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Biogas System — Specifications — Wet Anaerobic Digestion Process

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Foreword

During the Meeting on the enforcement and regulation of Philippine National Standards (PNS) held in February 2020, the Bureau of Agricultural and Fisheries Engineering (BAFE) of the Department of Agriculture (DA) put forth a proposal to amend the Philippine Agricultural Engineering Standards (PAES) 413:2001 (Agricultural Structures – Biogas Plant). The amendment aims to consider the current regulation and the existing industry practices, particularly the training regulation of the Technical Education and Skills Development Authority (TESDA) on biogas plants and the existing International Organization for Standardization (ISO) standards. As a response, the DA-Bureau of Agriculture and Fisheries Standards (BAFS)-Standards Development Division (SDD) included the proposal in the CY 2022 Priority List of standards for development.

In line with this, the DA-BAFS created a Technical Working Group (TWG) composed of representatives from relevant DA agencies, other National Government Agencies (NGAs), academe/research institutions, private sector, and Civil Society Organizations (CSO) to develop the PNS. The TWG was established under the following Special Order (SO):

1. SO No. 103, series of 2022 (Creation of Technical Working Groups [TWG] for the Development of Philippine National Standards [PNS] for Agriculture and Fishery Products, Machineries, and Infrastructures);
2. SO No. 487, series of 2022 (Addendum to the SO No. 103, Series of 2022 Entitled “Creation of TWG for the Development of PNS for Agriculture and Fishery Products, Machineries, and Infrastructures”);
3. SO No. 617, series of 2022 (Amendment to SO No. 487, Series of 2022 [Addendum to the SO No. 103, Series of 2022 Entitled “Creation of TWG for the Development of PNS for Agriculture and Fishery Products, Machineries, and Infrastructures”]); and
4. SO No. 146, series of 2023 (Creation of TWG for the Development of PNS for Agricultural and Fishery Products, Machinery, and Infrastructures).

The draft PNS underwent a series of TWG meetings and stakeholder consultations conducted via blended platforms from June 2022 to June 2023 prior to its endorsement to the DA Secretary for approval. Throughout these activities, the TWG reached a consensus to retain the existing PAES 413:2001 (Agricultural Structures - Biogas Plant). It was further agreed that this particular project would be considered as a distinct and separate standard. This decision demonstrates a well-balanced approach that recognizes the significance of the existing standard, PAES 413:2001, while also accommodating the unique requirements and considerations associated with advancements in biogas systems.

This PNS was drafted in accordance with the editorial rules of the DA-BAFS-SDD Standardization Guide No. 1 (Writing the Philippine National Standards).

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1 Scope

This Standard specifies the minimum requirements for the design, construction, components, safety, and operation and maintenance of a biogas system. This applies to household and non-household biogas systems and facilities utilizing agricultural, fishery and agro-industrial wastes through a wet anaerobic digestion process. All biogas systems covered by PAES 413:2001 (Agricultural structures — Biogas plant) are not included in this Standard.

2 Normative References

The following documents are referred to in the text in such a way that some or all their contents constitute the requirements of this document. The latest edition of the referenced documents (including any amendments) applies:

Agricultural Machinery Testing and Evaluation Center (AMTEC)-University of the Philippines Los Baños (UPLB). (2001). Agricultural structures — Biogas plant (PAES 413:2001). https://amtec.ceat.uplb.edu.ph/wp-content/uploads/2020/06/PNS-PAES-413-2001-Agricultural-Structures-Biogas-Plant.pdf

American Society for Testing and Materials (ASTM). (2016). Standard specification for loadbearing concrete masonry units (ASTM C90).

ASTM. (2017). Standard specification for nonloadbearing concrete masonry units (ASTM C129).

ASTM. (2019). Standard practice for establishing structural grades and related allowable properties for visually graded lumber (ASTM D245).

ASTM. (2019). Standard specification for carbon structural steel (ASTM A36).

ASTM. (2019). Standard specification for high strength structural bolts, steel and alloy steel, heat treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) minimum tensile strength, inch and metric dimensions (ASTM F3125).

ASTM. (2020). Standard specification for deformed and plain carbon-steel bars for concrete reinforcement (ASTM A615).

ASTM. (2020). Standard specification for pipe, steel, black and hot-dipped, zinc-coated, welded and seamless (ASTM A53).

ASTM. (2020). Standard specification for steel sheet, zinc-coated (galvanized) or zinc-iron alloy-coated (galvannealed) by the hot-dip process (ASTM A653).

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Department of Environmental and Natural Resources (DENR). (2015). Rules and procedures for the implementation of the Globally Harmonized System (GHS) in preparation of Safety Data Sheets (SDS) and labelling requirements for toxic chemical substances. https://chemical.emb.gov.ph/wp-content/uploads/2017/03/DAO-2015-09-Implementation-of-GHS.pdf

Department of Labor and Employment (DOLE). (2020). Occupational safety and health standards. Occupational Safety and Health Center (OSHC). https://oshc.dole.gov.ph/wp-content/uploads/2020/02/OSH-Standards-2020-Edition.pdf

Department of Public Works and Highways (DPWH). (2005). Revised Implementing Rules and Regulations (IRR) of the NBCP (PD 1096). http://www.iibh.org/kijun/pdf/Philippines_02_IRR_of_NBC_of_the_Philippines.pdf

International Organization for Standardization (ISO). (2020). Flares for combustion of biogas (ISO 22580:2020).

ISO. (2021). Biogas systems — Non-household and non-gasification (ISO 24252:2021).

ISO. (2021). Household biogas system requirements: design, installation, operation, maintenance and (ISO 23590:2020).

National Building Code of the Philippines (NBCP), Presidential Decree (PD) No. 1096. (1977). https://ray.dilg.gov.ph/files/national_building_code_of_the_philippines.pdf

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Philippine Society of Mechanical Engineers (PSME). (2012). Philippine mechanical engineering code. PSME, Inc.

