
Biogas systems — Non-household and non-gasification

Installations de méthanisation — Non-domestique et sans gazéification

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 255, *Biogas*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

0.1 General

The technical committee on biogas (ISO/TC 255) was established in 2011 in order to:

- provide liberalization and facilitation for international trade of biogas systems;
- contribute to international co-operation on technical regulations, standards and assessment procedures;
- curb discriminatory technical requirements as the main form of trade protectionism; and
- reduce and eliminate the technical barriers for international trade of biogas systems.

This document about biogas systems is applicable for biogas production by anaerobic digestion, biogas conditioning, biogas upgrading and biogas utilization. The main purpose of this document is the safe operation of biogas systems without damaging the environment.

The availability of a standard for biogas systems is necessary in order to:

- ensure that biogas systems are built, operated and maintained safely;
- facilitate development of regional and national regulations and incentive programs to regulate methane emissions;
- moderate communication between the different biogas parties through meaningful discussions;
- contribute to reinforcement of biogas flares' safety and business competitiveness with recognized terms and definitions that clarify actors' expectations related to procurement, contracts and services as well as reporting on biogas related action plans, road maps, etc.; and
- contribute to the use of standards by facilitating their development and furthering users' understanding and application of standards.

ISO/TC 255 intends to promote international technology exchange and to accelerate international application of biogas (products) and equipment by developing and maintaining globally harmonized standards. For the avoidance of doubt, it is noted that national legislation may apply which may deviate from or may be additional to the contents of this document.

0.2 Description of the applied technologies

Biogas systems are amongst others applied at industrial plants like food and beverage industries, waste water treatment plants, waste plants, landfill sites, and small-scale plants next to agricultural companies.

Biogas is produced by anaerobic digestion of organic matter.

Biogas mainly comprises methane, carbon dioxide, nitrogen, oxygen, hydrogen sulphide and/or water and furthermore could contain hydrogen, carbon monoxide, heavier hydrocarbons (including aromatic hydrocarbons), siloxanes and/or other substances.

Biogas can be treated in order to eliminate hydrogen sulphide, siloxanes, water and other substances and be upgraded to a gas with higher methane content. Sometimes the biogas is pressurized.

A description of the most common technologies used in biogas systems is included in [Annex B](#).

Guidelines to prevent risks from gasses and explosive atmospheres in buildings are included in [Annex C](#).

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Biogas systems — Non-household and non-gasification

1 Scope

This document applies for systems for biogas production by anaerobic digestion, biogas conditioning, biogas upgrading and biogas utilization from a safety, environmental, performance and functionality perspective, during the design, manufacturing, installation, construction, testing, commissioning, acceptance, operation, regular inspection and maintenance phases.

The following topics are excluded from this document:

- boilers, burners, furnaces and lighting in case these are not specifically applied for locally produced biogas;
- gas fuelled engines for vehicles and ships;
- the public gas grid;
- specifications to determine biomethane quality;
- transportation of compressed or liquefied biogas;
- transportation of biomass or digestate;
- assessment and determination whether biomass is sourced sustainably or not.

An informative explanation of the scope is included in [Annex A](#).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20675, *Biogas — Biogas production, conditioning, upgrading and utilization — Terms, definitions and classification scheme*

ISO 22580, *Flares for combustion of biogas*

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

IEC 62305-2, *Protection against lightning — Part 2: Risk management*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20675 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 hazardous substance
any product or chemical that has properties which are explosive, flammable, oxidising, toxic, corrosive or toxic to the environment

4 Abbreviated terms

CBG	compressed biogas
CBM	compressed biomethane
CNG	compressed natural gas
HAZID	hazards identification study
HAZOP	hazards and operability study
LBG	liquefied bio gas
LBM	liquefied biomethane
LNG	liquefied natural gas
SDS	safety data sheet
P & ID	piping and instrumentation diagram
PPE	personal protective equipment
PSA	pressure swing adsorption
PVC	polyvinyl chloride
RIE	risk evaluation and inventory
THT	tetrahydrothiophene
TRA	task risk analysis
CHP	combined heat and power plant

5 Guide for reading this document

This document consists of different types of systems that might or might not be used in combination with each other. [Clauses 1 to 9](#), and [Clauses 12 to 13](#) are applicable for all types of system. [Table 1](#) shows which chapters are applicable to the type of system.

Table 1 — Clauses applicable to the type of system

Type of system	General clauses	Specific clauses in force
Biogas production	Clauses 1 to 9 and Clauses 12 to 13	Clause 10
Systems of biogas treatment, CHP, biogas upgrading and liquefaction	Clauses 1 to 9 and Clauses 12 to 13	Clause 12

6 Safety principles

In the conceptual, basic and detailed design and management of biogas systems, the following principles shall be used to deal with risk based on declining preference:

- Eliminate: Minimize the risk of exposure and the influence of the human actor. Consider process design and process control measures.
- Manage: Risk management; In design, think about maintenance and inspection of equipment and controls, and how risks can be mitigated. This may include the generation of alarms for human handling, physical security systems (such as pressure protection and flame arresters), and instrumental safety systems.
- Accept: Acceptance of risks shall be avoided at all times. If technical elimination or control is not possible or if these measures fail, procedural measures shall be taken to control the risks. Emergency plans are an example of this.

Since in many cases biogas systems are small-scale and in some cases the people concerned have limited knowledge of the risks of industrial plants such as gases, high temperatures and pressures etc., special attention is paid to knowledge, culture and behaviour. This can include recurrent training and training of relevant employees and third parties.

The following elements play a role in safety:

- process safety;
- explosion and fire safety;
- safe management of the biogas system.

As basis for this document, the following safety measures have been taken into account:

- technical safety measures have priority above organizational measures;
- maintenance systems or parts of systems shall have provisions for isolation and be able to be locked out and tagged out for maintenance;
- the system can be controlled;
- the system can be maintained, for this reason sections of the process can be isolated;
- pressures safety control system is working properly;
- in case of electrical power interruption, the system shall automatically go to safe mode ('fail safe');
- monitoring of gases unintentionally released;
- sufficient mechanical and natural ventilation:
 - lightning study, particularly in the event of zones with explosion risks;
- alarm alerts and transfer of these alarms to the responsible people;
- for compiled systems (for example, parts of the system from different vendors), safe installation and maintenance of the total system shall be integrated.

7 Safety studies

7.1 General

In many cases, a risk study or an additional risk inventory and evaluation is required for biogas systems. Also, specific national regulations can be applicable for large biogas systems with significant risks for the surroundings.

Companies shall investigate themselves whether specific safety regulations are applicable. This can depend on the biogas composition and the system size.

7.2 Risk assessment and evaluation

7.2.1 Risk assessment construction, start-up and maintenance

During design and prior to the start of the construction, risk assessment and evaluation (regarding occupational health aspects) shall be performed. Generally, this is mandatory because of national health and safety regulations. For specific risks additional task risk analysis shall be made by the involved workers and construction managers before the start of the activities.

Before the start of the commissioning and the operation, an additional risk assessment and evaluation shall be done. Specifically, the start-up and shut-down of a biogas systems can cause specific safety risks. A list of preventive measures shall be part of the report. All the intervention and maintenance procedures shall be established before the commissioning of the plant. The same applies to the start-up, shutdown, and maintenance of all equipment.

These risk assessments are additional to the HAZOP mentioned below.

7.2.2 HAZOP/HAZID

Process safety risk assessment tools which are often used are HAZID and HAZOP and are described in this subclause.

The implementation of a hazards and operability study (HAZOP), a hazards identification study (HAZID), or similar risk assessment tools are recommended in this document prior to commissioning and prior to the implementation of changes. Please refer to national regulations to see if this requirement is mandatory. If standard systems are realized, this shall be done for the standard part only once and not for each location specifically. In such case, an assessment of location-specific and project-specific risks related to environmental factors that can increase risk shall be added. In case the biogas system consists of several subsystems, a HAZOP shall be executed for the entire system including the interfaces between the subsystems.

Although a HAZOP is required prior to the commissioning, it is advisable to carry this out in the conceptual stage of the design and, if necessary, to be repeated in the further stages of design. It is important to take explosion protection and process safety into account in the design.

A HAZOP shall be performed by multidisciplinary specialists for design, operations and maintenance with knowledge of the gas-side part of the system and the risks. The chairman and preferably a part of the specialists shall be independent from the supplier.

At least three multidisciplinary specialists shall participate in the HAZOP. The following expertise is required during a HAZOP:

- independent chairman;
- safety expert (can also be independent chairman);
- process engineer;
- process control engineer;

- mechanical engineer;
- (civil/structural engineer).

The following documentation is required for a HAZOP session:

- action list;
- P & ID;
- lay-out drawing;
- operating and maintenance instructions (see [Clause 13](#)).

For more details regarding the executing of HAZOP, refer to IEC 61882.

7.3 Explosion protection document (EPD)

It is recommended that the owner of the system prepares an explosion protection document (EPD) prior to the start of work or prior to changes in the workplace, work tools or work process.

NOTE In the EU, this is mandatory according to ATEX 1999/92/CE. In North America, area classifications are defined by NFPA 820. Other risk evaluations or equivalent reports can be integrated therein.

The EPD shall contain at least the following information:

- identification of the risks and the considerations made herein;
- adequate measures which have been taken for safe operations and maintenance;
- which locations are classified as an explosion safety zone including safety requirements;
 - lightning study determining the risks of lightning in relation to explosion safety zones and measures;
- documentation proving that the workplace and work equipment, including warning devices, are designed with due regard for safety, operation and maintenance; and
- documentation regarding the safe use of work equipment.

7.4 Environmental requirements

Besides safety in the design of biogas systems, it is very important to observe the environmental requirements during the design and before the start of procurement and construction. This prevents adjustments in a later stage after commitments have been made.

The environmental requirements are addressed in national or regional legislation. Most important items to take into consideration are soil protection, surface water protection, noise, odour and storage of hazardous materials. Specifically, for soil protection, it is important to use liquid-tight floors in buildings, to prevent soil pollution by for example mineral oils. It shall be noted that soil protection as well as overflows or leakages of biomass or digestate storage might lead to surface water pollution.

In the context of environmental pollution, it is also important to minimize the loss of methane (greenhouse gas) of biogas systems making use of best practices such as leak testing. The potential sources of methane loss shall be identified and, if a loss of methane occurs, measures shall be taken immediately shall reduce it as much as reasonably practical.

NOTE This document does not include a maximum percentage of methane loss for the biogas system, because limit values are arbitrary. Common areas where methane losses occur are: biomass/digestate storage, pressure relief valves, CHP, flare, biogas treatment and upgrading systems.

8 General design requirements

8.1 Materials and structures

8.1.1 General

This subclause describes general design requirements for materials and structures.

8.1.2 Materials

Requirements for materials and structures are applicable to:

- roofs;
- load-bearing structures;
- pipes and pipelines (above ground and underground);
- process equipment, vessels, storage tanks;
- floors (whether or not liquid-tight), stairs, platforms; and
- walls.

It shall be noted that the materials used are suitable for:

- contact with substances in biomass, biogas or chemicals;
- corrosion;
- pressure: for pressure-containing vessels and pipes (> 50 kPa), the choice of material shall also comply with national regulations (such as PED in the EU);
- weights (including pressure load), also depending on the shape and dimensions of the structure;
 - the expected temperature and temperature changes;
- climate conditions (such as wind, sun, snow, earthquakes).

