

Biowaste to Biogas

BIOGAS Know-how_1

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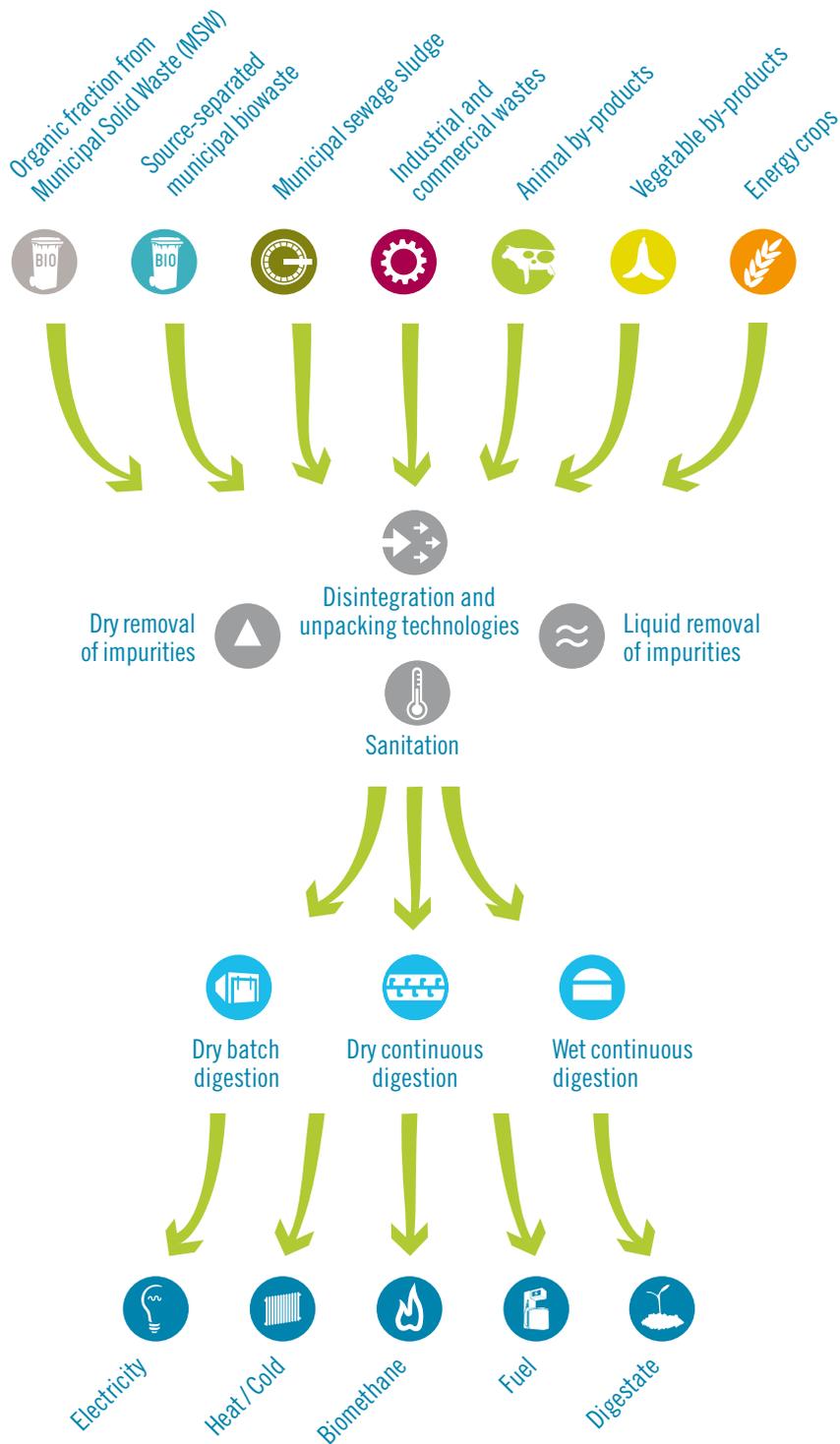


Fachverband
BIOGAS

German Biogas Association
www.biogas.org

BIOWASTE TO BIOGAS

The production of energy and fertilizer from organic waste



The depicted symbols are used repeatedly throughout the brochure and as a classification system of the different companies in the directory.