3 Terms and Definitions

For the purpose of this Standard, the following definitions shall apply:

3.1
anaerobic digestion process
biological conversion of biodegradable materials by microorganisms in the absence of oxygen creating two main products: biogas and digestate (ISO, 2018)

3.2
biochemical methane potential (BMP)
amount of organic matters in a substrate that can be degraded by anaerobic microorganisms. It also indicates the biogas output per unit quantity of substrate (Deng et al., 2020)

3.3
biogas
gas produced by anaerobic digestion of organic matter (ISO, 2018). It consists typically of 40-75 % methane, 14-45 % carbon dioxide, along with small amounts of water vapor and other gases (ISO, 2020)

3.4
biogas system
system used to process agricultural, fishery, and agro-industrial waste to produce biogas and sludge consisting of, but not limited to, a mixing tank/inlet, digester, gas chamber and outlet/sludge tank/hydraulic pressure tank (AMTEC-UPLB, 2001, *modified*)

3.5
biomass resources
biomass
non-fossilized, biodegradable organic materials originating from naturally occurring or cultured plants, animals and microorganisms, including agricultural products, by-products and residues that can be used in bioconversion process and other processes, as well as gases and liquids recovered from the decomposition and/or extraction of non-fossilized and biodegradable organic materials (Renewable Energy Act of 2008, 2008, *modified*). Biomass resources include but are not limited to the following:

3.5.1
agricultural and fishery wastes
consist of solid and liquid waste, slurry including by-products and residues resulting from the production and processing of crops, livestock, poultry, and fishery (AMTEC-UPLB, 2002a;2002b, *modified*)

3.5.2
agro-industrial wastes
consist of solid and liquid waste generated from local activity or series of activities to maintain or raise the quality or change the form or characteristics of agricultural, fisheries and forestry products (Agricultural and Fisheries Mechanization [AFMech] Law, 2013, *modified*)

3.6
carbon nitrogen ratio (C/N)
ratio of carbon and nitrogen content in substrate (Deng et al., 2020)

3.7
chemical oxygen demand (COD)
amount of oxygen consumed by oxidizing substrate under heating condition with chemical oxidants, usually expressed in terms of oxygen consumption in mg/L or g/L (Deng et al., 2020)

3.8
digester
anaerobic digestion installation including reactors, tanks and related equipment (ISO, 2018); also known as biodigester or bioreactor

3.9
effluent
residue that comes out at the outlet after the substrate is digested/processed inside the digester (AMTEC-UPLB, 2001)

3.10
flare
safety component meant to combust biogas during exceptional situations when the biogas is not utilized (ISO, 2018)

3.11
freeboard
distance as measured from the slurry filling line to the inside top of the inlet tank (Code on sanitation of the Philippines, 1975, *modified*)

3.12
gas chamber
space inside or outside the digester for the collection and storage of biogas (AMTEC-UPLB, 2001); also known as gasholder or biogas storage

3.13
hydraulic retention time
retention time
average period that a given quantity of slurry is retained in the digester expressed either in hours or days (AMTEC-UPLB, 2001)

3.14
inlet pipe
serves as passage or duct of the slurry from the inlet tank to the digester (AMTEC-UPLB, 2001, *modified*)

3.15
inlet tank
chamber where substrate and water are collected, stored and separated from heavy and non-biodegradable materials before feeding them into the digester (AMTEC-UPLB, 2001, modified); also known as mixing tank or equalization tank

3.16
mesophilic temperature
temperature range of 20 to 40 ^{o}C where mesophilic microorganisms operate (AMTEC-UPLB, 2001)

3.17
outlet pipe
serves as passage or duct where the effluent or the slurry is forced out (AMTEC-UPLB, 2001)

3.18
organic loading rate
amount of volatile organic dry matter entering the digester over time, measured in kilogram per cubic meter digester volume per day (ISO, 2018)

3.19
outlet tank
chamber where digestate is stored (AMTEC-UPLB, 2001, *modified*)

3.20
scum
layer of floating material that may accumulate on the surface of the digester tank (AMTEC-UPLB, 2001)

3.21
seeding
adding or introducing anaerobic microorganism to the digester to enhance bio-digestion (AMTEC-UPLB, 2001)

3.22
sludge
settled portion or precipitate of the slurry; a mud-like, semi-solid mass (AMTEC-UPLB, 2001)

3.23
slurry
mixture of substrate and water (AMTEC-UPLB, 2001, *modified*)

3.24
storage period
average period time the slurry is in the inlet tank prior to digestion, expressed in days (ISO, 2018, *modified*)

3.25
substrate
feedstock
part of the biomass which is biodegradable and converted by anaerobic microorganisms and/or enzymes as catalyst into biogas (ISO, 2018)

3.26
total solid (TS)
amount of residues remaining after evaporation and dehydration of substrate at a certain temperature, expressed in percent (%); It is also referred to as dry matter, expressed in g/L (Deng et al., 2020)

3.27
volatile solid (VS)
the difference of the total solids and ash content (remaining solid after burning total solids for one hour at 550 ± 50 °C), expressed in percent (%); It is also referred to as organic dry matter, expressed in g/L (Deng et al., 2020)

3.28
wet anaerobic digestion
anaerobic digestion which uses organic material with consistency of 10-20% dry matter or less (Angelonidi & Smith, 2015, *modified*)

4 Classifications

The classifications for biogas systems according to scale shall be mainly used in terms of minimum requirements. The following shall be used to classify biogas systems:

4.1 According to capacity (ISO, 2021)

Table 1 shows the different digester size capacity for biogas systems classified according to scale.

Table 1. Digester size based on classification according to scale

Classification	Biogas digester volume[1], m^3	Estimated Energy content per year[2], GWh/Yr
Household	Less than 140	Less than 0.1
Non-household[3]		
Small-scale	140 to 7000	0.1 to 5
Medium-scale	7,000 to 140,000	5 to 100
Large-scale	Greater than 140,000	Greater than 100

[1] For the purpose of this Standard, the energy content specified in ISO 24252:2021 (Biogas systems — Non-household and non-gasification) is converted to biogas digester volume. A sample conversion is shown in Annex A (Conversion of energy content to biogas digester volume).

[2] International Organization for Standardization (ISO). (2021). Biogas systems — Non-household and non-gasification (ISO 24252:2021).

[3] Can either be a farm-scale or commercial-scale.

4.1.1 Household biogas system

This type of biogas system uses biomass resources from one household for its own use and consists of a digester and an application for cooking, heating or lighting only (ISO, 2021).

4.1.2 Non-household biogas system

The classification of non-household biogas systems can be grouped as follows:

4.1.2.1 According to utilization

a) Farm-scale biogas system

This type of biogas system uses agricultural fishery and agro-industrial wastes from a farm for its own use and an application for heating, lighting or electrical power production only (ISO, 2021, *modified*).

b) Commercial-scale biogas system

This type of biogas system uses agricultural fishery and agro-industrial wastes to produce biogas available for sale (ISO, 2018, modified).

4.1.2.2 According to energy content

a) Small

Biogas system with a production capacity of biogas having an energy content of 0.1 GWh to 5 GWh per year, as specified in Table 1.

b) Medium

Biogas system with a production capacity of biogas having an energy content of 5 GWh to 100 GWh per year, as specified in Table 1.

c) Large

Biogas system with a production capacity of biogas having an energy content of more than 100 GWh per year, as specified in Table 1.

4.2 According to the number of digesters

4.2.1 Single-digester biogas system

Biogas system composed of only one digester (AMTEC-UPLB, 2001, *modified*).