For piping, plastic or steel materials can be applied. PVC shall not be used as material for biogas due to poor experience with durability. A technical study shall show which material shall be used depending on the gas or fluid transported and the atmosphere in which the pipes are located. In case polyethylene (PE) or other plastic materials are used for piping the materials shall be resistant against extension by heat and against UV-radiation, especially for above ground piping. In case steel is used for piping, rustproof galvanized steel or rustproof stainless steel can be used. In case rustproof stainless steel is used, at least AISI 304 shall be applied in case the H_2S concentration is lower than 900 mg/m^3 , and AISI 316 in case the H_2S concentration is 900 mg/m^3 or more. Supporting structures shall be made of rustproof hot dip galvanized steel or stainless steel. For cast products such as valves and flame arresters, low copper aluminium can be applied. For underground pipelines, refer to [9.2](#).

In case of use of different steel materials (e.g. stainless steel and galvanized steel), these materials shall be separated from each other to prevent galvanic corrosion.

In the operations manual, it shall be recorded which materials are chosen and for what reason.

The technical life time of structures, tanks, reactors, vessels and pipes of the system shall be specified by the supplier and be described in the operations or maintenance manual.

8.1.3 Structures, weight and stability calculations

Requirements for structures are applicable to:

- roofs;
- load-bearing structures;
- pipe supporting;
- storage tanks, supports for vessels;
- floors, stairs, platforms; and
- walls.

Generally national regulations contain detailed requirements for structures, roofs, floors, walls, stairs and platforms and for the weight and stability calculations. Climate conditions as wind, sun, snow and earthquakes shall be considered.

In order to use and access the plant safely, facilities such as stairs and platforms shall be present. Based on a risk assessment and depending on the height, frequency of use and way of use a proper design for the stairs and platform shall be made.

8.1.4 Use of used materials and equipment

The use of used materials is allowed provided these materials are in accordance with the requirements of this document.

8.2 Process system facilities

8.2.1 General

This subclause describes the requirements for equipment, pipes, valves and other process system facilities with regard to:

- the gas-side part of the system (parts containing gas or in direct contact with gas); and
- cooling systems using refrigerants.

8.2.2 Gas-side part of the system

Requirements for equipment, pipes, valves and other process system facilities of the gas-side part of the system are:

- Pipes on the pressure side of pumps and compressors shall be provided with a back-flow preventer or non-return device;
- Pipes on the suction side of pumps and compressors are provided with a manual or automated shut-off valve as close as possible to this equipment or, if applicable, connected vessel;
- Spigot-and-socket joints that are not in themselves axially restrained shall be secured against thrust according to the pressures arising. The pipe connections shall be axially restrained;
- Pumps, compressors and agitators used for hazardous substances shall use a mechanical seal, or a similar shaft seal to prevent leaks;
- Gas valves shall be able to be closed manually. Shut-off valves, which shall continue to function in case of fire, shall be carried out fire-resistant;

- Valves shall be tested for tightness in accordance with manufacturer's specifications on a regular basis, to prevent hazards and methane emissions to the environment;
- The valves shall be made of stainless steel with seals which are suitable for the biogas composition and temperature. Seals shall be fire resistant unless a risk assessment determines that it is not necessary;
- In the absence of power supply, the automated shut-off valves shall take the safe position ("fail safe"). Valves which are necessary in emergencies, shall be operated manually or self-closing in case the automation fails in a way that the system is brought into safe operation.

It is advisable to place a manual valve before the biogas pipe or pipeline enters the biogas system, at an accessible location (preferably just outside or inside the gate of the plant). This valve may not be accessible to unauthorized persons.

- Looking at a shut-off valve, it shall be easily accessible and visible that it is opened or closed.
- Vessels, reactors and filter systems shall be equipped with one or more pressure relief valves (see [8.3](#) regarding pressure protection). The outlet of the pipes of the pressure system (vent) shall be routed to a safe location (controlled and zoned location).
 - The location of valves shall be designed in a way that makes it possible to isolate sections of the biogas system in order to enable maintenance and inspections.
- Condensate drain facilities shall be constructed in a way that discharge of condensed water does not reach the soil, but for example, is returned to the digester. Condensate drain facilities shall be easy to inspect and maintain, preferably without having to climb into shafts or pits.
 - Pressurised seal systems shall be designed such that the sealing liquid is unable to escape when the system is triggered but instead flows back automatically. However, these seals also play the role of ultimate safety in the event of a defect in the valves of the anaerobic digestion reactor. Consequently, the filling level of the liquid seal shall not be excessive to limit the risk of rupture of the methanization reactor. The fill level value for each seal shall be justified during the design. These systems shall be fitted with an automatic re-fill valve in case the seal level goes below the minimum. The filling level of the liquid seal is monitored using measuring instrumentation if necessary for safety reasons and corresponds with a suitable safety margin, for example 1,5 times the set pressure of the relief device.
- Process control and pressure safety systems in a way that safe process operation is guaranteed and intervention takes place in case of deviations. During failing of these systems, safe process operation shall be guaranteed.

8.2.3 Cooling systems

For cooling systems using refrigerants (especially refrigerants which are damaging the ozone layer) is referred to national regulations about design, regular testing, certificates, log books, etc. It is critical no leakage occurs, because some refrigerants are ozone layer depleting.

8.3 Pressure protection

A system for biogas system, including vessels, reactors, tanks, pipes and pipelines, shall be gas-tight.

Each vessel, reactor, tank, pipe system, pipeline or other process part shall be provided with one or more pressure relief valves. During maintenance of one of the pressure relief valves, a (temporary) provision shall be implemented in order to protect the system against over pressure or under pressure.

A pressure relief valve shall meet the following criteria:

- it shall be resistant to the corrosive elements of the gas;
- it shall be protected from deposition, clogging or freezing;

- provisions shall be made to provide for safe and easy maintenance;
- it shall not be isolated such that pressure protection is compromised;
- its settings shall prevent venting during normal process conditions;
- it is designed for the maximum expected biogas production.

The outlets of the vent pipes shall be in a location that facilitates maintenance and ensures maximum safety for personnel and shall not interact with air handling systems.

It is advised to monitor the pressure to prevent unnecessary venting.

It is important that the system is designed or operated in such a manner that prevents accidental venting during maintenance. This shall be done either by purging and shutting down the system prior to maintenance, or by the provision of three-way valves that isolates the system being maintained while still providing protection. In no case shall a system be operated without proper overpressure protection.

NOTE Different pressure protection types are present. An example of a relief valve is a mechanical safety valve. Another frequently used example is a hydraulic flush provision.

The discharge of vent pipes (connected with pressure systems and safety valves) shall not be located near ignition sources or ventilation openings. For this purpose, a minimum required safety distance shall be calculated based on e.g. gas discharge and environmental circumstances. If no calculations are made, a minimum distance of 5 m shall be observed. Furthermore, these discharges shall be located at altitudes where is no risk of inhalation by humans and not in places with poor natural ventilation. The supplier of the system shall describe the explosion safety zones in the EPD and relevant manuals and include the locations where the vents are discharged.

The safety devices are tested on proper functioning on an annual basis. The test report shall be recorded for five years. The safety devices are inspected visually on a monthly basis.

8.4 Safety distances

The environmental risks of the biogas system requires distances between the plant and vulnerable objects.

NOTE Vulnerable objects can include homes, schools, public buildings, offices where people are present daily, other residence buildings and buildings for livestock, pets, and plants.

It is recommended to use these distances also for short term occupancies.

The indicative internal safety distances in [Table 2](#) shall be applied as much as possible for new biogas plants (built after the publication date of this document) to protect parts of the biogas plant.

From the minimum distances mentioned in [Table 2](#) can be deviated if thermal radiation calculations and explosion calculations show that smaller distances are safe. In addition, for large flow rates (>500 Nm³/h) thermal radiation calculations and explosion calculations shall always be executed, which can lead to an increase of minimum safety distances and heights.

Table 2 — Indicative internal safety distances for biogas plants

hazards plant parts	digester + gas storage	external gas storage	room for process technology, control systems	room for electrical installations	drying plants for digestate or manure	control room	external adsorber	biogas flare		neighboring buildings on the plant site (e.g. storage for straw, storage for flammable materials)
								Open flare	Closed flare	
digester + gas storage	6 m/10 m ^a	6 m/10 m ^a	10 m	6 m	15 m	6 m	10 m	15 m	5 m/15 m ^c	depending on national regulations, but at least 15 m
external gas storage		6 m/10 m ^b	10 m	6 m	15 m	6 m	10 m	15 m	5 m/15 m ^c	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 m	5 m/10 m ^c	depending on national regulations
room for electrical installations				F90/T30	F90/T30	F90/T30	F90/T30	10 m	5 m/10 m ^c	depending on national regulations
drying plants for digestate or manure					F90/T30 into the open	F90/T30 into the open	F90/T30 into the open	10 m	5 m/10 m	depending on national regulations
control room						F90/T30 into the open	F90/T30 into the open	10 m	5 m/10 m ^c	depending on national regulations
biogas flare open enclosed								7,5 m	3 m	depending on national regulations

a 10 m for systems with digester whose maximum gas volume exceeds 5 000 m³.

b 10 m for separate gas storage tanks whose maximum gas volume exceeds 5 000 m³.

c 5 m for gas flare with <2 MW thermal input and 10 m for gas flare with >2 MW thermal input.

fire resistance class short name	function maintenance via	description
F90	90 minutes	The fire resistance or the fire resistance class of a component stands for the duration during which a component retains its function in a standard fire.
fire resistance class for fire barriers Short name (e.g. doors)	function maintenance via	
T30	90 minutes	The number after the T indicates the duration in minutes, for which duration the fire protection closure shall prevent the passage of the fire (not the smoke) and then shall be opened.

Besides the indicative distance mentioned in Table 2, the distances mentioned below are mandatory, except if thermal radiation calculations and explosion calculations show that smaller distances are safe.

Gas storage tanks shall have a minimum distance of 5 m from the boundary of the terrain. For biogas systems a minimum distance of 2 m to the boundary of the terrain is required. For distances to vulnerable objects an external risk study shall be executed, taking into account the type of biogas and the quantity. A minimum distance of 7,5 m to public traffic routes shall be applied.

A radius of 5 m around the flare shall be kept free of combustible materials (such as bushes, trees). Gas flares shall not be placed on the lowest point of the direct surroundings.

8.5 Electronic monitoring of the process

8.5.1 General

The system is provided with a process-oriented and safety oriented electronic monitoring system.

Notifications and/or alarms referred to in this subclause shall be forwarded automatically to the owner, plant manager and/or (shift and/or stand-by) operators.

The entire system shall be monitored regarding at least:

- a) power failure;

At notification of power failure, the system shall automatically be put in safe mode immediately. The owner, plant manager or operator shall automatically receive a warning and take further action if necessary.

The system and the surrounding buildings shall be monitored regarding at least:

- b) fire or smoke at and around indoor areas where biogas is processed or stored.

The owner, plant manager and/or operators receive a fire warning signal automatically. The company emergency plan enters into force. The design of fire and smoke monitoring systems shall be based upon a HAZOP and/or risk assessment. National legislation can impose additional requirements. For areas where no biogas is processed or stored, national legislation can be applicable.

8.5.2 Monitoring of the process

The following parameters are recommended to be included in the electronic or regular manual monitoring of the process depending on the applicable national regulations and complexity and size of the systems. The safe mode shall be defined at design time, taking into account the functional configuration of the system and the various associated risks.

- a) gas storage;

If the maximum filling level of the gas storage facilities (under which the gas storage which is part of the digester) is exceeded, an automatic alert is generated. Subsequently without delay, automatic action needs to be taken to the gas pressure and/or gas level within the pre-set values, by flaring (see [8.13](#)) or venting. The set values in which these variables are allowed to move, depend on the design of the plant. If necessary, a flare needs to be placed permanently or temporarily (see also [8.13](#)).