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Statements



'A future-oriented and sustainable energy supply is possible only if the particular advantages of each kind of renewable energy source are combined in an optimal way. Biogas offers flexibility: it can be used when wind or sun are not available. And the opportunities for biogas are manifold: it provides power, heat, fuel and fertilizer from organic resources – regional, reliable and climate friendly. Biogas is the way forward!'

– **Horst Seide, President of the German Biogas Association**



'Energy is a fundamental part of sustainable development. From a development policy perspective biogas offers many advantages: from the creation of jobs and provision of decentralised clean energy to rural development and the reduction of greenhouse gases. By improving solid waste management practices, substantial co-benefits can be provided, such as minimising threats to human health and better resource efficiency.'

– **Dr Christoph Beier, Vice-Chair of the GIZ Management Board**



'Biogas is the link between renewable energy, circular economy and waste management. It is also one of the few ways to portray the tangible benefits of circular economy to citizens, as organics' closed loops are primarily local. Finally, it's a great tool to fight energy poverty involving communities and develop decentralised waste management options. This brochure demonstrates the advances and challenges of biogas technologies, and I hope it will improve the recycling of organic waste due to biogas projects worldwide.'

– **Antonis Mavropoulos, President of the International Solid Waste Association**



'Around the globe, countries are trying to identify sustainable climate solutions. Biogas clearly represents one of these solutions, thanks to the energy independence it provides along with numerous other benefits. Anaerobic digestion contributes to setting up a circular economy, as it has three distinct purposes: it produces gaseous bio-fuel that substitutes fossil fuels, balances the nutrient cycle through bio-slurry as organic fertilizer and provides a waste management solution that allows biogenic waste to be reduced instead of being discarded. Biowaste-to-biogas has clearly become an essential method of sustainably meeting the ever-increasing demand for energy.'

– **Gaurav Kumar Kedia, Chairman of the Indian Biogas Association**

Preamble

The use of biogas technology has increased tremendously over the last fifteen years, especially in Germany. By the end of 2017, nearly 9,500 of the around 13,400 European biogas plants were located in Germany. They are digesting municipal and industrial biowaste (688 plants), manure, other agricultural residues, as well as energy crops (12,721 plants). When also counting plants based on landfill and sewage gas, the number amounts to a total of 17,783 European biogas plants.

These 9,500 biogas plants supply around five percent of Germany's gross electricity production with over 4 GW installed electrical capacity. They also provide households, industries, farms and other buildings with heat. Furthermore, around 450 upgrading plants in Europe transform biogas into valuable biomethane, which can be used in all the same ways as natural gas, also as transport fuel. Besides renewable energy, biogas plants produce highly valuable nutrient and humus-rich fertilizer, making biogas technology a real all-rounder.

By 2019, around 400 waste digestion plants in Germany were using **biowaste as feedstock** and, in that year alone, some 135 of these plants used a total of two million tonnes of source-separated organic waste from households. Globally, biogas production from waste is on the rise and it may become the most important waste management and energy production system in developing countries and emerging economies.

Given that interest in and the need for **biogas technology deployment** is currently rising in many countries, this publication by the German Biogas Association is timely. It is undoubtedly the case that plenty of organic waste and residue is currently available for such uses, but they often go unexploited. Left to degrade in an uncontrolled way, these materials instead end up emitting methane and, in so doing, have a negative impact on climate change.

This brochure provides an introduction to biogas technology that uses waste as feedstock, setting out how it is used and its various applications. It covers, among other things, a description of the biological process, the different ways to efficiently use biogas, a comparison of the energetic potential of different feedstock, and its handling and preparation. The brochure further provides an overview of the common digester technologies in use and tackles the safety issues involved in operating biogas plants.

Partners of this publication are the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the International Solid Waste Association (ISWA) and the Indian Biogas Association (IBA), who promote biogas production from different waste streams, share the experience gained in installing integrated waste management systems, and add their voice to the debate, especially on the role of biogas in **developing and emerging countries**.