4.2.2 Multi-digester biogas system

Biogas system composed of two or more digesters arranged in either series or parallel, or a combination of both (AMTEC-UPLB, 2001, *modified*). This can also be a multi-stage digester biogas system.

4.3 According to feeding method

4.3.1 Continuous-fed

Biogas system that is fed with substrate continuously to produce biogas. This type of biogas system needs a continual supply of substrate.

4.3.2 Batch-fed (mixed or unmixed)

Biogas system that are filled and discharged completely after a fixed retention time.

5 Location

5.1 General considerations

5.1.1 Biogas system should be located at a site with good drainage.

5.1.2 Biogas system should be located as near as possible to any substrate source and should be lower than the elevation of its storage area, if applicable.

5.1.3 Soil foundations should be stable and away from tree root intrusion for biogas systems with digesters located underground (AMTEC-UPLB, 2001, *modified*).

5.1.4 The non-household biogas system should require a 25-m (Code on sanitation of the Philippines, 1975, *modified*) distance from vulnerable areas and water sources in compliance with local and national ordinances, other laws, and rules and regulations which may be later created or otherwise identified relevant to biogas systems regarding environmental concerns (ISO, 2021, *modified*).

NOTE Vulnerable areas include but not limited to houses, schools, public buildings, offices where people are present daily, other residence buildings, and buildings for livestock, pets, and plants (ISO, 2021, *modified*).

5.2 Vicinity map

There shall be a vicinity map duly signed by an applicable licensed engineer(s) included in the engineering plans for the biogas system with geographical coordinates using Philippine Reference System (PRS) 92 as reference. The vicinity map shall comply with the requirements of the Department of Energy

(DOE) Department Circular (DC) No. DC2019-10-0013 (Omnibus guidelines governing the award and administration of renewable energy contracts and the registration of renewable energy developers).

5.3 Site development plan

A site development plan depicting the layout and configuration of a biogas system should be drafted, which shall be duly signed by an applicable licensed engineer(s). This should include property lines, existing conditions, zoning, fire hazards, building layout, street layout, appropriate scale, and nearby water bodies.

6 Biogas System Components

6.1 Process block diagram

A sample process block diagram indicating the basic component of a biogas system is shown in Figure 1.

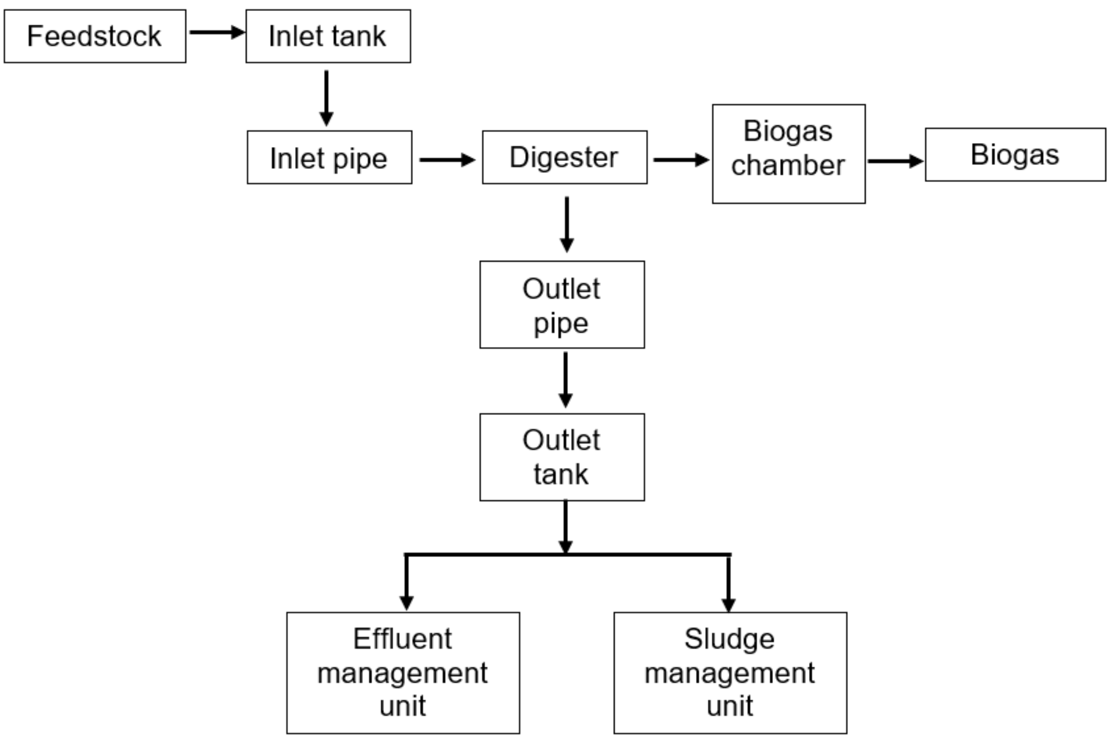


Figure 1. Simple process block diagram of a biogas system

6.2 Basic components

6.2.1 Inlet tank

6.2.1.1 The biogas system shall have an inlet tank to be used for collection, storage or separation of substrate from heavy and non-biodegradable materials.

Note The purpose of the inlet tank is to separate any substances that can obstruct the production of biogas, harm the system, or both. This component helps to make sure that the biogas generation process is as efficient and effective as possible by eliminating heavy or non-biodegradable components such as stones or rocks, metals such as iron or steel, plastics, including PVC, polystyrene, glass or ceramics, other materials that are not easily biodegradable, such as rubber or certain types of textiles from the biomass resource before it enters the system.

6.2.1.2 The size of the inlet tank should hold the equivalent slurry volume for a minimum of 1 day and maximum of 10 days (AMTEC-UPLB, 2001, *modified*), unless appropriately justified by a designed calculation. The volume of the inlet tank shall be designed using the formula specified in Annex B (Formulas used in calculating the dimensions).

6.2.1.3 Inlet tank may have accessories (e.g., agitator, mixer, pumps, etc.), as applicable.

6.2.2 Inlet pipe

6.2.2.1 The biogas system shall have an inlet pipe to allow the slurry to enter the digester where it will be broken down by microorganisms to produce biogas.

6.2.2.2 The minimum diameter for the inlet and outlet pipe shall be designed using the speed of flow formula as shown in Annex B (Formulas used in calculating the dimensions).

