0.4

BIOGAS PRODUCTION

Input materials	Pre-condition/Pre-treatment	Operation & maintenance needs	Description	Key technical parameters
Suitable organic waste: – Fish or meat waste – Vegetables/fruit peels – Animal manure **Unsuitable waste:** – Garden trimmings – Big chunks of woody materials – Feedstock with high salt content	Waste segregation at source Optional: shredding	Regular operation and maintenance required.	Anaerobic degradation of waste producing biogas, which can be used as fuel, and digestate.	Process time: 10-40 days Mass reduction: None (or 20% total solids (SOWATT) Space: 100-530 m2/t*d SOWATT
Outputs / products	**Technical complexity**	**Maturity level**	**Educational aspect**	
Biogas, combustible gas (mainly CO_2, CH_4) Digestate	Higher-level skill required for appropriate design of infrastructure Higher-level skills required on construction (gas-tight) Medium-level skills required regarding O&M	Proven technology globally Experience with application may vary depending on country	**Topics:** Anaerobic processes, Organic degradation, Microbiology, Emissions calculations, Renewable energy, Nutrients recovery **Practical exercises:** pilot example with balloon	

Anaerobic digestion (AD) is a microbiological process through which organic materials are biochemically decomposed while generating biogas and nutrient-rich digestate. Biogas is a mix of methane (CH_4), carbon dioxide (CO_2) and other trace gases, which can be converted to heat, electricity or light. The AD process occurs in absence of oxygen in airproof reactor tanks called digesters.

The AD process is common to many natural environments, such as swamps or the stomachs of ruminants [1].

A wide range of different biomasses can be used as substrates for biogas production. AD feedstock includes sewage sludge, animal manure, food industry waste (incl. slaughterhouse waste), energy crops and harvesting residues (incl. algae), and the organic fraction of municipal solid waste [2]. Usually, feedstock of with high moisture content (> 60% water content) can be processed without pre-treatment.

The main products of AD are biogas and digestate. The biogas is a combustible gas mainly composed of methane (CH_4) and oxygen dioxide (CO_2). Apart from CH_4 (55–60%) and CO_2 (35–40%), biogas also contains several other gaseous "impurities", such as hydrogen sulphide, nitrogen, oxygen and hydrogen. The energy value of biogas derives from the contained methane and shows typical lower heating values (LHV) for biogas of 21–24 MJ/m³ or around 6 kWh/m³.

Directly burning biogas in stoves is the easiest way of taking advantage of biogas energy. The produced slurry (digestate) is rich in nitrogen.

The AD process is only partly able to inactivate weed seeds, bacteria, viruses, fungi and parasites and depending on if sewage sludge is used as feedstock, a treatment is necessary to be able to use it as fertilizer.

Applicability: Biogas digesters can be used at different scale and with different use of technology mechanization. They are particularly applicable in rural areas where animal manure can be added and there is a need for using digestate as fertilizer and gas for cooking. Biogas reactors are less appropriate for colder climates (< 15°C) as the rate of organic matter conversion into biogas becomes very low. Even though biogas reactors are watertight, it is not recommended to construct them in areas with high groundwater tables or where there is frequent flooding [3].

Design considerations: Biogas reactors can be built as fixed dome, floating dome or tubular digesters (also called flexidigester). In the fixed dome, the volume of the reactor is constant. As gas is generated it exerts a pressure and displaces the slurry upward into an expansion chamber. When the gas is removed, slurry flows back into the reactor. The pressure can be used to transport the biogas through pipes. In a floating dome reactor, the dome rises and falls with production and withdrawal of gas.

The hydraulic retention time (HRT) in the reactor should be at least 15 days in hot climates and 25 days in temperate climates. This means the size of the reactor should be able to contain 15-20 days of waste volume (incl. water if required). For highly pathogenic inputs, a HRT of 60 days should be considered. Sizes can vary from 1,000 L for a single family up to 100,000 L for institutional or public toilet applications. Because digestate production is continuous, there must be provisions made for its storage, treatment, use and/or transport away from the site [3].

Materials needed: A biogas digester can be made out of bricks, cement, steel, sand, wire for structural strength (e.g. chicken wire), waterproof cement additive (for sealing), water pipes and fittings, a valve and a prefabricated gas outlet pipe. Prefabricated solutions include geo-bags, reinforced fiber plastic modules, and router molded units and are available from specialist suppliers [3].

Operation & maintenance: To start the reactor, it should be inoculated with anaerobic bacteria (e.g. by adding cow dung). Once running, waste needs to be added regularly (ideally daily) else the bacteria will starve. Digestate needs to be removed from the overflow frequently and will depend on the volume of the tank relative to the input of solids, the amount of indigestible solids, and the ambient temperature, as well as usage and system characteristics. Gas production should be monitored and the gas used regularly. Water traps should be checked regularly and valves and gas piping should be cleaned so that corrosion and leaks are prevented. Depending on the design and the inputs, the indigestible materials accumulating at the bottom of the reactor should be emptied and the reactor cleaned and checked every 5 to 10 years.

Health and safety: The digestate is partially sanitised but still carries a risk of infection, therefore during digestate removal, workers should be equipped with proper personal protective equipment (PPE). Depending on its enduse, emptied liquid and digestate require further treatment prior to use in agriculture. Cleaning of the reactor can be a health-hazard and appropriate safety precautions (wearing proper PPE, ensuring good ventilation) should be taken. There are also dangers associated with the flammable gases but risks are the same as natural gas. There is no additional risk due to the origin of the gas [3].

Costs: This is a low to medium cost option, both in terms of capital and operational costs. However, additional costs related to the daily operations needed by the digester need to be taken into consideration. Community installations tend to be more economically viable, as long as they are socially accepted. Costs for capacity development and training for operators and users must be budgeted for until the knowledge is well-established.

Social, legal, and environmental considerations: Social acceptance might be a challenge for communities that are not familiar with using biogas or digestate. Social cohesion can be created through shared management and shared benefits (gas and fertiliser) from Biogas Reactors, however, there is also a risk that benefits are unevenly distributed among users which can lead to conflict [3].

If the digester is not gas-tight, there is a risk of methane leakages which is a greenhouse gas contributing to climate change. Also, digestate has an organic load (COD) 5 times higher than regulations for discharge into surface water. Digestate may contain pathogens and should not be used directly on crops without prior treatment nor directly discharge into the environment without appropriate treatment.

Strengths and weaknesses:

- (+) Generation of useable products like gas and fertilizer
- (+) Small land area required (if structure sis built underground)
- (−) Requires expert design and skilled construction
- (−) Incomplete pathogen removal, the digestate might require further treatment
- (−) Variable gas production depending on the input material and limited gas production below 15°C
- (−) Medium level investment cost

> References and further reading

1. Zabaleta, I., et al., Selecting Organic Waste Treatment Technologies. SOWATT, Eawag, Editor. 2020.
2. Lohri, C.R., et al., Treatment technologies for urban solid biowaste to create value products: a review with focus on low- and middle-income settings. 2017.
3. Gensch, R., et al., Compendium of Sanitation Technologies in Emergencies. 2018.

Vögeli et al. Anaerobic Digestion of Biowaste in Developing Countries. 2014

MOOC Youtube videos:

- *MOOC Mod.3.7 The Basics of Anaerobic Digestion of Biowaste*
- *MOOC Mod. 3.8 Anaerobic Digestion Technologies and Operation*
- *MOOC Mod. 3.9 Using the Products of Anaerobic Digestion*