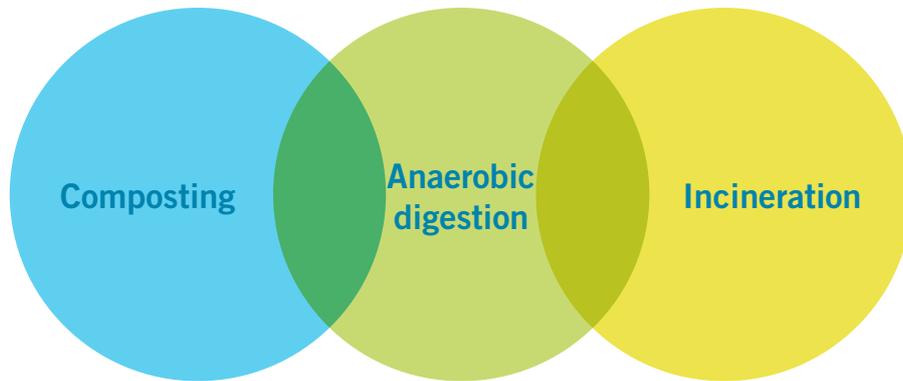
In the second part, this brochure contains several **reference plants** and a **directory of experienced companies** that include turnkey system providers, project developers, manufacturers of feedstock preparation systems, component producers, and other services in the field of anaerobic waste digestion.

This brochure aims to contribute to safer and more efficient biogas plants that use different kinds of organic waste feedstock to produce organic fertilizer, electricity, heat or biomethane (which can also be used as vehicular fuel). Decades of experience with thousands of professionally operated biogas plants prove that this is state-of-the-art technology. Therefore, stakeholders do not need to start from scratch. If biogas projects are to be successful and the market is to be developed, it is vital to create partnerships with the companies and organisations that promote and deliver biogas projects, and to exploit their wealth of know-how and experience.



1 Introduction

This brochure focuses on biogas production from different waste sources such as municipal biowaste collected by households, as well as industrial and commercial operations, sewage sludge and waste in the form of animal and vegetable by-products.



Though **energy and fertilizer production** are central aspects of biogas technology, in many countries these are not the most relevant ones. Especially in countries struggling with overfilled landfills, biogas is an interesting technology to help solve the problem of municipal organic waste in cities, and to avoid contamination from industrial and commercial effluents.

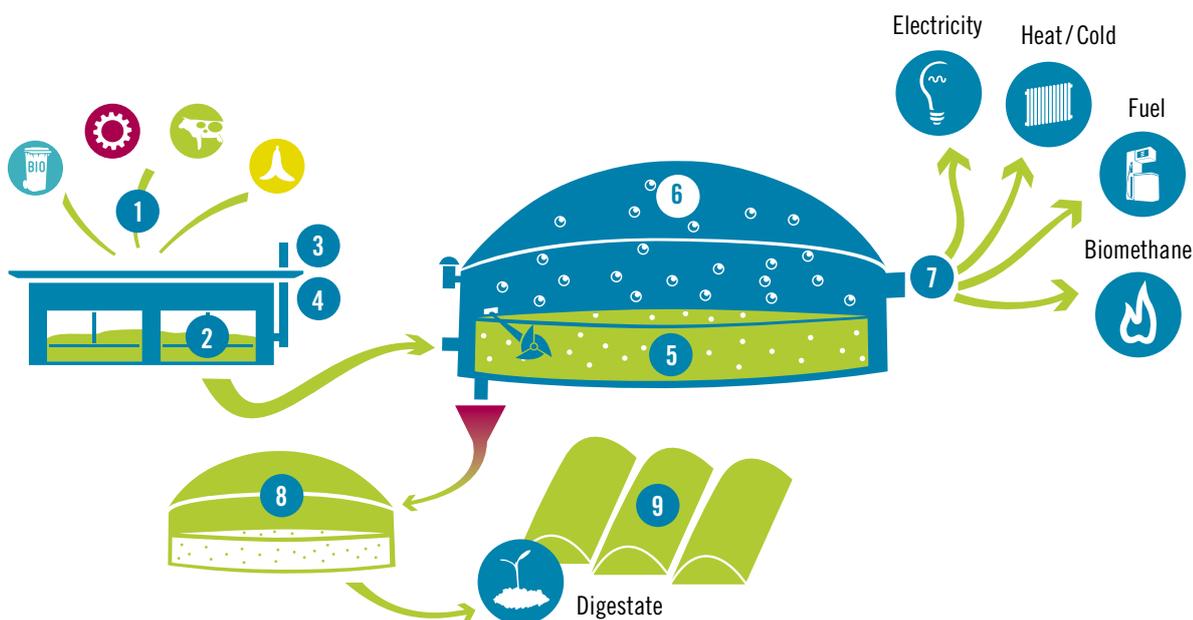
Composting offers the possibility to recover nutrients from organic waste but not energy, and incineration of this waste leads to an energetic recovery, but the nutrients are not recycled, because the remaining ash usually has to be landfilled. Anaerobic digestion constitutes both nutrients and energy recovery from organic waste. This makes anaerobic digestion an advanced recycling