6.2.2.3 Inlet and outlet pipes shall be made of non-corrosive materials.

6.2.3 Digester

6.2.3.1 General consideration

a) The biogas system shall have a digester, where the breakdown of organic matter through the process of anaerobic digestion, shall take place to produce biogas and other gases.

b) Digester capacity shall be computed using the formulas indicated in Annex B (Formulas used in calculating the dimensions) and choosing the highest volume. A sample calculation for sizing of the digester is shown in Annex C (Sample calculation for the design of digester volume).

c) Organic loading rate represents the quantity of organic matter that the biogas system can effectively process within a given time frame. Typically, Low organic loading rates for biogas systems ranges at 0.15 to 1 kgCOD/m^3-d, whereas high organic loading rates fall within the range of 1 to 10 kgCOD/m^3-d.

d) Recommended digester hydraulic retention time for mesophilic temperature is shown in Annex D (Digester hydraulic retention time).

e) Materials used for the digester shall not impart any color, odor, or any toxic effect and does not contaminate the slurry.

f) Generally, a manhole with diameter of at least 600 mm should be constructed in place for maintenance. For stainless steel digester, the manhole should be made of stainless steel as well, with a diameter of at least 500 mm.

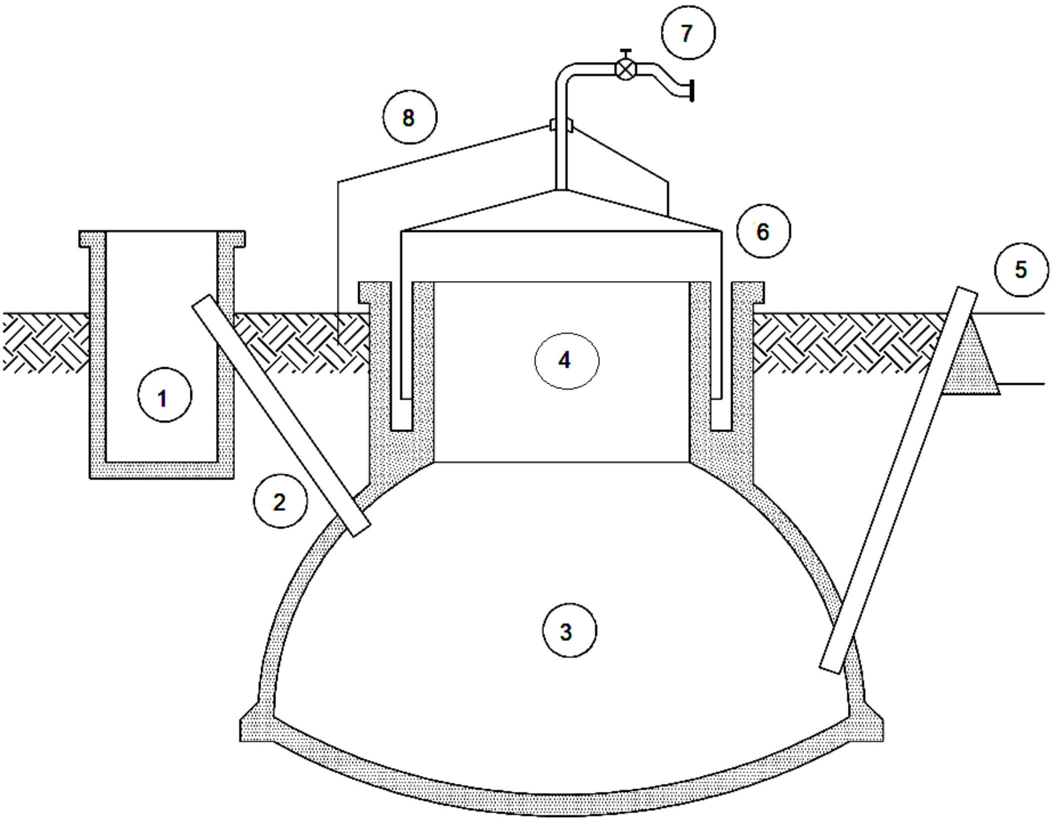
g) Structural design of the digester should comply with the National Structural Code of the Philippines (NSCP).

6.2.3.2 Classification of biogas digester

a) According to gas chamber design

1. Floating type

Composed of a moving gas chamber that either floats directly in the fermenting slurry or in a separate water jacket. An example is shown in Figure 1. (AMTEC-UPLB, 2001, *modified*)



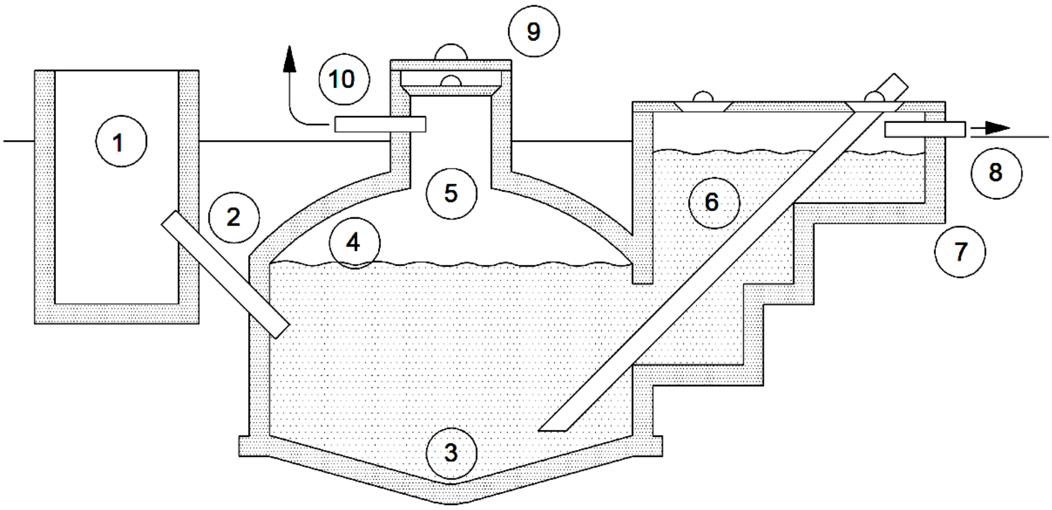
Key

1	Collecting tank	5	Slurry store
2	Inlet pipe	6	Gas chamber
3	Digester	7	Gas pipe
4	Gas holder	8	Guide frame

Figure 1. Example of a floating type biogas system (AMTEC-UPLB, 2001)

2. Fixed type

Composed of a gas chamber fixed to the digester with an example shown in Figure 2. (AMTEC-UPLB, 2001, *modified*)



Key

1	Inlet tank with inlet pipe and sand trap	6	Outlet pipe
2	Digester	7	Outlet tank
3	Accumulation of thick sludge	8	Reference level
4	Supernatant scum	9	Entry hatch
5	Gas chamber	10	Gas pipe

Figure 2. Example of a fixed type biogas system (adapted from Deng & Wang, 2020)

b) According to position

1. Ground digester

Digester placed above ground level.

2. Underground digester

Digester placed below ground level to avoid disruption.

