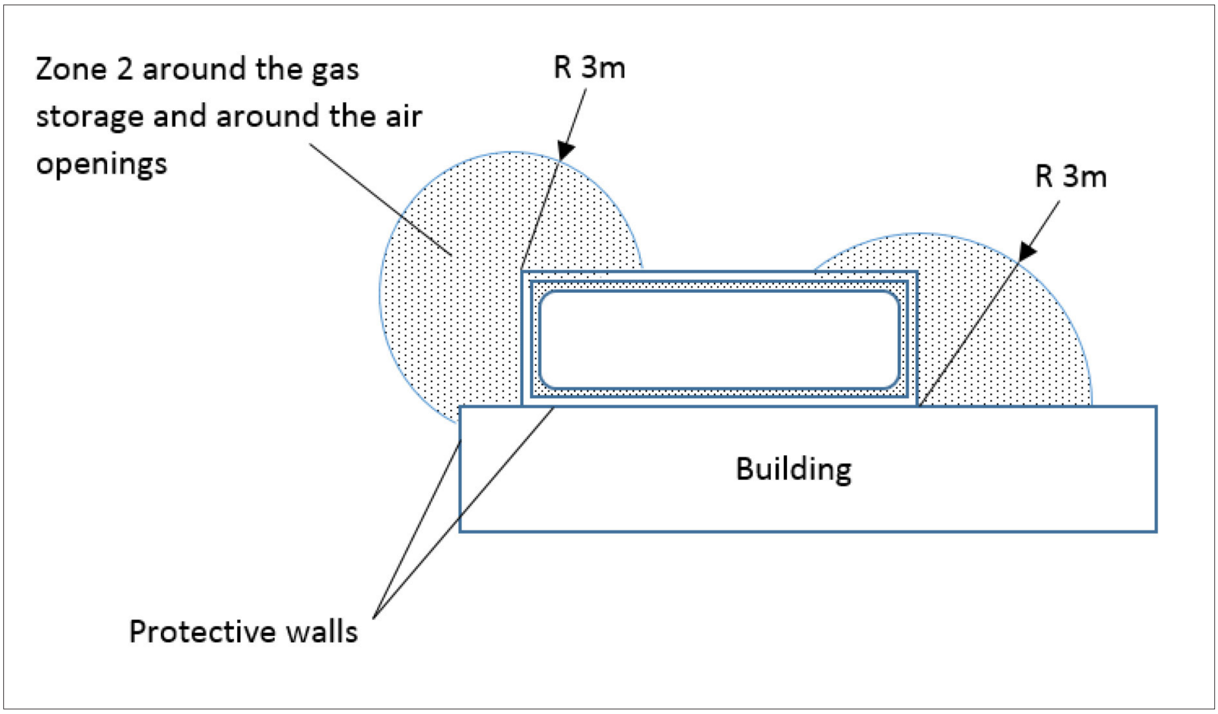




Gas storage housed in a storage room without additional technical measures.


Zone 2 around the gas storage and around the ventilation opening
Protective Wall
R 3m
Building
Gas storage


Zone 2
Protective wall, vapor-tight F 90
Gas storage
R 3m
Door T 30 self-locking
Zone 2 around the gas storage and around the air openings


Zone 2 around the gas storage and around the air openings
R 3m
R 3m
Building
Protective walls

APPENDIX C: BIOGAS PLANT DESIGN CHECKLISTS FOR OWNER/DEVELOPER

This is basic suggested checklist in designing a biogas plant. Additional element should be considered to suit own use.

DESCRIPTION	REMARKS
a) Availability of suitable qualified technical support; • Personnel requirement (suitable and trained personnel to run and maintain the plant) • After sales service (reliable)	
b) Appropriate level of complexity; • Technology (meeting minimum requirement and serving the purpose) • Pre-project consideration - Feedstock evaluation (appropriate and comprehensive management of handling the feedstock and preparing for digestion) - Biogas technology selection; o Digester Configuration (as simple and suitable as possible) o Biogas use (such as CHP, Bio-CNG or flaring) o Conveyance and conditioning (suitable and safe) - Access to and handling of sludge and treated effluent;	
c) Corrosion resistance; Should be able to resist corrosion: • Such as piping system, fittings and equipment	
d) Automation; • To provide appropriate level automation and control monitoring device such as Programmable Logic Control (PLC), valve and sensor	

DESCRIPTION	REMARKS
e) Feedstock and digestate conveyance by gravity as much as possible to minimize manual handling;	
f) A safe design including appropriate infrastructure and safe operating procedures to mitigate the risk of harm to humans and the environment; • Plant layout: (control in access and ingress, safe handling, and to consider Zone rating and setback for equipment) • Equipment fail safe devices throughout including flare, pressure relief valve and heat dump • Lightning and surge protection device should be installed according to MS IEC 62305	
g) Digester size and safe design appropriate for the current and/or projected future volume and nature of waste to be dealt with;	
h) Biogas storage for maximising value of biogas utilisation; • Safe design	
i) Biogas handling equipment including pipe work, valves, blower; • Meeting design specification	
j) Appropriate biogas utilisation equipment – electricity generating equipment or boilers (if applicable); • Energy demand	
k) Meeting legal requirement such as environmental management, local authorities and safety management;	

APPENDIX D: OPERATION AND MAINTENANCE CHECKLISTS

This is only suggested elements on the checklist that need to be monitored, daily, weekly, quarterly and annually. Additional elements may need to be included to suit own use and objective.

DESCRIPTION	REMARKS
a) Daily activities: To check that • There is no obstructive material in the mixing tank/pit • The feeding mechanisms is functioning • The Agitator/stirring device is functioning • There is no clogging of the overflow point/recycle outlet • The appearance and odour of the digested slurry is within the normal specification • The gas pressure is within the design specification • There is no leak on equipment and piping connections	
(b) Weekly activities: • Inspect the water trap and release as necessary • Visually inspect motors and electrical lines for abnormality (sound, vibration, tightness) • Check digester covers & gas storages for leakages • Visual inspection of digestate level in tanks (to avoid overflow) • Check and clean over-pressure valves, relief stack and gas line • Check for corrosion on pipes, valves etc.	
(c) Quarterly activities: • Verify that fire extinguishers are available, valid and functioning • Inspect and test the plant (CA pond/tank) and other peripheral for water tightness and gas tightness • Piping should be checked and free from defects • Check flare and system for fit for service • Inspect and test lightning arrester for functioning	
(d) Annual activities: • Plant and digester should be stopped and cleaned. Inspection should made to verify that every equipment is fit to function safely (fit for service).	

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