Biogas plant producing renewable energy and fertilizer for agricultural areas



and waste treatment method with multiple benefits according to the European Waste Framework Directive. In this brochure, the diversity of biogas technology will be explained step by step, from the inputs (feedstock) to the different kinds of usages as energy and fertilizer. Nevertheless, an overview of the components used in a waste treatment biogas plant is introduced here already:

Components of a waste treatment biogas plant



Different types of feedstock **1** can be used to produce biogas, including municipal biowaste, industrial and commercial waste, as well as animal and vegetable by-products (see Chapter 3: “Possible feedstock”). Depending on the feedstock used, liquid feedstock is stored in tanks while stackable feedstock is most likely stacked in buildings specially built for this purpose **2**. The latter is often the case for biowaste and other digestible waste. The enclosed building should have an air collection system **3**, and offer housing for other pre-processing steps inside. Additional biofilters **4** help reduce smells coming from organic compounds.

The anaerobic digestion process takes place in the digester **5**. In Chapter 7. “Digester technology”, different types of digesters are introduced and further explained. Gas tight storage **6** is a fundamental part of a biogas plant and it is often situated on top of the digester or as external, independent unit nearby. Before using the biogas in a Combined Heat and Power (CHP) plant, for example, the gas has to be cleaned

from sulphur compounds and water; this is done in the gas cleaning system **7**. After this step, the biogas is ready to be used in a CHP plant or to be further upgraded in a biomethane plant (see www.biogas-to-biomethane.com). The digestate, on the other hand, is collected in separate storage **8** in order to be applied afterwards. It is also possible to upgrade the digestate by separating the solid and liquid phases, drying, pelleting and composting it **9**. Water can be extracted by vacuum evaporation or membrane filtration and nutrients can be extracted by precipitation or by stripping the digestate or exhaust air with acid washers. This adds value and facilitates transportation (see www.digestate-as-fertilizer.com).

Finally, there are safety measures, and equipment should be implemented in order to prevent damage to human beings and the environment. These measures can be simple organisational measures or more complex technical ones (see www.biogas-safety.com).

2 Advantages of waste digestion

The anaerobic digestion of organic waste and vegetable or animal by-products, offers many advantages. In this context, the conservation of fossil resources, avoidance of greenhouse gas emissions (GHG) and the associated climate protection should be mentioned in particular.

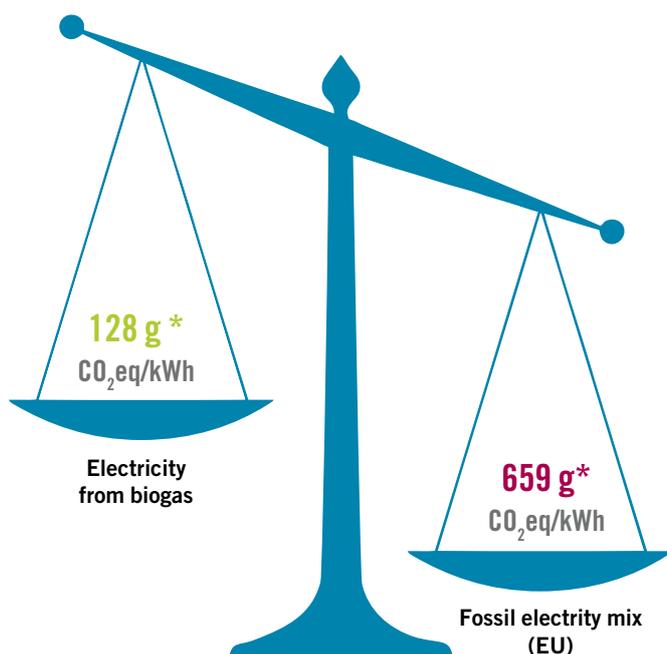
The separate collection of biowaste **decreases residual waste** and thus the required capacity of waste incineration plants and landfills. Additionally, further organic waste can also be digested and biogas can be produced. In this context, biogas technology offers a distinct advantage as it makes it possible to store energy in the form of biogas or biomethane and produce **electricity on demand**. Moreover, biogas is a perfect solution for decentralised off-grid electricity situations, especially in rural areas that are not connected to the electricity grid, but have an abundance of biomass. In developing countries, biogas is often directly used for cooking, heating or gas lighting.