6.2.4 Biogas chamber

6.2.4.1 The biogas system shall have a biogas chamber to provide storage and management for the valuable biogas produced by the digester.

6.2.4.2 For floating type, the biogas chamber shall be equipped with an appropriately designed stopper for safety purposes.

6.2.4.3 A flare or other regulating devices (e.g., pressure valves/gas meter, open manometer, etc.) shall be installed in the biogas chamber.

6.2.4.4 Structural design of the digester shall be in conformance with NSCP.

6.2.5 Outlet pipe

6.2.5.1 The biogas system shall have an outlet pipe to facilitate the removal of digested material or digestate from the digester.

6.2.5.2 The considerations for outlet pipe shall conform to Clause 6.2.2.2.

6.2.6 Outlet tank

6.2.6.1 The biogas system shall have an outlet tank to receive and temporarily store the effluent coming out from the digester.

6.2.6.2 For floating, the minimum volume of the outlet tank shall be equal to the daily slurry input of the digester (AMTEC-UPLB, 2001).

6.2.6.3 For fixed type, the volume of the outlet tank shall be 1/3 of the digester volume occupied by the slurry (AMTEC-UPLB, 2001).

Note By requiring the outlet tank to be at least 1/3 of the digester volume occupied by the slurry, the design of the system provides sufficient space for biogas collection and helps maximize the biogas yield and improve the overall efficiency of the system.

6.2.6.4 Calculation of optimum dimension should follow the same procedure used for the digester tank (AMTEC-UPLB, 2001).

6.2.6.5 For batch-feed type, the outlet tank shall function as a storage tank with a minimum volume equal to the digester before disposal.

6.2.7 Effluent management unit

The biogas system shall have an effluent management unit to collect, store and treat the effluent coming from the outlet tank.

6.2.8 Sludge management unit

The biogas system shall have a sludge management unit to process and manage the residual sludge generated during the anaerobic digestion process, in a way that minimizes environmental impacts and maximizes the potential for beneficial reuse.

6.2.9 Auxiliary components (optional)

6.2.9.1 A hydraulic pressure tank, if provided, shall act as a pressure regulator and outlet of the biogas digester.

6.2.9.2 Additional biogas storage balloons/tanks should be provided, as necessary.

6.2.10 Non-household biogas system requirements

For a non-household biogas system, in addition to Clause 8.3, the following provisions shall be considered:

6.2.10.1 Conditioning lagoon and aeration pond.

6.2.10.2 Process control systems (e.g., alarms and emergency lights), gas leak detection devices, and electronic monitoring systems which will remain in operation for at least 30 minutes after a power failure (ISO, 2021, *modified*).

6.2.10.3 Backup power units (e.g., generators) in case of power failures (ISO, 2021, *modified*).

7 Design and Structural Requirements

7.1 General design requirements

7.2.1 Design of a non-household biogas system should be in accordance with the general design requirements stipulated under Clause 8 of ISO 24252:2021 (Biogas system — non-household and non-gasification).

7.2.2 In the case of the construction of biogas pipelines, the design requirements should be in accordance with Clause 9 of ISO 24252:2021 (Biogas system — non-household and non-gasification).

7.2.3 Other technical requirements should comply with Clauses 10 and 11 of ISO 24252:2021 (Biogas system — non-household and non-gasification) as applicable.

7.2.4 A process block diagram should be prepared to be used as guidance for the drafting of the facility layout.

7.2.5 Materials used for the components of the household biogas system should be in accordance with the minimum requirements specified in Table 3 (ISO, 2020a)

Table 3. Materials requirements for biogas system (ISO, 2020a, *modified*)

Parameter	Minimum requirements
Tensile strength	12 MPa (12 N/mm^2)
Gas permeability	<350 cc/m^2/d/bar of methane
Safety considerations	Shall be in conformance with Occupational Safety and Health (OSH) Standards

7.2.6 A biogas system should have a facility layout prepared, which is composed of, but not limited to:

a) Complete list of facility components with dimensions/footprints;
b) Distance of components in accordance with each other as specified in Annex E (Indicative internal safety distances for biogas facilities), as applicable (ISO, 2021); and
c) Access roads.

7.2 Masonry

Concrete masonry should conform to the American Society for Testing and Materials (ASTM) C90 (Standard specification for loadbearing concrete masonry units) and ASTM C129 (Standard specification for non-loadbearing concrete masonry units) (BAFS-DA, 2021).

7.3 Steel/metal

7.3.1 Structural steel should conform to ASTM A36 (Standard specification for carbon structural steel) and ASTM A53 (Standard specification for pipe, steel, black and hot-dipped, zinc-coated, welded and seamless).

7.3.2 Welded connections should conform to criteria specified in Table 8.1 or Table 10.15 of American Welding Society (AWS) D1.1 (Structural welding — Steel).

7.3.3 Bolted connections should conform to ASTM F3125 (Standard specification for high strength structural bolts, steel and alloy steel, heat treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) minimum tensile strength, inch and metric dimensions).

7.3.4 Steel sheets should conform to ASTM A653 (Standard specification for steel sheet, zinc-coated (galvanized) or zinc-iron alloy-coated (galvannealed) by the hot-dip process).

7.4 Rubber and plastic

High Density Polyethylene (HDPE) type of plastic should be recommended for gas holder/gas storage lining in conformance with ASTM 3350 (Standard specification for polyethylene plastics pipe and fittings materials). Polyvinyl

Chloride (PVC) should be in conformance with ASTM D1785-21a (Standard specification for Poly [Vinyl Chloride] [PVC] plastic pipe, schedules 40, 80, and 120). The PVC materials should not be used if the location is exposed to heat or sunlight (ISO, 2021).

7.5 Composite materials

Reinforcing steel bars should conform to ASTM A615 (Standard specification for deformed and plain carbon-steel bars for concrete reinforcement). (BAFS-DA, 2021)

7.6 Wood/timber

Wood or timber to be used should conform to ASTM D245 (Standard practice for establishing structural grades and related allowable properties for visually graded lumber). (BAFS-DA, 2021)

8 Construction and Installation Requirements

The following are the general process for the construction of a biogas system.

8.1 General

8.1.1 Biogas system structures are categorized as Industrial or Storage and Hazardous under Group F or G of Presidential Decree (PD) 1096, series of 1977 (Adopting a National Building Code of the Philippines [NBCP] thereby revising Republic Act numbered sixty-five hundred forty-one [R.A. NO. 6541]), and shall comply with the requirements indicated along with the existing Implementing Rules and Regulations (IRR) of the NBCP (PD 1096).

8.1.2 During the project planning phase, the user shall comply with local, national, other laws, and rules and regulations which may be later created or otherwise identified relevant to biogas systems.