- b) gas (over) pressure;

If the pressure of the biogas is above or below the set values because of the non-functioning of the various pressure relief valves, the system is automatically put into the safe mode. The owner, plant manager and/or operators shall receive a notification.

- c) temperature;

If the temperature in the system is different from the set critical process values, a notification shall be generated automatically. The owner, plant manager and/or operator receive a notification and take action immediately. On time action shall be taken to maintain the temperature within the set values (also called the pre-set values) or to bring the plant into a safe position. The pre-set critical values within which the temperature can vary is allowed to move itself, depends on the design of the system.

- d) methane content;

- e) gas flow at inlet and outlet;

Gas flow should be monitored at the outlet of the digester, inlet of users of biogas (such as flares, CHP, heating boilers) inside the biogas plant and the inlet and outlet of systems for treatment, upgrading or

liquefaction of biogas. This can also occur (partly) by means of reliable derivation of values. Depending on the circumstances it may be advisable to measure the gas flow in and out for each subsystem.

Gas flow measurement devices shall be suitable for wet and corrosive gas flows.

f) oxygen content;

It shall be verified that no explosive condition can occur because of the oxygen content in biogas. Oxygen content should be measured for biogas entering a biogas upgrading installation, CHP and other uses.

When for example air is used as a desulphurization agent to reduce hydrogen sulphide inside the digester or gasholder, monitoring of the air pump flowrate in the gasholder shall be carried out at regular intervals. Regular monitoring of the air pump flowrate reduces the risk of creating an explosive atmosphere inside the gasholder. When the digestion process is not in normal operating condition, the air pump flowrate shall be adjusted or shutdown according to the biogas flowrate.

g) carbon dioxide content;

If the variables a) to g) are outside the critical values specified by the supplier, a warning signal is automatically delivered to the owner, plant manager and/or operators. In such case automatic mechanisms or an immediate call to (on-call) operators shall make it possible to bring the process back to the defined values or to put it in safe mode. The set critical values within the variables are allowed to move, depend on the design of the system and are determined by the supplier.

8.6 Buildings and building services

8.6.1 General

This subclause describes ventilation (forced and natural ventilation) and gas detection and safety oriented electronic monitoring inside buildings.

The system is provided with a safety oriented electronic monitoring system.

Notifications and/or alarms referred to in this chapter shall be forwarded automatically to the owner, plant manager and (shift and/or stand-by) operators.

The entire system shall be monitored regarding at least:

a) power failure;

At notification of power failure, the system shall automatically be put in safe mode immediately. The owner, plant manager and/or operator shall automatically receive a warning and take further action if necessary.

The plant and the surrounding buildings shall be monitored regarding at least:

b) fire or smoke in and around indoor areas where biogas is processed or stored.

The owner, plant manager and/or operators receive a fire warning signal automatically. The company emergency plan enters into force. The design of fire and smoke monitoring systems shall be based upon a HAZOP and/or risk assessment. National legislation can impose additional requirements. For areas where no biogas is processed or stored, national legislation can be applicable.

8.6.2 Gas detection and electronic monitoring inside buildings

Indoor spaces where equipment, instruments or pipes which contain biogas are present, shall be equipped with gas detection which generate alarms including internal warning notification and visual and sound alarm on the side in case of:

a) reaching 10 % lower explosion level (LEL) for methane;

NOTE 1 This detects biogas or methane leakage. In addition to risk of explosion, biogas or methane leak can lead to oxygen displacement.

In case of biogas or methane leakage the system is automatically placed in the safety position.

- b) reaching a volume percentage of 0,5volume % CO₂ in case CO₂ is stored inside the building;

NOTE 2 Leakage of CO₂ can lead to oxygen displacement. This risk mainly occurs at biogas upgrading plants where CO₂ is separated from the biogas.

- c) Reaching 7,5 mg/m³ hydrogen sulphide;
- d) reaching a volume percentage of less than 19,0volume % O₂ or more than 23,0 volume % O₂;
- e) fire or smoke.

These requirements apply unless deviation from these requirements is justified on the basis of, amongst others, a risk assessment. Based on such risk assessment for example a deviation can be made in case only completely welded pipes or vessels are used without connections with a risk of leaks.

When the above-mentioned points are reached, the spaces shall be left by human beings immediately and the emergency plan shall come into effect.

The measurements shall take place at the correct height, taking into account the differences in mass between methane, CO₂, hydrogen sulphide, hydrogen and CO relative to air, and the less ventilated parts of the space. The heavier gases are measured 30 cm from the floor, and the lighter gases 30 cm from the ceiling.

The warning notification and the detection point concerned shall be made visible outside the respective areas at a safe distance.

8.6.3 Ventilation

When designing a safe system and specifically assessing the explosion safety, ventilation is crucial. The bigger the danger for explosion by the release of gas, the higher the demands on the absence of ignition sources in the vicinity. Preventive measures to avoid gas emissions in buildings are of primary importance. Placement of gas containing equipment and pipes outside buildings is preferable. If despite preventive measures, a risk of gas accumulation in building still exists, ventilation measures shall be taken.

Mechanical ventilation makes it possible to control the ventilation rates used and is necessary to renew the air in the entire room, it makes it possible in particular to control dead zones. For mechanical ventilation, regular maintenance is needed to prevent defects. Mechanical ventilation shall be monitored in order to determine its operational functioning.

Natural ventilation is not sensitive to mechanical defects; however, it is dependent on external weather circumstances and possible dead zones. In case of natural ventilation, a gas detection device shall give a warning in case the natural ventilation does not function properly. In such case, mechanical ventilation shall start automatically or a procedure to control the leak and to make the room the room accessible shall enter into force.

The rate of ventilation determines the explosion safety zones. Natural ventilation is preferred above mechanical ventilation, since the latter can fail.

In case of indoor spaces where biogas could be released (refer to the [8.6.2](#)), at least sufficient natural ventilation shall be present (ventilation rates expressed in air changes per hour shall be based on IEC 60079-10-1:2021, Annex D or can alternatively be based on national regulations), including cross-ventilation. If the indoor space cannot be ventilated in a natural way (e.g. in basements), forced ventilation (100 % ventilation capacity) and gas detection (optical and acoustical alert) shall be present, including an automatic detection on the proper functioning thereof. Ventilation openings shall be

provided at ceiling level and at floor level. For gas detection in indoor spaces, reference is made to the relevant paragraph electronic monitoring.

NOTE Biogas can accumulate in low locations (H_2S and CO_2 are heavier than air), or in high locations (methane is lighter than air).

Explosion-proof motors and components shall be used in accordance with applicable ISO and/or IEC codes.

8.7 Noise protection

Noise reduction measures are important for persons working nearby the biogas system and also for persons working or living outside in the neighbourhood of the biogas system. The limit values for noise emission on 1 meter from each noise source, the cumulative noise levels and the noise level at vulnerable objects, can differ depending on national regulations. The expected noise levels shall be calculated during the design, based upon source levels obtained from manufacturers of equipment. The actual noise levels shall be measured during the operation of the biogas system. The source emission can be reduced by source reducing materials, such as source reducing walls, doors and ventilation grids.

8.8 Odour prevention

Odour emissions mainly occur because of biomass and digestate storage. Odour emissions can also occur because of leakages of raw biogas. For leakages of odorant, refer to [11.5.9.3](#).

Odour emission can be measured by for example odour panels.

NOTE Odour samples are diluted to different levels by olfactometers and submitted to a group of different persons, the odour panel. The limit value is when the halve of the number of persons distinguishes the odour. This limit value is often expressed as 1 odour unit per m^3 . Such odour study is also called an olfactory impact study.

Limit values can be applicable if present and prescribed in national legislation. The odour impact is evaluated using dispersion modelling. National legislation may prescribe the model to be used. Odour emission can be avoided by choosing an appropriate location and/or by creating a buffer zone around the biogas system and/or by treating the odour molecules. The sources of odour, such as feedstock delivery locations, separation machinery, etc., shall be controlled by containment as much as possible and/or shall be operated under negative pressure to avoid odour emissions. The fragrant air shall be discharged into the atmosphere with or without treatment depending on the odour level measured during the olfactory impact study and the applicable limit values. Leakage of biogas can be avoided by proper selection of construction materials, testing, and maintenance.

8.9 Soil and surface water protection

Soil protection measures are very important during the design. Soil protection measures also protect the surface water. After the start of the construction it is difficult and expensive to include soil protection measures. Amongst others many types of biomass (such as manure), adsorbing materials (contaminated with H_2S or siloxanes), (mineral) oils and cooling agents (used for gas treatment or upgrading) can threaten the soil. To protect the environment and prevent soil pollution, liquid-tight floors are mandatory on locations where soil threatening materials, such as materials containing hazardous substances, mineral oils, cooling agents, and adsorbing materials, are present. In many countries national certification systems exist to provide proof that a floor is liquid tight. When no certification system exists, a physically liquid-tight floor in combination with a drain box can be sufficient to achieve a negligible risk to the soil. Under a supply and drain point of (mineral) oils and coolants a drip tray shall be placed. Leak detection is also a useful to minimize the risks for the soil.

NOTE Soil protection measures are very important during the design. After the start of the construction it is difficult and expensive to include soil protection measures.

For biogas production plants, specific measures shall be taken to prevent the contents of a biomass or digestate storage or the contents of a digester contaminating surface water. This is described in [10.7.9](#). For soil protection and surface water protection also national legislation can be applicable.

8.10 Condensate and particle removal

Condensate drain facilities shall be constructed in a way that discharge of condensed water does not reach the soil, but for example, is returned to the digester, transported to a sewage system or transported to an alternative location such as a storage facility.

Condensate drain facilities shall be easy to inspect and maintain minimizing cases where confined spaces need to be entered. When working in confined spaces, permanent hazardous gas monitoring and ventilation is required.

The condensate removal system shall be designed such that gas cannot escape through the condensate removal system under normal operation.

Condensate drain pipes and raw biogas pipes shall be protected against the risk of freezing (e.g. thermal insulation or heating).

8.11 Storage of hazardous substances

8.11.1 Storage hazardous substances in general

Hazardous materials shall be stored in safe storage areas. National regulations can be applicable. Specific storage cabinets or storage buildings shall be used. Hazardous substances shall be used in accordance with safety data sheets (SDS). Special attention shall be paid to liquid-tight floors to prevent soil pollution, ventilation and explosion prevention. A SDS shall be kept in the control room and readily available to plant operators.

For smaller quantities of hazardous substances, on locations where leakage of soil-threatening substances may occur, a liquid-tight floor shall be present with a storage capacity of at least 110 % of the total amount of present soil-threatening substances. If this liquid-tight floor is not certified, this floor can be combined with a drip tray.

8.12 Facilities at power failure

In case of power failure an emergency power supply shall be started immediately and run for at least a minimum period of 30 min to prevent unsafe situations and to have a controlled shut down. The minimum period the emergency power supply shall be able to run can be reduced in case during a HAZOP or risk assessment is determined that the minimum period can be shorter still preventing unsafe situations and having a controlled shut down.

NOTE An example of an emergency power supply is an "uninterrupted power supply" (battery) or a standby power generator.

The emergency power supply shall:

- ensure that the system will be put in a safe mode or shut down in a safe way;
- ensure that all safety devices and critical components for operation (e.g. mixing system) remain functioning;
- ensure notification of owner, plant manager and operator;
- ensure that the flare remains in operation;
- ensure that the process control system, alarms and emergency lights remain in operation for at least 30 min and for emergency lights longer in case this is required by national legislation;

- ensure that electronic monitoring systems continue to operate for at least 30 min; and
- ensure that mechanical ventilation of explosion safety zones remains functioning.