potash fertilizers is enormously important as these are finite resources. The content of cadmium and uranium are high in mineral fertilizers and are already considered to be problematic.

Furthermore, biogas production substantially **reduces greenhouse gas emissions (GHG)** by substituting fossil energy carriers and energy-intensive mineral fertilizers, and it avoids the emission of methane (CH_4) into the atmosphere that results from the storage of digestible organic material like manure or organic waste (e.g. in landfills, open lagoons or other types of storage). Biogas is an almost carbon-neutral form of energy generation because as plants grow, carbon dioxide (CO_2) from the atmosphere is taken up by plants and stored in form of carbon containing molecules (CO_2 reduction). After combustion, the same amount of CO_2 that was originally taken in from the atmosphere is emitted again (CO_2 neutral process).

In Germany, for example, nearly 2 million tonnes of CO_2 are avoided each year by digesting organic waste. The average carbon footprint of a German citizen is around 10 tonnes per year. Through waste digestion, the emissions of nearly 200,000 inhabitants can be neutralised accordingly. Other countries have higher as well as lower carbon footprints. In India, for example, each person generates less than two tonnes per year approximately. Although the various organic waste and by-products used in biogas plants have different energy contents, about 150 kg of CO_2 per tonne of digested biowaste can be avoided on average. That means, the biogas production from about 10 tonnes of biowaste saves the GHG emissions of one citizen in India.

Emissions from waste digestion and fossil fuels



Besides **renewable energy**, biogas plants produce highly valuable **nutrient- and humus-rich fertilizers**. All the nutrients contained in the feedstock remain in the post-processing digestate, which can be used as a fertilizer or soil improver in agriculture, landscaping and horticulture. In this way, the carbon and nutrient cycles are closed. Digestate and composts are important humus sources for preserving soil fertility, structure, activity, respiration and water retention and protecting against erosion. In comparison, mineral fertilizers do not build up humus in the soil. The substitution of phosphate and

* Data of the graph are based on the directive (EU) on the promotion of the use of energy from renewable sources (RED II)

3 Possible feedstock

The feedstock for biogas plants is made up of all kinds of organic material that can be degraded anaerobically by microorganisms. Additionally, the cleanliness and purity of the feedstock defines the quality of the output of the digester (digestate), and with this, the requirements on preparation and application possibilities of the digestate.

A vast variety of organic waste and residue are suitable for use as feedstock for biogas production. Among others, the water content and degradability of the biowaste are particularly important factors when choosing the right preparation treatment. For example, catering waste and other digestible wastes that may be too wet and lack structure for composting, are actually excellent feedstock for anaerobic digestion. That said, not every kind of organic material can be degraded in a digester. One of the main limitations of the biogas process is its inability to degrade lignin (a major component of wood), which is something that can be accomplished with aerobic degradation processes (composting).

In this brochure, possible feedstock is categorised into municipal biowaste (separately collected or technically separated) and sewage sludge, industrial and commercial wastes, animal by-products including liquid and solid manure, as well as vegetable by-products. Especially in Germany, energy crops, such as maize and whole crop silage, or wild plant mixtures, also play an important role as feedstock for biogas plants. However, this brochure focusses on waste digestion, thus energy crops will not be further regarded. The indicated symbols for each feedstock are used consistently throughout this brochure and facilitate the identification of plant concepts, even though the classification cannot always be 100% accurate, because e.g. slaughterhouse waste might be animal by-products and industrial waste at the same time.