8.1.3 Construction works shall comply with Chapters 11 and 12 of the PD 1096, series of 1977 (Adopting a NBCP thereby revising RA 6541) along with the corresponding IRR.

8.2 Construction phase

8.2.1 Geotechnical investigation

8.2.1.1 For non-household biogas system, before construction, a geotechnical investigation shall be conducted in the area where the biogas system shall be built. The results of the geotechnical investigation shall then be incorporated into the design of the biogas system (BAFS-DA, 2021, *modified*). The geotechnical investigation shall include:

a) Location of water table;
b) Soil bearing capacity; and
c) Other relevant information that would like to be considered.

8.2.1.2 Geotechnical investigation for household biogas system shall include:

a) Ocular inspection; and
b) Manual digging of about 1.5 m to check the level of the water table.

8.2.2 Excavation

8.2.2.1 Excavation shall be in accordance with the soil specifications and the design of the biogas system.

8.2.2.2 Excavation for the digester should be vertical as possible. A 0.15 m minimum gap on both sides shall be allowed for backfill. Slope of the earth bank (ratio of excavated height to width) should be considered in order to avoid the collapse of earth as shown in Table 2.

Table 2. Maximum excavation slope on various grounds (AMTEC-UPLB, 2001)

Kind of soil	Ratio of height to width
Sandy soil	1:1
Clayey sandy soil	1:0.67
Clayey soil	1:0.50
Clay	1:0.33
Soil with gravel	1:0.67
Dry loess	1:0.25

8.2.2.3 Foundation of the digester should be made of cobbles or crushed stones, and tamped before pouring of concrete.

8.2.2.4 For loose soil, the mixture of the backfill should be 30% gravel or broken stones and 70 % soil. Water content in the backfilled soil should be about 20 % – 25 %.

8.2.2.5 Each layer of backfill outside the wall should be compacted.

8.2.2.6 The backfill area should be well-sloped to allow easy drainage of surface water. Grass and plants but not trees, should be grown in the backfilled area.

8.3 Installation requirements

8.3.1 Plumbing

All plumbing works shall comply with the Revised National Plumbing Code of the Philippines.

8.3.2 Electrical installation

Any electrical installations shall comply with the National Electrical Code (NEC).

8.3.3 Mechanical/equipment installation

All mechanical installations shall comply with the Philippine Mechanical Engineering Code (PMEC).

9 Safety Requirements

9.1 General

9.1.1 Biogas systems shall comply with applicable safety provisions indicated in Sections V (Biomass facilities) and VI (Biofuel facilities) of the DOE DC No. DC2021-06-0020 (Biomass and Biofuels Safety, Health and Environment Code of Practice).

9.1.2 Biogas systems shall conform to safety provisions indicated in PNS/BAFS 330:2022 (Technical means for ensuring safety — Guidelines).

9.1.3 Materials shall comply with the Globally Harmonized System (GHS) as specified in the DENR Department Administrative Order (DAO) 2015-09 (Rules and procedures for the implementation of the GHS of classifications and labeling of chemicals in preparations of Safety Data Sheets (SDS) and labeling requirements of toxic chemical substances).

9.1.4 For the design of any pressurized component of the biogas system, a minimum factor of safety of 2.0 shall be used.

9.2 Flare

9.2.1 Flare shall be provided depending on the output of a biogas facility as shown in Table 6.

Table 6. Biogas flare presence requirement (ISO, 2021, *modified*)

Capacity production or processing raw biogas, Nm^3/h	Biogas flare required	Biogas buffer
0-10	Flare within 24 h call-off basis	2 h; no buffer if flare is available
10-20	Flare within 12 h call-off basis	2 h; if no buffer, flare readily available
>20	Permanent Flare	0.5 h; immediately to permanent flare, as far as no buffer is available or buffer is exceeded
NOTE Nm^3/h = Normal cubic meter per hour		

9.2.2 In case of methane release in the facility, it shall be combusted by an emergency flare (i.e., enclosed or open flare) with a minimum destructive efficiency as defined in Flares for combustion of biogas (ISO 22580:2020) taking into account the terms in Table 6. (ISO, 2021, *modified*)

9.2.3 Flare shall comply with the IRR of RA 9514 (Fire Code of the Philippines).

9.3 Venting and discharge of hazardous gases

9.3.1 Discharge of vent pipes shall not be located near ignition sources or ventilation openings, altitudes where the risk of inhalation is possible. A minimum required safety distance of 5 m shall be applied. A manual describing the explosion safety zones and their location, along with where the vents are discharged, shall be provided. (ISO, 2021, *modified*)

9.3.2 Safety measures shall be taken to ensure that the effluent is sufficiently stable so that the release of hazardous gases that are dangerous to humans, animals and the environment is minimized. Required permit or any equivalent document shall be secured before releasing hazardous gases in compliance with Section 16 of the Philippine Clean Air Act of 1999.

9.4 Fire control and mitigation

The biogas plant shall comply with the fire control and mitigation requirements indicated in Item V (Fire hazards, protection and control) of the Section III of DOE DC No. DC2021-06-0020 (Biomass and biofuels safety, health and environment code of practice), Section 26 of DOE DC No. DC2012-11-0009 (Renewable energy safety, health and environment rules and regulations), and the IRR of RA 9514 (Fire Code of the Philippines). The biogas plant shall be provided with the following, as applicable:

a) Fire suppression devices, equipment or systems (e.g., flame arrester, biogas control valve, or fire extinguisher);
b) Fire safety structures (e.g., fire exits, fire break); and
c) Fire protection and warning systems (e.g., fire alarm, smoke detectors).

10 Operation and Maintenance

The operation and maintenance provision shall be in conformance with the provisions from PAES 413:2001 (Biogas Plant – Specifications), which are as follows:

10.1 Initial loading

10.1.1 Starter/Seeding

The initial raw materials should contain slurry with a high bacteria population. About 5-10% of the total slurry volume should be added when the digester is about 25% full.

10.1.2 Filling the digester

Before putting any slurry into the digester, all valves should be open. Mix the biomass resource and water thoroughly and fill the digester up to the ring level or top beam as shown in Figure 2.

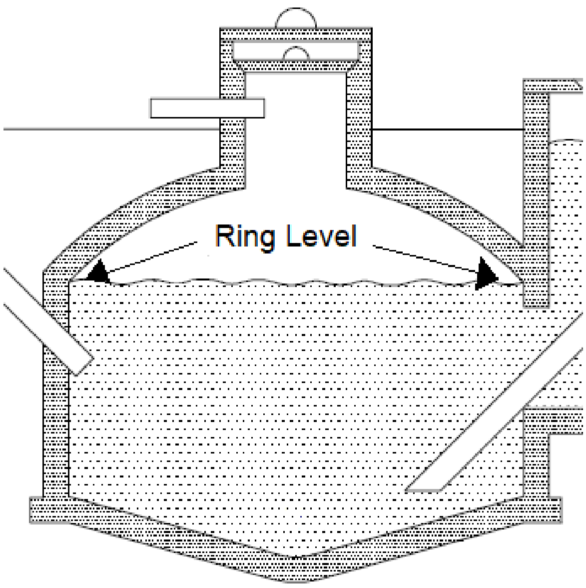


Figure 2. Digester diagram with ring level or top beam

10.2 Mixing slurry for loading

Mixing slurry for loading should be based on the designed organic loading rate as specified in the design or by the manufacturer.