Generators shall be located in an area where fumes from operation of the generator cannot present a hazard and away from any biogas discharge from a biogas system.

8.13 Air pollution control devices for removal of superfluous biogas (flares, thermal oxidizers gas, etc.)

It is recommended that for plants with an output of more than 20 Nm³ biogas per hour are provided with a flare (open flare, enclosed emergency flare or enclosed high efficiency flare). This flare starts automatically in the event of failure of the regular gas consumers, for example the gas engine, boilers or biogas upgrading system, after the maximum biogas buffer capacity is reached and it shall start before the pressure relief valve opens. Maintenance of the biogas system or parts thereof are no reason for venting via the pressure relief valve instead of buffering or flaring.

For smaller biogas systems (<20 Nm³/h), the above also applies, unless there is no permanent biogas flare present. If there is no permanent biogas flare present on the location, a call-off contract shall be present to get a (mobile) enclosed emergency flare on site within the number of hours given in [Table 3](#). In the event of the release of methane, this shall be disposed in a safe manner (sufficient height and distance of the outlet from where people and animals are located).

Table 3 — Overview needed presence of a biogas flare

Capacity production or processing crude biogas in Nm ³ /h	Biogas flare required (see below for application of the emergency flare or high temperature flare)	Biogas buffer in hours
0 to 10	flare within 24 h call-off basis	2 h; no buffer if flare is available
10 to 20	flare within 12 h call off basis	2 h; if no buffer flare readily available
>20	permanent flare	30 min, immediately to permanent flare, as far as no buffer is available or buffer is exceeded.

In case of an incident leading to the release of methane, the methane shall be combusted by an emergency flare, which is an enclosed flare or open flare and has a minimum destructive efficiency as defined in ISO 22580, taking into account the terms mentioned in the above table. If the flare is in operation during more than 10 % of the number of hours per year (i.e. more than 876 hours per year), an enclosed high efficiency flare with a minimum yield as defined in ISO 22580 shall be used instead of an emergency flare. This percentage can be determined by expected operation hours based upon historical data. These requirements for the application of flares with the mentioned combustion yields are not applicable in case national regulations deviate from these requirements. The number of operation hours shall be registered in order to prove the conformance with the above-mentioned requirements.

NOTE 1 An emergency flare is a biogas flare which is meant to combust biogas during exceptional situations when the biogas is not utilized. Emergency flares can be of the type enclosed flare, enclosed high efficiency flare or open flare.

NOTE 2 An enclosed flare is a biogas flare which consists of an enclosed combustion chamber, where the flame is invisible from outside. An enclosed flare is burning more efficiently with a relatively higher temperature than an open flare and a minimum destructive efficiency as defined in ISO 22580.

NOTE 3 An enclosed high efficiency flare means: biogas flare which consists of an enclosed combustion chamber, where the flame is invisible from outside. An enclosed high efficiency flare is burning more efficiently than an enclosed flare and has a minimum destructive efficiency as defined in ISO 22580.

Flares shall be in accordance with ISO 22580.

8.14 Unwanted venting and discharges of hazardous gases

Vent pipes discharge gases in case of incidents. Often vent pipes are connected to one or more safety relief valves. In case gas consuming equipment is present, this shall be put into operation before overpressure safety devices respond or venting starts, to prevent unnecessary discharge of biogas.

Vent pipes shall end on a location which facilitates maintenance, which ensures maximum safety, which is part of an explosion safety zone, which is well-ventilated and, at a height where the gas cannot come into direct contact with people who perform daily activities, livestock, pets, or the emergency generator.

By monitoring the air flow or using a gas warning device, unnecessary venting can be avoided.

It is important that the vent is not blown off by accident during maintenance of the vent provision or vent pipe. This can be done by securing that during this maintenance, the system pressure is always low. The refilling of a water lock or glycol lock deserves special attention, for example, a separate provision for refilling.

The discharge of vent pipes (connected with pressure systems and safety valves) shall not be located near ignition sources or ventilation openings. For this purpose, a minimum required safety distance shall be calculated based on, for example, gas discharge and environmental circumstances. If no calculations are made a minimum distance of 5 m shall be applied. Furthermore, these discharges shall be located at altitudes where is no risk of inhalation by humans and not in places with poor natural ventilation. The supplier of the system shall describe the explosion safety zones in the relevant manuals and include the locations where the vents are discharged.

8.15 Flame protection and mitigation

All combustion devices (among others, flares, boilers), shall be equipped with a flame arrester. The flame arresters shall either be equipped with some means of thermal shut-off which are activated by a continuous burn on the flame arrester or alternatively the burner nozzle pressure shall be monitored and switch off when the flare burner pressure falls below a specified value to prevent back burning. It may sometimes be necessary to add a flame arrester between the burner and the isolation valve.

8.16 Fire-fighting and extinguishing

In or close to each indoor space, and close to storage tanks of gases, a suitable fire extinguisher shall be present. Fire-fighting equipment shall be inspected annually. Extinguishing media shall be protected against environmental influences such as frost.

It has proven worthwhile to discuss and coordinate fire protection considerations at the plant with the responsible fire brigade prior to commissioning and at regular intervals. Close coordination with the leaders of the local fire brigade units is essential in advance of tactical deployment of the fire brigade in the event of fire or for other forms of technical assistance. It is recommended to hold an exercise in order to ensure that correct action is taken in the event of a deployment. In case of deployment, the fire brigade shall use appropriate personal

protective equipment, a gas detector (CH₄, CO₂, H₂S, etc.) shall be kept ready for use, attention shall be paid to the wind direction when approaching the site, a safe distance shall be maintained, the formation of ignition sparks shall be avoided (e.g. electrical switches!), and the operator on site shall be consulted.

NOTE Further requirements, such as minimum extinguishing capacity, can be included in national regulations.

Stickers with inspection date shall be present at the respective firefighting and extinguishing equipment. In addition, safety signs or warnings shall be present at the appropriate locations, equipment, tanks and piping.

EXAMPLE For example: "Smoking and flames prohibited."

The owner or plant manager shall make an inventory of gases and other hazardous, combustible or flammable substances based on safety data sheets (SDS) which may not be extinguished with water. By means of stickers, operators and fire guards shall be informed about deviating extinguishing media. The fire department shall also be informed.

Within the safety distances, there shall not be combustible materials stored in quantities of over 200 kg without additional protective measures, and there shall neither be buildings that do not belong to the biogas plant nor public roads or paths.

For civil requirements, such as fire protection of structures, fire resistance and fire compartments are given in [8.1](#) and national regulations. Requirements for fire resistance and fire compartments shall be indicated on the drawings of buildings and systems.

8.17 Earthing and lightning protection

Objects shall be properly earthed and protected against electrostatic charges. Earthing shall be executed and inspected in accordance with IEC 62305-2.

NOTE A point of attention is the periodic inspection once a year or two years (depending on the situation, as described in IEC 62305-2). Another word used for (protective) earthing is (protective) grounding.

The need to place a lightning protection system varies per situation. IEC 62305-2 describes the situations in which and for which systems and buildings lightning protection is required. By executing a risk assessment, the proper measures shall be determined.

Objects which are higher than the surrounding buildings and objects, typically shall have a lightning system. Explosion safety zones can also require lightning provisions.

8.18 Emergency routing

Proper emergency routing shall be present, ensuring that escaping in at least two directions is possible. National regulations and fire brigade regulations containing detailed requirements can be applicable. Emergency routes shall be indicated clearly and in indoor spaces the indications shall be visible in the dark. Emergency routes shall be free from obstacles and doors shall be suitable to open from inside.

In order to use and access the plant safely, facilities such as stairs and platforms shall be present. Based on a risk assessment and depending on the height, frequency of use and way of use a proper design for the stairs and platform shall be made.

8.19 Anti-collision

An appropriate collision protection shall be present near above-ground pipelines, equipment containing gas and gas storage tanks, in case heavy vehicles can come close. This protection has preferably also to protect the plant against collision on purpose.

NOTE This can include poles or bumper rails which can withstand collisions with heavy vehicles.

8.20 Access control

For safety reasons, to control access, the biogas system shall be enclosed inside a gated, fenced area. Alternative measures can be considered as long as all safety devices are protected from unauthorized access.

8.21 Electrical, instrumentation and process control

The electrical system of the biogas system shall be in accordance with IEC 60364. For facilities at power failure, see [8.12](#).

For instrumentation and process control is referred to best industrial practices and to the paragraphs about electronic monitoring (of the process and inside buildings) in this document.

Process control systems shall be protected against digital burglary (hacking) and other digital external attacks, especially if these are connected to the internet. The protection of these systems shall be verified at least once a year.

NOTE Hacking can have huge consequences for safety, think about intentional explosions by modifying pressure systems. Usually a security test or penetration test is executed by an external party.

9 Biogas pipelines for untreated biogas

9.1 General

This clause is applicable to pipelines for biogas outside the site of the plant on private and public lands.

In case biogas shall be transported from for example a digester to a biogas treatment or biogas upgrading installation, sometimes pipelines are applied in public ground or in private ground of third parties. These pipelines can be applied above ground or underground (or a combination thereof).

EXAMPLE Several digesters can be connected by pipelines to one biogas treatment system or one biogas upgrading plant.

A distinction is made between pipelines for raw biogas and pre-treated biogas. For the definitions of raw biogas and pre-treated biogas, refer to ISO 20675.

9.2 Materials

The choice of the right material is essential to transport biogas safely and the choice shall be made taking the (expected) biogas composition and the safety risks into account. For example PE (polyethylene) pipelines are preferred for underground pipelines, because lack of corrosion and resistant to frost, ultraviolet radiation and soil containing iron. Also possible corrosion effects on metal valves and instruments shall be considered.

All connections are to be carried out as tension-free as possible. It is recommended to use welded joints. The materials used and the personnel shall be suitably qualified.

Before commissioning, the gas line shall be pressure tested.

In the case of open installed gas pipes, the pipes are secured by pipe supports. These pipe supports are to be arranged in such a way that the pipes can move in a defined manner without releasing undue forces on the pipe.

The materials and wall thicknesses shall be calculated on the basis of 2 times the maximum operating pressure, taking into account that the materials shall be suitable for at least 400 kPa. This minimum requirement of 400 kPa is to guarantee the mechanical strength of the pipeline. The choice of the material is to be made on the basis of composition of the gas, the application, the temperature of the gas and the maximum working pressure. As material for underground pipelines can be used, for example high density polyethylene (ISO 4427 PE 100), or corrosion resistant steel (rustproof stainless steel). For the welding of ISO 4427 PE 100 underground pipelines both mirror or electrofusion welding can be used. Welders shall be certified for making ISO 4427 PE 100 welding. For above ground pipelines the use of ISO 4427 PE 100 is risky, since these pipelines adequately shrink or expand under the influence of the temperature (e.g. by the sun), which increases the risk of cracks in, for example, the welding. For above ground pipelines corrosion resistant steel (rustproof stainless steel) or (depending on the biogas composition refer [8.1.2](#)) rustproof galvanized steel is preferred, however ISO 4427 PE 100 is allowed in case sufficient measures in the structural design are taken to prevent shrinking and expanding because of the temperature.

9.3 Civil design

For the civil design, see national regulations and standards used for the civil design of natural gas pipelines. The following shall be considered:

- The depth in order to protect the pipeline against frost and damage by external factors such as trucks, mowing machines, etc.
- Pipelines shall be marked by colours or imprints with the text "biogas" and a underground pipeline warning tape at least 10 cm above the pipeline.

9.4 Removal of moisture and contaminants

Raw biogas generally contains too much water vapor, which can cause congestion problems in the pipeline after condensation. Furthermore, raw biogas can contain hydrogen sulphide, the risks of this shall be mitigated.

Raw biogas can also contain high levels of ammonia which can be detrimental to appliances and equipment that combust raw biogas. Proper removal methods, such as biogas washing or biogas cooling, can be necessary to limit damage to piping materials and equipment, such as a CHP.

Static electricity could occur in case of humid biogas in combination with non-conductive pipeline materials and a possible explosive mixture, in which case measures shall be taken such as conductive polyethylene.

In case of the untreated gas which is not dried, the pipes shall be placed with a slope with provisions for the condensate drain at the lowest points. With the aid of a draw-off point at the outside of an underground condensate vessel and/or a pump, the vessel can be emptied. This condensate can be returned, for example, to the purification or the fermentation process. Condensate drain pipes and raw biogas pipes shall be protected against the risk of freezing (e.g. thermal insulation or heating).

10 Technical specifications and requirements biogas production

10.1 General

This clause is applicable to anaerobic digestion systems including reactors, tanks, related equipment, pipes and pipelines and storage for biomass and digestate.

Biogas from anaerobic digestion can have several sources, such as biogas from digesters at industrial plants, waste water treatment plants, agricultural facilities and landfill sites.

This clause describes specifications for:

- materials and structures;
- desulphurization;
- pressure protection, buffering capacity and the presence of flares;
- piping, fittings and other process equipment;
- stabilization of digestate;
- storage of hazardous substances;
- electronic monitoring systems;
- other safety systems; and
- safety distances.

10.2 Biomass supply and storage

During supply of biomass and storage adequate measures shall be taken to prevent soil pollution and surface water pollution. At least measures shall be taken to prevent overflow of liquids from storage tanks. See [10.7.9](#) for information on soil protection.

Furthermore, attention shall be paid to biogas, which can be produced during transportation and storage and which leads to the risks of biogas described elsewhere in this document.

10.3 Desulphurization

Desulphurization, the removal of hydrogen sulphide, is applied in order to protect materials against corrosion.

Removal of hydrogen sulphide can also be needed for the application in a combined heat and power system (e.g. oxidation or SCR-catalysts) or for the end products like biomethane, CBM and LBM, for which is referred to chapter biogas treatment, CHP, biogas upgrading and liquefaction.

Hydrogen sulphide is highly toxic gas, has a low odour threshold and is therefore a major health and safety risk. The contact of people with hydrogen sulphide shall be avoided. For more information about the properties and hazards of hydrogen sulphide, see [B.4.3](#).

10.4 Biogas buffer

If the plant fails or parts thereof, for example by a technical malfunction or failure of the electricity grid, the fermentation process will not stop. In order to prevent immediate pressure release as a result of such incidents, a biogas buffer capacity shall be maintained, for example by using storage capacity of the digester. If no biogas buffer capacity is present or is exceeded, a biogas emergency flare needs to be present and used to avoid unwanted emissions of methane.

Maintenance of the biogas system or its components may not be a reason for venting through the pressure relief valve.

The design and the size of biogas buffer is depending on various aspects:

- availability of additional biogas utilization and flare (capacity and expected operation time);
- kind of utilization of biogas and energy production (base load, peak load, continuous, interval);
- potentially possible failures of gas utilization (e.g. feed-in management in the electric power grid).

The effective size of buffer storage shall be determined on a case-by-case basis depending on the biogas consumers and their reaction time to bring the biogas system in safe operation and to avoid an untimely discharge of biogas into the atmosphere. For the number of storage of the buffer for small-scale biogas systems with a capacity of less than 20 Nm³ biogas per hour, see [Table 3](#), in which case the size of the biogas buffer is related to the availability of a flare or the ability to procure mobile flares.

10.5 Storage, removal and stabilizing digestate

During storage and removal of digestate measures shall be taken to prevent soil pollution.

During normal operation of the plant, during decommissioning, measures are taken to ensure that the digestate is sufficiently stable so that the release of gases that are dangerous to humans, animals and the environment is minimized.

The principle is that digestate can never be considered completely stable. It may be that the digestate is not properly mixed, and consists of stable and non-stable digestate. The fermentation process does not stop. Methane is also produced under cold conditions, only the quantity will be less than under warmer conditions. For example, during mixing hazardous gases can be released.

Biomass shall be processed sufficiently in order to reduce the biomethane potential and thereby reducing the methane production from the digestate. The potential for production of biogas by digestate can be reduced by storing the digestate the fermentation in a closed storage (such as a post-digester or digestate storage where no rain-water enters) and to mix it sufficiently. In order to determine whether digestate is sufficiently stable, national legislation can be applicable. If no applicable legislation exists, it is recommended that the biogas potential is reduced to 0,25 l of biogas per gram volatile matter. However, as a result of biological activity there is still a risk that gases is released after stabilization, especially in storage or during transportation. During storage or transportation of digestate pressure relief provisions are necessary.

To minimize release of biogas from digestate storage, the collection of gases released by the digestate is required by storing the digestate in a closed storage, unless the digestate has been stabilized.

Dried, pelletized and composted digestate are sufficiently stable with regard to fermentation activity that they can be stored, transported and applied without further precaution. Further hazards can be dust explosion and self-heating.

10.6 Specific attention points and requirements landfill sites

Landfill gas contains more contaminates than biogas. In addition to hydrogen sulphide, landfill gas also contains nitrogen, oxygen, siloxanes, and aromatic hydrocarbons in the raw gas. The landfill gas is generated at a pressure lower than atmospheric pressure. Besides the pressure of the gas is normally very low (around minus 10 kPa).

10.7 Specific requirements additional to [Clause 8](#)

10.7.1 Materials and structures

Requirements for materials and structures are applicable to:

- roofs;
- load-bearing structures;
- flexible roof tops of gas tanks and/or biomass tanks;
- pipes and pipelines (above ground and underground);
- vessels, storage tanks;
- floors (whether or not liquid-tight), stairs, platforms;
- walls.

Amongst others, many types of biomass (such as manure) and adsorbing materials (contaminated with H₂S or siloxanes) can threaten the soil. For biomass and digestate which do not contain hazardous substances, measures shall be taken to prevent soil pollution, however liquid-tight floors are only mandatory if required by national legislation. To protect the environment and prevent soil pollution, liquid-tight floors are mandatory on locations where other soil threatening materials (such as materials containing hazardous substances, mineral oils, cooling agents adsorbing materials) are present, refer to [8.9](#).

NOTE Soil protection measures are very important during the design. After the start of the construction, it is difficult and expensive to include soil protection measures.

It shall be noted that the materials used are suitable for:

- contact with substances in biomass, biogas or chemicals;
- corrosion;

- climate conditions (such as wind, sun, snow, earthquakes).

The technical life time of structures, tanks, reactors, vessels and pipes of the system shall be specified by the supplier and be described in the operations or maintenance manual.

In case a flexible roof of the digester, gas container and/or manure bag is present, such roof shall be inspected on a regular basis as determined by the supplier of the system. The frequency for inspection is at least once every five years, because of possible damage by wear or external influences. This frequency shall be mentioned in the maintenance manual. If a defect is detected during the inspection, repair or replacement shall be executed.

It is important that flexible roofs have sufficient pressure from the down side; when the pressure is not sufficient, the wind can destroy the membrane.

In case a flexible roof of the digester, gas container and/or manure bag is present and a double-membrane system is used, a gas detection between the two membranes shall be present in order to detect gas leakage. The correct operation of this gas detection can be critical, since ventilation is not normally provided between the two membranes.

In biogas production systems, used (second-hand) materials and equipment are sometimes applied. These materials and equipment shall comply with the requirements in this document.

10.7.2 Equipment, pipes, valves and other process system facilities

Requirements regarding equipment, pipes, valves and other process systems specific for biomass and digestate are:

- pipes, valves and vessels are liquid-tight;
- siphoning by connected vessels is prevented;
- pipes on the pressure sides of pumps are provided with a back-flow preventer or non-return device; and
- pipes on the suction side of pumps are provided with a manual or automated shut-off valve as close as possible to the tank, pit or biomass storage.

10.7.3 Pressure protection

A system for the fermentation of biomass (digesters) and a completely closed storage of digestate, which is not stable yet, shall be gas-tight and shall be provided with one or more pressure relief valves. Negative pressure can also occur in digesters.

It is important that the vent is not blown off by accident during maintenance of the vent provision or vent pipe. This can be prevented during this maintenance by ensuring that the system pressure is always low. The refilling of a water lock or glycol lock deserves special attention, for example, a separate provision for refilling.

The emission of methane from a digestate storage, when the digestate is not stable yet, shall be prevented as much as possible (an exception is the blow off of a vent during an incident).

The safety devices are tested on proper functioning on an annual basis. The test report shall be recorded for five years. The safety devices are inspected visually on a monthly basis. Safety devices like water locks and glycol locks shall be inspected visually on a weekly basis.

Furthermore, no additional requirements are applicable in relation to [Clause 8](#).

10.7.4 Foam

Foam can arise during the production of biogas. Foam can, for example, be detected using guided wave radar instrumentation. Foam formation may be prevented by, for example, adding anti-foaming agent

at various locations in the digester (this is also widely used in aerobic wastewater treatment plants). In the case of digestate storage, the digestate can also be mixed to reduce anaerobic conditions. Biomass and digestate can also be sprayed with water, provided that this does not lead to soil contamination.

Foaming in the digester shall not impact the operation of the pressure relief systems. A back up relief device shall be considered to protect the digester in case the primary relief device gets clogged by foaming. When such back-up device is applied, this device shall have a higher setting than the primary relief device.

Also, provisions shall be present for the discharge of excess foam. After solving the foam formation problems, the functionality of the safety device shall be verified. Foam bubbles include biogas which is a security risk. If the foam has gone outside the digester or tanks, the following environmental measures shall be taken:

- spreading of the foam shall be prevented; and
- the foam shall be broken off from windward side by spraying with water, provided that this does not lead to soil contamination.

These instructions shall be described in the emergency plan.

10.7.5 Safety distances

No additional requirements in relation to [Clause 8](#).

10.7.6 Electronic monitoring of the process

The following additional requirements are applicable in relation to [Clause 8](#).

a) Biomass over filling

Anaerobic digestion tanks and biomass and digestate storages filled by pump systems are monitored on over filling and contain an overfill protection. In case the overfill protection enters into operation, the flow stops immediately and a notification is generated automatically. The owner, plant manager or operator receives a notification and takes action immediately. The system shall be put in a safe position immediately.

b) pH of the digester

The digester(-s) shall be equipped with sampling ports at suitable locations in order to determine the pH of the digester contents as well as to determine total alkalinity and total volatile fatty acids if necessary.

10.7.7 Buildings and building services

No additional requirements in relation to [Clause 8](#).

10.7.8 Noise protection

No additional requirements in relation to [Clause 8](#).

10.7.9 Soil and surface water protection

Especially for biogas production systems soil protection measures shall cover:

- liquid over flow;
- storage of biomass;
- storage of digestate; and

— foam.

Furthermore, for biogas production systems specific measures shall be taken to prevent that the contents of a biomass or digestate storage or the contents of a digester will contaminate surface water.

Containment measures for retention of liquid biomass or digestate, such as earthen berms and dykes, double wall constructions, or use of other materials and construction methods shall be put in place to protect surface water and soils. Regular leak tests on storage structures shall be carried out. The area where a spill or a reservoir leak can occur shall contain the above ground level volume of the largest reservoir of biomass or digestate. Containment measures also facilitates clean-up operations following a large spill, pipe or flange breakage or reservoir leak. National regulations can be applicable and, if they are more restrictive, shall also be taken into account.