10.3 Loading of slurry and removal of effluent from outlet tank

The biogas system shall be operated based on the designed organic loading rate. The amount of slurry to be loaded should be in accordance with the requirement of the particular digester volume and its hydraulic retention time. The loading of new slurry displaced an equal volume of effluent to the outlet chamber which should be removed.

10.4 Agitation

For household biogas system, if applicable, agitation should be done regularly. For non-household, pump or any stirring mechanisms should be used for agitation.

10.5 Entering the digester

When entering a digester while wearing the appropriate Personal Protective Equipment (PPE), the manhole should be removed for several days and the gas line closest to the digester should be disconnected. The contents should be removed, and the tank should be ventilated. Before entering, the presence of harmful gases or sufficient air should be first checked either by a detection device or using pressurized air to dissipate harmful biogas. Flames should be avoided near or within the digester. A piece of pipe or hose through which the worker inside the pit may breathe should be provided. Another person should be constantly watching from the outside of the pit that can respond to any emergency.

10.6 Servicing scum

All gas within the digester shall be released and the gas piping closest to the digester should be disconnected before cleaning or scraping off the scum.

10.7 Periodic cleaning of the digester

The digester should be emptied at intervals to remove the settled sludge and other inorganic solids that accumulate at the bottom of the digester.

10.8 Repairing works within the digester

10.8.1 Masonry

If the digester is damaged in the form of cracks or leaks, the damaged area should be repaired. The edges of the damaged area should be cleaned and roughened. Two to three layers of chicken wire should be attached to the walls with nails at least 30 cm from either side of the crack. The plastering cement-sand (1:3) mortar should be at least 13 mm thick. The finish should be roughened and should be allowed to dry for at least two weeks. Wax/paraffin seal shall be applied. Testing shall be performed afterward for verification (AMTEC-UPLB, 2001).

10.8.2 Steel

Upon any signs of corrosion, cleaning shall be performed followed by repainting of anti-corrosive paint to ensure the integrity of the steel materials. If necessary, welding shall be performed as needed.

10.8.3 Plastic and rubbers

Reapplication of sealants for leaks and patching of tears shall be done as necessary. If needed, replacement of plastic and rubber materials shall be completed.

Annex A
(Informative)

Conversion of energy content to biogas digester volume

A.1 Energy content (kWh/year) to volume of biogas (m^3)

According to ISO 24252:2021, it is determined that 1 Nm^3 of biogas composed of 100% methane yields an energy content of 9.97 kWh. Assuming a biogas composition consisting of 60% methane and assuming an operational duration of 330 days annually, a daily production of 50.66 m^3 of biogas is achieved.

Solution:

$$100{,}000\,\frac{kWh}{year} \times \frac{1\,Nm^3}{9.97\,kWh \times 0.6} \times \frac{year}{330\,days} = 50.66\,m^3\ of\ Biogas\ per\ day$$

A.2 Volume of biogas (m^3) to volume of digester (m^3)

Considering the utilization of vinasse from cassava alcohol as a substrate, the biogas yield falls within the range of 0.331 to 0.678 cubic meters per kilogram of Chemical Oxygen Demand (COD) (Deng et al, 2020). For the purpose of this Standard, the lower limit of the data will be used to determine the digester volume corresponding to a given biogas volume of 50.66 cubic meters.

Note The biogas yield of a biogas system is influenced by the type of substrate utilized. Annex F (Characteristics of substrate used in a biogas system) provides information on the characteristics of different substrates employed in biogas systems.

Assumptions:

Biogas volume: 50.66 m^3/day	Methane content: 60 %
Substrate: Vinasse of cassava alcohol	COD removal efficiency: 90%
Biogas yield: 0.331 m^3/kgCOD	Organic loading rate: 2kgCOD/day/m^3

Solution:

Biochemical methane potential (BMP):

$$0.331\frac{m^3}{kgCOD} \times 0.6 = 0.1986\ m^3/kgCOD$$

Volume of digester:

$$\frac{50.66\,m^3}{day} \times \frac{1}{0.1986\ m^3/kgCOD} \times \frac{1}{0.9} \times \frac{1}{2kgCOD/day/m^3} = 141.7\,m^3$$

Annex B
(Informative)

Formulas used in calculating the dimensions

B.1 Sizing of inlet tank

B.1.1 Effective volume

$$V_E = Q \times HRT$$

Where:

V_E is the effective volume, m^3
Q is the flowrate, m^3
HRT is the hydraulic retention time, day or h

B.1.2 Volume of Inlet tank

$$V_{IT} = V_E + V_f$$

Where:

V_{IT} is the volume of inlet tank, m^3
V_E is the effective volume, m^3
V_f is the volume of freeboard, m^3

B.2 Sizing of inlet/outlet pipe

$$Q = Av$$

Where:

Q is the volumetric flowrate of the pipe, m^3/s
A is the cross-sectional area of the pipe, m^2
v is the speed of flow, m/s

B.3 Sizing of digester

a) Based on animal population

$$V_d = \frac{P_A}{C_d}$$

Where:

V_d is the volume of the digester, m^3
P_A is the total number of animals, animal
C_d is the number of animals to produce $1m^3$ of waste, animal/m^3

b) Based on hydraulic retention time

$$V_d = HRT \ x \ Q$$

Where:

V_d is the volume of the digester, m^3
HRT is the hydraulic retention time, days
Q is the flowrate, m^3/day

c) Based on livestock unit

$$V_d = \frac{T_{LU}}{C_{LU}}$$

Where:

V_d is the volume of the digester, m^3
T_{LU} is the total livestock unit, LU
C_{LU} is the number of livestock unit to produce $1m^3$ of waste, LU/m^3

Note 1 LU is equivalent to 500 kg animal weight

d) Based on organic loading rate

$$V_d = \frac{S_o Q}{OLR}$$

Where:

V_d is the volume of the digester, m^3
S_o is the chemical oxygen demand (COD) of the slurry, kg/m^3
Q is the flowrate or volume of slurry added per day, m^3/day
OLR is the organic loading rate, $kgCOD/m^3/day$

Annex C
(informative)

Sample calculation for the design of digester volume

C.1 Given and assumptions

The following data are the assumptions for the sample computation:

Given:

Organic loading rate = 1.5 kgCOD/m^3-day
Hydraulic retention time = 6 days
Chemical Oxygen Demand (COD) removal = 80 %

Assumptions:

Wastewater characteristics of waste from 11,000 swines (60 kg)
CODi = 10,000 mg/L
Q = 300 m^3/day
1 animal (swine) produces 1 m^3 of biogas
1 LU (swine) produces 1.25 m^3 of biogas

C.2 Sizing of biogas digester based on animal population

$$V_d = \frac{P_A}{C_d}$$

$$V_d = \frac{11{,}000\ animals}{\frac{6\ animals}{m^3}}$$

$$V_d = 1{,}833\ m^3$$

C.3 Sizing of biogas digester based on hydraulic retention time

$$V_d = HRT\ x\ Q$$

$$V_d = 6\ days\ x\ 300\ m^3/day$$

$$V_d = 1{,}800\ m^3$$

C.4 Sizing of biogas digester based on livestock unit

$$V_d = \frac{\left(\frac{11{,}0000 \ \times 60}{500}\right) LU}{\frac{0.8LU}{m^3}}$$

$$V_d = \ 1{,}650 \ m^3$$

C.5 Sizing of biogas digester based on organic loading rate

$$V_d = \frac{S_o Q}{OLR}$$

$$V_d = \frac{\left(\frac{10{,}000 \ mg}{L}\right)\left(\frac{300m^3}{day}\right)}{1.5 \ kgCOD/m^3/day} \times \frac{1kg}{1{,}000{,}000mg} \times \frac{1{,}000L}{1m^3}$$

$$V_d = \ 2{,}000 \ m^3$$

Annex D
(informative)

Digester retention time

Substrate	Hydraulic retention time[1, 2], days
Liquid pig manure	15-25
Liquid cow/carabao manure	20-30
Liquid chicken manure	20-40
Animal manure mixed with plant material	50-80
[1] The hydraulic retention time is based on the mesophilic temperature range [2] Agricultural Machinery Testing and Evaluation Center (AMTEC)-University of the Philippines Los Baños (UPLB). (2001). Agricultural Structures — Biogas Plant (PAES 413:2001). https://amtec.ceat.uplb.edu.ph/wp-content/uploads/2020/06/PNS-PAES-413-2001-Agricultural-Structures-Biogas-Plant.pdf	

Annex E
(Normative)

Indicative internal safety distances for biogas facilities (ISO, 2021)

Hazards / Plant parts	Digester + gas storage, m/m	External gas storage	Room for process technology, control systems	Room for electrical installations	Drying plants for digestate	Control room	External adsorber	Biogas flare: Open flare, m	Biogas flare: Closed flare, m	Neighboring buildings on the plant site
Digester + gas storage	6/10[1]	6/10[1]	10 m	6 m	15 m	6 m	10 m	15	5 or 15[3]	depending on national regulations, but at least 15 m
External gas storage		6/10[2]	10 m	6 m	15 m	6 m	10 m	15	5 or 15[3]	depending on national regulations, but at least 15 m
Room for process technology, control systems			F90/T30 into the open	F90/T30 into the open	F90/T30 into the open	F90/T30 into the open	F90/T30 into the open	10	5 or 10[3]	depending on national regulations
room for electrical installations				F90/T30	F90/T30	F90/T30	F90/T30	10	5 or 10[3]	depending on national regulations

Hazards / Plant parts	Digester + gas storage, m/m	External gas storage	Room for process technology, control systems	Room for electrical installations	Drying plants for digestate	Control room	External adsorber	Biogas flare		Neighboring buildings on the plant site
								Open flare, m	Closed flare, m	
drying plants for digestate or manure					F90/T30 into the open	F90/T30 into the open	F90/T30 into the open	10	5 or 10	depending on national regulations
control room						F90/T30 into the open	F90/T30 into the open	10	5 or 10[3]	depending on national regulations
biogas flare open enclosed								7.5	3	depending on national regulations

[1] 10 m for systems with digester whose maximum gas volume exceeds 5 000 m^3
[2] 10 m for separate gas storage tanks whose maximum gas volume exceeds 5 000 m^3
[3] 5 m for gas flare with <2 MW thermal input and 10 m for gas flare with >2 MW thermal input

NOTE F90 refers to the fire resistance class of a component for the duration which a component retains its function in a standards fire. T30 refers to the duration for which the fire protection closure shall prevent the passage of the fire (not the smoke) and then shall be opened.

Annex F
(Normative)

Characteristics of substrate used in a biogas system (Deng et al., 2020)

In biogas systems, substrate can typically be categorized into four types, which include animal waste, crop straws, industrial wastes, and aquatic plants. Below is the information outlining the characteristics of various substrates used in biogas systems:

F.1 Animal waste

Substrate, manure	TS, %	VS/TS, %	C/N ratio	Biogas yield, m^3/kg TS
Swine	20-25	77-84	13-15	0.252-0.352
Cow	16-18	70-75	17-26	0.180-0.250
Beef [cattle]	17-20	79-83	18-28	0.180-0.250
Goat	30-32	65-70	26-29	0.206-0.273
Chicken	29-31	80-82	9-11	0.323-0.375
Duck	16-18	80-82	9-15	0.359-0.441
Rabbit	30-37	66-70	14-20	0.174-0.210

F.2 Crop straws

Substrate, straw	TS, %	VS/TS, %	C/N ratio	Biogas yield, m^3/kg TS
Corn	80-95	74-89	51-53	0.33-0.35
Rice	82-88	74-83	68-87	0.32-0.33
Wheat	83-85	82-84	51-67	0.30-0.31

F.3 Industrial organic waste

Substrate	COD, mg/L	BOD, mg/L	Biogas yield, m^3/kg COD
Vinasse of molasses alcohol	80,000–110,000	40,000–70,000	0.360–0.495
Vinasse of cassava alcohol	50,000–70,000	20,000–40,000	0.331–0.678
Wastewater of starch processing	3000–9000	1500–5000	0.340–0.440

Substrate	COD, mg/L	BOD, mg/L	Biogas yield, m^3/kg COD
High-concentration wastewater of beer	4000–6000	2400–3500	0.420
Wastewater of citric acid	10,000–44,000	6000–25,000	0.430–0.530
Wastewater of MSG	30,000–70,000	20,000–42,000	0.340–0.520

F.4 Aquatic plants

Substrate, straw	TS, %	VS, %	Biogas yield	
			m^3/kg TS	m^3/kg VS
Water hyacinth	8	80	0.245–0.302	0.292–0.362
Alligator weed	10	75	0.184–0.334	0.250–0.447
Blue algae	4	90	0.255–0.345	0.285–0.366

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