10.7.10 Condensate and particle removal

No additional requirements in relation to [Clause 8](#).

10.7.11 Storage of hazardous substances

Common hazardous substances in digester systems are nutrients, acids and bases to treat biomass or digestate, anti-foam agents and mineral oils for the purpose of possibly existing engines and machines.

Hazardous substances shall be stored and used in accordance with the safety data sheets (SDS). Appropriate personal protective equipment (PPE) shall be used. Unintentionally released hazardous substances shall be collected and disposed of immediately in accordance with the instructions in the safety data sheet. Only instructed and trained employees may handle hazardous substances. The type of storage and the maximum quantity to be stored depend on national regulations.

10.7.12 Facilities at power failure

No additional requirements in relation to [Clause 8](#).

10.7.13 Air pollution control devices for removal of superfluous biogas (flares, thermal oxidizers gas etc.)

No additional requirements in relation to [Clause 8](#).

10.7.14 Venting

No additional requirements in relation to [Clause 8](#).

10.7.15 Flame protection and mitigation

No additional requirements in relation to [Clause 8](#).

10.7.16 Firefighting and extinguishing

No additional requirements in relation to [Clause 8](#).

In or close to each indoor space, and close to storage tanks of gases and storage of biomass and digestate a suitable fire extinguisher shall be present. A temperature control system and fire-fighting equipment such as water protection systems have also to be present on storage of dry biomass or digestate. Fire-fighting equipment shall be inspected annually. Extinguishing media shall be protected against environmental influences such as frost.

National legislation can provide additional requirements.

10.7.17 Earthing and lightning protection

No additional requirements in relation to [Clause 8](#).

10.7.18 Emergency routing

No additional requirements in relation to [Clause 8](#).

10.7.19 Anti-collision

No additional requirements in relation to [Clause 8](#).

10.7.20 Electrical, instrumentation & process control

No additional requirements in relation to [Clause 8](#).

11 Technical specifications and requirements biogas treatment, CHP, upgrading and liquefaction

11.1 General

This clause is applicable to:

- biogas treatment, the removal of water, CO₂, O₂, N₂, H₂S, aromatic hydrocarbons and other contaminants. This is also called biogas conditioning;
- the gas side part of a combined heat and power system (co-generation);
- biogas upgrading to biomethane (increase of the methane content of the biogas); and
- liquefaction of biomethane to LBM at low temperatures.

For the non-gas side part of a combined heat and power system (the gas turbine or gas engine) no requirements are included in this document. In particular, IEC and national standards regarding high voltage requirements can be applicable for the non-gas side part.

This clause describes specifications for:

- materials and structures;
- desulphurization;
- pressure protection, buffering capacity and the presence of flares;
- piping, fittings and other process equipment;
- storage of hazardous substances;
- electronic monitoring systems;
- other safety systems; and
- safety distances.

11.2 Desulphurization

Desulphurization, the removal of hydrogen sulphide, is applied in order to protect materials against corrosion. Also, the end product (biomethane, CBM, LBM etc.), has restrictions for the percentage of H₂S in the gas. When biogas is used in a combined heat and power systems, the manufacturer of this system will also impose limit values for H₂S.

Hydrogen sulphide is highly toxic gas, has a low odour threshold and is therefore a major security risk. The contact of people with hydrogen sulphide shall be avoided at all times. For more information about the properties and hazards of hydrogen sulphide, see [B.4.3](#).

11.3 Biogas upgrading and liquefaction

The specific risks of the various technologies for biogas upgrading are:

- water scrubbing: besides the risks of gases described before, polluted water emitted to the surface water or soil, health effects of polluted water;
- amine scrubbing: besides the risks of gases described before polluted liquids emitted to the surface water or soil, human contact with chemicals or polluted liquids;
- membrane technology: besides the risks of gases described before pressure, environmental and health effects changing of polluted membranes;
- cryogenic technology: besides the risks of gases described before pressure, cold media and materials, environmental and health effects of polluted condensate;
- pressure swing adsorption: besides the risks of gases described before pressure, health and environmental effects of polluted adsorption materials;
- liquefaction: besides the risks of gases described before pressure, cold media and materials, polluted condensate.

11.4 Process system facilities

11.4.1 General

This subclause describes the requirements for equipment, pipes, valves and other process system facilities with regard to:

- the gas-side part of the system (parts containing gas or in direct contact with gas); and
- cooling systems using refrigerants.

11.4.2 Gas-side part of the system

Special attention shall be paid to specific characteristics of the biogas and contaminants during its transformation from raw biogas to the final product. Biogas is present in different forms during this process, such as raw biogas, treated biogas, biomethane, compressed biomethane or liquefied biomethane. Temperature, pressure, the existence of contaminants such as H_2S , volatile organic compounds or siloxanes is relevant and can have impact on the design and operation. For example, volatile organic compounds can disrupt membranes used for methane separation during biogas upgrading and siloxanes can have effect on materials and for example CHP systems, boilers or vehicle engines. During the HAZOP and/or other risk assessments attention shall be paid to these characteristics.

11.4.3 Cooling systems

For cooling systems using refrigerants (especially refrigerants which are damaging the ozone layer) is referred to national regulations about design, regular testing, certificates, log books, etc. It is critical no leakage occurs, because the refrigerants are ozone layer threatening.

11.5 Specific requirements additional to [Clause 8](#)

11.5.1 Materials and structures

Special attention shall be paid to the (possibly high) pressures and (possibly high or low) temperatures of the applied technologies to treat, upgrade or liquefy biogas. During the HAZOP and/or other risk assessments attention shall be paid to the choice of materials because of the specific conditions.

Piping materials shall be made of rustproof stainless steel. At least AISI 304 in case the H₂S concentration is lower than 900 mg/m³ and stainless steel AISI 316 in case the H₂S concentration is 900 mg/m³ or more. Supporting structures shall be made of hot dip galvanized steel or stainless steel. For cast products such as valves and flame arresters, low copper aluminium can be applied.

In the case of the use of different materials (e.g. stainless steel and galvanized steel), these materials shall be separated from each other to prevent galvanic corrosion.

In the operations manual, it shall be recorded which materials are chosen and for what reason.

The technical life time of structures, tanks, reactors, vessels and pipes of the system shall be specified by the supplier and be described in the operations or maintenance manual.

11.5.2 Pressure protection

A system for biogas treatment, combined heat and power generation, biogas upgrading, liquefaction, including vessels, reactors, tanks, pipes and pipelines, shall be gas tight and shall be provided with one or more pressure relief valves.

11.5.3 Safety distances

The risks of the biogas system require distances between the plant (especially gas storage tanks) and vulnerable objects.

For distances to vulnerable objects an external risk study shall be executed, taking into account the type of biogas and the quantity.

11.5.4 Electronic monitoring of the process

No additional requirements are applicable in relation to [Clause 8](#).

11.5.5 Buildings and building services

No additional requirements are applicable in relation to [Clause 8](#).

11.5.6 Noise protection

No additional requirements in relation to [Clause 8](#).

11.5.7 Soil protection

Especially for systems for biogas treatment, CHP, upgrading and liquefaction soil protection measures shall cover:

- storage of chemicals;
- storage of cooling agents; and
- storage of mineral oils.

11.5.8 Condensate and particle removal

No additional requirements in relation to [Clause 8](#).

11.5.9 Storage of hazardous substances

11.5.9.1 General

In addition to [Clause 8](#), the presence of other hazardous substances shall be taken into account.

Common hazardous substances in upgrading and liquefaction systems are storage of gases (including CBM, LBM, calibration gases), odorants (such as THT) and mineral oils for the purpose of possibly existing engines and machines.

In this subclause, special attention is paid to storage of liquefied biomethane and odorant.

11.5.9.2 Storage of liquefied biomethane

The tank in which liquid biomethane is stored is provided with a relief valve. A well-insulated tank (e.g. vacuum insulated) shall be applied in order to keep the liquid biomethane cold and to prevent energy loss. Possible contact by people with cold pipes, vessels and equipment, and/or with cold biogas shall be avoided in any case. For this reason, pipes, vessels, tanks and equipment shall be properly insulated. Vent discharges of cold biogas shall be located in such way that no contact with human beings can occur. Furthermore, vent discharges of biogas shall be done in a manner to avoid risk or injury to animals and plants, and away from the emergency generator.

For stationary and non-stationary LNG and/or LBM tanks and the filling and emptying thereof, specific national regulations or standards can be applicable. Sometimes these are related to LNG fuel stations.

A stationary storage tank for liquid biogas is emptied with composite tubing. When emptying potential equalization is applied to the tank in order to prevent static charging.

NOTE 1 Methane can be liquefied by compression and cooling. It is then called LBM. The hazardous properties are similar to LNG (liquefied natural gas).

NOTE 2 The reason for using composite tubing is that it reduces the external safety risk zones.

NOTE 3 It is also possible to store LBM in a liquid gas shipping container, specific for LNG and similar gases with the same bandwidths for pressure and temperature. When the container is full, it is closed and replaced by an empty container. Such shipping container is inspected and approved for the transport of dangerous substances (road, rail and/or water, which is applicable). If the liquid gas shipping container is approved, it means that is safe enough for a stationary situation.

Minimum distances between LBM storage tanks and external vulnerable objects and internal objects are applicable. Between a LBM storage tank with a content up to 20 Nm³ and an external vulnerable object (e.g. where people live or work on a daily basis) the distance shall be at least 50 m, calculated from the discharge point of the storage tank. For other circumstances, a specific external risk assessment shall be done. The minimum distance between a LBM storage tank with a content up to 20 Nm³ and internal objects where people are working daily (such as control room of the biogas system, office, etc.) is 5 m.

11.5.9.3 Storage of odorant

For injection of biomethane into the public grid, the public grid operator requires the addition of odorant to the biomethane. A small amount of odorant can ensure the safety of the public gas supply. Currently, tetrahydrothiophene (THT) or mercaptan is mostly used for this purpose. Because the presence of sulphur compounds is undesirable for vehicle fuels, alternative odorants are currently being for future use. THT or mercaptan is the fragrance which gives natural gas its characteristic smell and has a very low odour threshold. Leakage of odorant is highly undesirable. If a small amount of odorant is released

accidentally, this leads to complaints about a natural gas smell in an extensive area around the leak and people might think a real gas leakage has occurred.

Odorant shall be added in a closed system. In addition, the odorant shall be stored in a sealed container. Operations with odorant shall be performed by authorized personnel only.

A leakage of odorant shall be reported to the operator of the natural gas grid, the fire brigade and the competent authorities, so they are informed in case of complaints and the fire brigade will not arrive unnecessarily. For this reason, a list of contact phone numbers shall be present near the place where odorant is stored and added.

In case of a spill with odorant on the floor or in the appropriate drip tray, the spill shall be immediately taken up with absorbent material and jointly disposed as hazardous waste in a gas-tight packing. In case of a spill on the soil, the soil is polluted and all environmental measures to prevent and remove the soil pollution shall be taken.

11.5.10 Facilities at power failure

No additional requirements in relation to [Clause 8](#).

11.5.11 Air pollution control devices for removal of superfluous biogas (flares, thermal oxidizers gas etc.)

No additional requirements in relation to [Clause 8](#).

Flares shall be suitable for raw biogas, untreated biogas and biomethane and for this reason shall be suitable for a wide range of methane percentages.

11.5.12 Venting

No additional requirements in relation to [Clause 8](#).

11.5.13 Flame protection and mitigation

No additional requirements in relation to [Clause 8](#).

11.5.14 Fire-fighting and extinguishing

No additional requirements in relation to [Clause 8](#).

11.5.15 Earthing and lightning protection

No additional requirements in relation to [Clause 8](#).

11.5.16 Emergency routing

No additional requirements in relation to [Clause 8](#).

11.5.17 Anti-collision

No additional requirements in relation to [Clause 8](#).

Special attention shall be paid to protect storage tanks of biogas or biomethane (e.g. liquefied biomethane).

11.5.18 Electrical, instrumentation & process control

No additional requirements in relation to [Clause 8](#).

12 Construction and testing

12.1 General

This clause describes occupational health and safety during construction, testing, commissioning and start-up.

The studies mentioned in this clause, such as risk assessments, are additional to studies mentioned in [Clause 7](#) (such as HAZOP).

12.2 Construction

12.2.1 Safety during construction

During design and prior to the start of the construction, risk assessment and evaluation (regarding occupational health technical aspects) shall be executed.

NOTE In many countries, it is mandatory to execute a risk assessment and evaluation (regarding occupational health technical aspects) because of national health and safety regulations.

For specific risks, additional task risk analysis shall be made by the involved workers and construction managers before the start of the activities.

During the construction phase the construction manager and the health and safety manager are jointly responsible for health and safety of all persons present on the site (whether employees or third parties).

A health and safety plan shall be present which describes responsibilities, communication lines and procedures about task risk analysis and working permits.

Weekly safety inspections are executed by the construction manager, health and safety manager and a representative of the client or the management team of the main contractor. A written report is made of this inspection, including a report of the follow-up of the actions of the previous inspections.

12.2.2 Prefabrication

For prefabrication, which is often done in a workshop or factory, the same health and safety regulations apply as on the construction site.

12.2.3 Construction on site

National regulations can apply in addition to the requirements given in [12.2.3](#).

12.3 Testing and commissioning

Before the start of the commissioning and the operation an additional risk assessment and evaluation shall be done. Specifically, the start-up of a biogas systems can cause specific safety risks. A list of preventive measures shall be part of the report. All the intervention and maintenance procedures shall be established before the commissioning of the plant. The same applies to the start-up and shutdown of all equipment. Before the commissioning starts, tests are executed of all individual electrical and non-electrical equipment, valves and instruments, especially of those located in explosion risk areas.

The preparation also includes a risk assessment and evaluation (RIE) to be held prior to commissioning. The RIE shall be kept current.

During the commissioning phase the commissioning manager and the health & safety manager are jointly responsible for health & safety of all persons present on the site (whether employees or third parties).

A health and safety plan shall be present which describes responsibilities, communication lines and procedures about task risk analysis and working permits. This can be the same plan as used during construction, possibly a paragraph about commissioning will be added.

Weekly safety inspections are executed by the commissioning manager, health & safety manager and a representative of the client or the management team of the main contractor. A written report is made of this inspection, including a report of the follow-up of the actions of the previous inspections.

12.4 Start-up

During start-up, the requirements for operations and maintenance (see [Clause 13](#)) apply. The plant manager is responsible for health and safety.

12.5 Requirements for commissioning and start-up of specific systems

12.5.1 Biogas production systems

Filling procedures for biomass or digestate in sealed tanks during commissioning or start-up (or re-commissioning or re-start-up) shall address functioning and pre-inspection of the over-under pressure release valves of storage tanks or digester tanks. The purpose is to prevent flexible gasholders or fixed cement roofs from collapsing or popping off.

Some systems may require inert purging using inert gas (e.g. nitrogen or CO₂).

Other requirement might follow from risk studies.

12.5.2 Biogas treatment, CHP, upgrading and liquefaction systems

PSSR (pre-startup safety review), instrumentation checkout, control loop testing, interlock testing shall be executed.

Other requirement might follow from risk studies.

13 Operations and maintenance

13.1 General

This document describes the requirements for operation, maintenance and handling of emergencies for:

- supplier of the biogas system;
- owner and plant manager of the biogas system;
- the service technician; and
- shut-down biogas system.

For maintenance of (parts of) biogas systems containing gas, a task risk analysis (TRA) or job hazard analysis (JHA) shall be made in collaboration with a trained and qualified person (for example a safety expert). Often these are derived from a risk assessment executed before. Furthermore, many companies use a system of work permits to make risks more transparent and manageable and to give work instructions. For regular maintenance for which a working permit is issued based upon a general TRA of JHA, it is not mandatory to do a TRA or JHA for each maintenance activity.

Confined spaces such as biomass and/or digestate storage facilities shall only be accessed by qualified persons. If there are mechanical hazards due to moving parts or system parts in confined spaces to be maintained, these shall safely be taken out of operation by lock out tag out before maintenance. When entering these confined spaces, the requirements of national working conditions regulations should be

taken into account. The confined spaces shall only be released for entrance after measurement of the absence of dangerous gases such as methane, hydrogen sulphide and CO₂ and the sufficient presence of oxygen. Furthermore, the wearing of independent breathing equipment (with respiratory air), the use of lining and personal gas measuring equipment (H₂S, CH₄, O₂ and CO₂) is mandatory, except when it is assured that sufficient oxygen is present and that the mentioned dangerous gases are completely absent and cannot enter the confined space. Before entrance and start of activities like cleaning and maintenance, the risks and how to act in case of emergencies shall be discussed with colleagues and other potential attendees. Furthermore, a task risk analysis shall be made and documented.

13.2 Supplier of the biogas system

The supplier of the biogas system provides the owner and the operator with the following documents:

- A user's manual: this contains instructions for the operation of the system by the user (also referred to as operations manual). The safe start-up, operation, maintenance and the decommissioning of the system are clearly described. A technical description of the system is included in this manual. The operation manual also optionally includes instruction manuals of the manufacturer of the individual parts.
- A maintenance manual for the user describes how the system shall be maintained by the user and when inspections shall take place. This manual also describes the maintenance requirements for the operator. Additionally, this document describes which activities are done by the operator and shall be done by a qualified service technician.
- A maintenance manual for the service technician which shows how the system can be inspected and maintained safely. This manual also describes the requirements for the required knowledge of the service technician.

These documents are at least written in a clear, concise and understandable way. This means that the documents shall be written in at least the national language and preferably also in the English language, in such way that the persons who need to understand can read the documents.

Also attention shall be paid to the requirements for use, maintenance and necessary action in case of an emergency, as described in this document.

Before start-up of the biogas system, the supplier of the system organizes a training about the operation of the system, the risks associated with the system and the emergency plan (including safety). It is recommended to test the emergency plan.

Upon commissioning of the system and before filling the biogas system (pipes, pipelines, vessels etc.) with biogas, the supplier of the biogas system shall execute a pressure test. The test pressure shall be a factor to be determined times the design pressure, which factor is depending on the applicable pressure (for example for pressure systems with a design pressure above 50 kPa a pressure test is often executed at 1,5 times the pressure). National legislation can apply for such pressure tests. A report shall be made with the results of the pressure test and an explanation how the test pressure is determined. For digester tanks, biomass and digestate storage tanks, and flexible gas storage facilities with flexible roofs such a pressure test is not possible and shall be agreed upon a different test at gas-tightness (for example, testing of overpressure), after consultation with the supplier.

13.3 System owner

The system owner and/or the plant manager (managing the plant on behalf of the system owner) shall have sufficient knowledge and experience to manage, supervise and/or operate a biogas system. The system owner and/or plant manager shall ensure that the EPD and the documents mentioned in the previous paragraph are present in digital and/or paper format in the control room or otherwise near the installation and readily available to plant operators.

The system owner, the plant manager and their staff shall conform with instructions described in the user manual and safety instructions.

The system owner shall make staff, visitors and potential neighbouring residents aware of relevant safety information.

NOTE Instructions on what to do in emergency situations are part of it.

The system owner and plant manager keep a log book registering any maintenance performed by the operator, staff or a service technician and the incidents which took place. If the supplier of biogas system (during maintenance or inspection) or the service technicians gives safety related instructions, this shall be documented in the log book.

For work on the system in safety-zone areas on (gas-side and non-gas-side) system critical components a work permit including TRA or JHA is required. Before working on the gas side part, the system has also to be made gas-free (inerted) and to be safeguarded and the wearing of personal gas detection (H_2S , CH_4 and O_2) is required.

The system owner and the plant manager shall keep a visual inspection tour of the plant on the basis of a checklist at least once a month. During this inspection shall be looked at occupational safety and compliance with this standard. The date, findings and follow-up of the inspection tour shall be recorded in a log book or report.

The system owner or plant manager shall visually inspect the pressure protection as often as necessary and described in the maintenance manual. If necessary, a service technician shall service the pressure protection in accordance with the maintenance manual listed in the previous paragraph, so it continues to function properly.

The system owner or plant manager shall define a maintenance concept and organize an inspection by a service technician at least twice a year. Such inspection includes at least an inspection for gas leakages and deterioration of materials. If the inspection reveals that maintenance is necessary for safe operation, the necessary maintenance shall be ordered to the service technician.

The system owner or plant manager takes action in response to warning signals from the electronic monitoring system, in the manner described in the relevant chapter on electronic monitoring.

The plant operator shall design the plant according to hazards (e.g. snow, rain, earthquakes). Therefore, it is mandatory to execute static calculations for important components, buildings and other safety devices. The plant operator shall protect safety devices from sabotage, e.g. by fences and other safety measures.

13.4 Emergency plan

The system owner is responsible to describe the emergency procedures, including the emergency escape routes and a list of phone-numbers of at least the system owner, the plant manager, the emergency services, the operator of the gas network (if applicable), the supplier, the service technicians, other relevant vendors, the fire brigade and the permit authorities. It is recommended to establish a scheme with people who shall be called in which situations. The system owner or plant manager shall ensure that the emergency plan is available in different parts of the plant.

NOTE An emergency plan drawn up by the supplier can be used as a basis because of the knowledge of the supplier and are complemented by the system owner or plant manager.

The supplier may provide specific system information for the emergency plan, for example specific risks and what to do in case of incidents and emergencies. In the emergency plan, it shall at least be described how to deal with failure of the system, power loss, fire, release of hazardous materials and the formation of foam. It concerns emergencies that the system will not get in safe mode (automatically) and an incident cannot be prevented by timely response to warning signals from the electronic monitoring system. For the actions as follow up of the electronic monitoring systems, refer to the instructions in [8.5](#), [10.7.6](#) and [11.5.4](#).

The emergency plan shall be tested on a regular basis by organizing emergency plan exercises.

13.5 Service technician

During maintenance and inspection, the service technician shall conform to the maintenance manual for the service technician. The service technician shall be qualified and shall have sufficient knowledge and experience on the type of system. The service technician can be an employee of the system owner, a supplier or a third party.

Prior to maintenance, elements of the system shall be blocked in to ensure that no gas or hot matter is present or can be released. Before opening the gas-carrying parts of the system, the parts shall be made gas-free by purging with an inert gas (for example nitrogen) and the parts can only be released after the measurement of the present gases. Subsequently the correct personal protective equipment (PPE) shall be used. The plant manager shall safeguard the system before the start of the work on the system. The same applies to the commissioning of the system prior to the start thereof.

When replacing the active carbon or another adsorbent the right PPE shall be used and the contaminated material shall be treated and disposed as hazardous waste or be recycled.

For monitoring and maintenance of pressure protection systems, it shall be ensured that the valves are not vented during inspection and maintenance. Before the start of maintenance on pressure protection systems, consider work permits, TRAs and special personal protective equipment.

The service technician carries out at least the inspections below with the indicated frequency.

- Because of the possible release of hydrogen sulphide, methane or CO₂ (parts of) the system shall be tested for pressure loss. This is done according to a frequency and method specified by the supplier of the system (but at least once every 10 years). For critical system components, such as safety valves, valves, connectors, tools, etc., the frequency will be higher and shall be tested at least once a year. This does not apply to the digester and biomass and digestate storage.
- Connections shall be checked for gas leaks, the frequency of this inspection shall be determined by a risk assessment.
NOTE This can be done by, for example, visual inspection, gas detectors, gas cameras, etc.
- The operation of a flare (if present) shall be tested at least once a year.
- Regular inspection of materials for safety guarantees.

13.6 Requirements for commissioning and start-up of specific systems

13.6.1 Biogas production systems

Emptying procedures for maintenance of biomass or digestate storage tanks and digester tanks shall address the risk of introducing oxygen inside the tanks and creating an explosive atmosphere until the tanks are refilled and until CO₂ has displaced O₂ in the gasholder. Before and during emptying, inerting is mandatory to avoid creating an explosive atmosphere. Similar to filling standard operating instructions the risk of collapsing fixed cement roof or tearing of the flexible membrane gasholder is present in case over-under pressure release devices are non-functional.

Filling procedures for biomass or digestate in sealed tanks after maintenance (re-commissioning or re-start-up) shall address functioning and pre-inspection of the over-under pressure release valves of storage tanks or digester tanks. The purpose is to prevent flexible gasholders or fixed cement roofs from collapsing or popping off.

Other requirements might follow from risk studies.

13.6.2 Biogas treatment, CHP, upgrading and liquefaction systems

Other requirements might follow from risk studies.

13.7 Requirements for shut-down of biogas system

In the case of a shut-down of a digester system, the supply of new input materials is reduced, the heating is switched off and the digester tanks are successively pumped empty. In order to avoid ex-zones, the potential explosive areas are adequately ventilated or inerted. The digester tanks and pipelines are rinsed with cold water and fully cleaned in order to avoid further biogas formation. In case entrance of tanks or other confined spaces is needed, specific working instructions regarding entrance of confined spaces apply, under which gas detection and respiration equipment is required.

When the biogas system is going to be offline for an extended period of time, shut-down shall be executed in accordance with shut-down procedures and the biogas system shall be maintained properly to keep the equipment and piping in a good condition to enable safe start up when necessary.

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Annex A (informative)

Explanation to the scope

Biogas is produced by making use of one or more of the following types of systems:

- biomass storage and preparation;
- biomass to biogas processes;
- anaerobic digestion;
- biogas and biomethane storage and management (including flares);
- biogas treatment: Biogas de-watering and cleaning (e.g. hydrogen sulphide and siloxanes);
- biogas to biomethane process:
 - upgrading
 - combined upgrading and liquefaction;
- biogas and biomethane applications:
 - raw material for chemical processes
 - transportation fuel (liquefied or compressed);
 - biogas combustion processes, as far as it concerns applications which are directly and specifically used for biogas:
 - boilers used for locally produced biogas
 - burners used for locally produced biogas
 - furnaces used for locally produced biogas
 - lighting by locally produced biogas;
- flares;
- combined heat and power (CHP) systems, such as:
 - micro gas turbines
 - fuel cells
 - gas engines;
- biogas and biomethane distribution: compression and pressure control systems;
- injection into the pipeline:
 - public grid;
 - private grid (e.g. raw biogas and treated biogas);
- liquefaction;

- re-fuelling stations;
- process and safety control;
- digestate storage and digestate conversion (separation of minerals) including manure conversion and conversion of sludge.

This document describes for information purposes as well:

- the parameters to determine the size (e.g. small, medium-sized, or large scale);
- the parameters to determine the type of system (e.g. household, industrial);
- the parameters to describe the type of technique;
- terms and processes in order to develop health, safety and environmental protection guidelines for biogas systems.

[Figures A.1](#) to [A.3](#) show the scope of this document in schemes. [Figure A.1](#) shows an example of the most simple biogas production process.

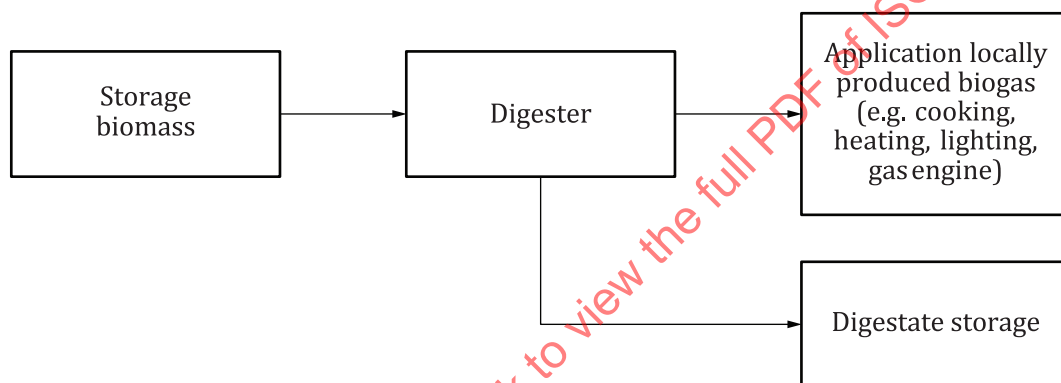
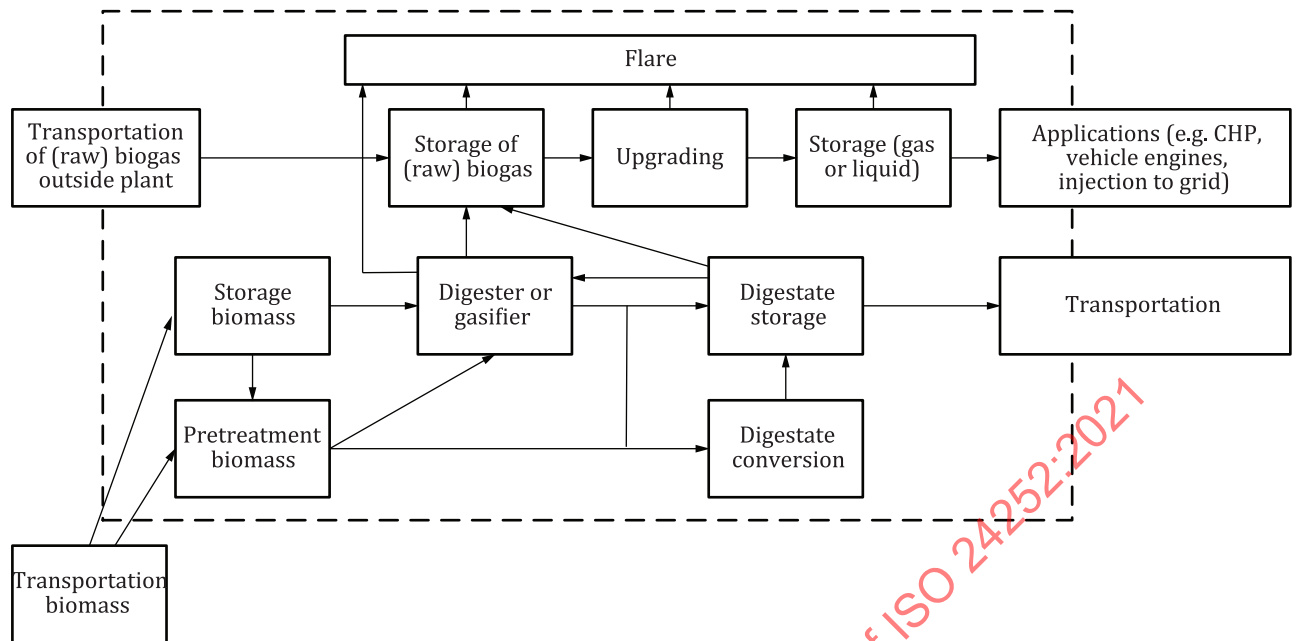


Figure A.1 — Scope of standard schematic overview: simple biogas production process

[Figure A.2](#) shows an example of a more complex biogas production process.



NOTE Not all process steps in this scheme are applicable, except for the process step “digester/gasifier”. All other boxes are possible pathways.

Figure A.2 — Scope of standard schematic overview: more complex biogas production process

Figure A.3 shows an example of the biogas production process based on power to gas from biomass.

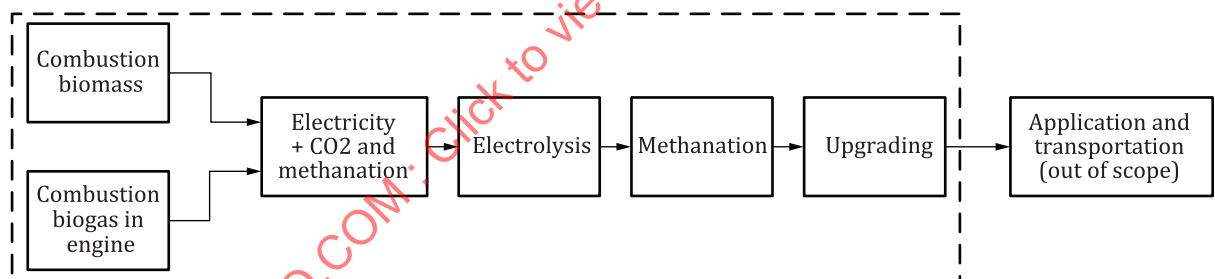


Figure A.3 — Scope of standard schematic overview: Power to gas from biomass source process

Annex B (informative)

Biogas characteristics, processes and classifications

B.1 Biogas and syngas characteristics

Biogas is produced by anaerobic digestion of biomass, meaning conversion of a part of the organic materials in biomass making use of microorganisms without the presence of oxygen.

The processes are described below.

Biogas consists for a main part of methane, carbon dioxide, hydrogen sulphide, nitrogen, oxygen.

Furthermore, contaminants like hydrogen sulphide, siloxanes, hydrocarbons and others are present. The percentages depend on the feedstock and the type of process. The caloric value of a normal cubic meter of methane is about 36 MJ per normal cubic meter.

Biogas properties can be described by:

- energy parameters such as kWh/Nm³ and/or Wobbe index;
- physical parameters like dew points, pressure, temperature;
- chemical parameters: chemical composition;
- biological parameters: Biogenic content, biological composition.

B.2 Description of the processes and the used technologies

B.2.1 General

For information purposes, a short description is given in this subclause regarding the most used processes and technologies mentioned in [Figure A.1](#).

B.2.2 Storage of biomass

Biomass is stored depending on its characteristics (solid or fluid; e.g. waste, sludge, manure) before it is led to the digester. Biomass can be stored in silos, storage tanks, basins.

B.2.3 Treatment of biomass

Biomass can be pre-treated with chemical, physical, thermal and/or biological methods in order to increase methane production when the biomass is digested. For example, it is possible to include hydrolysis as a pre-treatment step in order to speed up the process. Sometimes additives like enzymes or agents are added to the biomass (substrate) in order to improve the fermentation process.

B.2.4 Fermentation

The purpose of the fermentation process is to convert a part of the organic materials in the biomass to biogas making use of microorganisms. This process is anaerobic, without the presence of oxygen. The biomass can be solid or fluid and can be added batch wise or continuous flow.

A distinction can be made between psychrophile (0 °C to 25 °C), mesophile (25 °C to 45 °C) and thermophile (45 °C to 75 °C) fermentation. At higher process temperatures the fermentation process