Feedstock categories

-  Organic fraction from Municipal Solid Waste (MSW)
-  Source-separated municipal biowaste
-  Municipal sewage sludge
-  Industrial and commercial wastes
-  Animal by-products
-  Vegetable by-products
-  Energy crops



Municipal Solid Waste (MSW) arises in private households and public places. The **organic fraction from MSW** consists mainly of organic components like food waste from kitchen and plates, or garden and park waste like grass and bush cuttings. It can be technically extracted and cleaned with screens, air separation and metal deposition (see chapter 5: “Feedstock preparation”) for further use in biological treatment (composting, anaerobic digestion). In countries where fertilizer (compost, digestate) is produced from organic fraction, a strong separate collection for hazardous waste should be implemented to exclude harmful substances from MSW.



In most central and northern European countries, the production of fertilizer is only allowed if this organic fraction is separately collected as **Source-separated municipal biowaste**. This is usually collected by household bins or containers placed in the public areas, in combination with bins, sacks and containers for paper, glass, plastics and other waste fractions (see chapter 4: “Municipal waste collection”). Refuse teams empty the bins or containers into lorries and bring the collected biowaste to a biogas plant. Garden and park waste is often collected at collection points or brought directly to the biological treatment facility. In most European countries digestate from the treatment of municipal biowaste is post-composted, although in some (northern) countries the direct use of liquid digestate is also common.



Besides solid waste, waste water is also collected from households, introduced and transported in the sewer system to the waste water treatment plant (WWTP). **Municipal sewage sludge** from the different cleaning steps of the water treatment can also be used for biogas production in digesters in the area, or the WWTP or in decentralised plants, also in mixture with different feedstock to receive higher biogas yield. In each case, legal requirements have to be kept in mind, which can be very different for municipal biowaste, sewage sludge and animal by-products. This could be because of the potential presence of antibiotics (from the use of medication), hormones and non-biological substances in the sewage system.

 Organic residue from food, beverages or feed production, including catering waste and expired food e.g. from retail markets, are designated as **industrial and commercial waste**. Liquid waste, sludge from industrial processes and preconditioned catering waste can be collected and transported in tanks. Kitchens and canteens also collect catering waste in bio bins, while supermarkets tend to use containers. This feedstock often has a high biogas yield and is very attractive for anaerobic digestion, although depending on package and impurity, higher effort on unpacking and preparation are necessary (see chapter 5: “Feedstock preparation”).

 **Animal by-products (ABP)** are divided into three categories by the European animal-by product regulation (No 1069/2009). Category 1 material presents specific risks to the health of farmed and wild animals as well as humans and using it in biogas plants is not allowed. Manure, including excrement or urine of farmed animals and horses, digestive tract content, colostrum etc. is designated as category 2 material. The digestion of manure contributes to the reduction of GHG emissions not only due to renewable energy production, but mainly by the reduction of CH₄ emission from open storage. Category 3 materials include slaughterhouse waste and by-products from food processing like fat separator contents, flotation tailings etc. as well as other animal by-products like feathers, hairs, wool, whey, eggs, eggshells, blood, skin, etc. Category 3 material has to undergo pasteurisation at 70°C for 1 hour when used in a biogas plant and subsequently as fertilizer.

 Agriculture generates a broad range of **vegetable by-products** like straw or harvest residues, which can be used in biogas plants and provide additional biogas yields at almost no extra cost. Its usage can contribute to process stability when the main input of the biogas plant is nitrogen-rich feedstock like animal by-products, because it reduces the ammonia content, and, therefore, the danger of ammonia inhibition. In addition, brewers' grains, old bread, starch, molasses, husks, fruits and vegetables, spoiled feed silage etc. are classified as vegetable by-products.

The **characteristics of the feedstock** used and how it is mixed, have major impacts on the biogas process and biogas yield. If clean biodegradable feedstock is used, it is possible to apply the digestate as organic fertilizer or soil improver in agriculture. If the quality of the digestate cannot be ensured, it must be disposed of in landfills or incinerated.

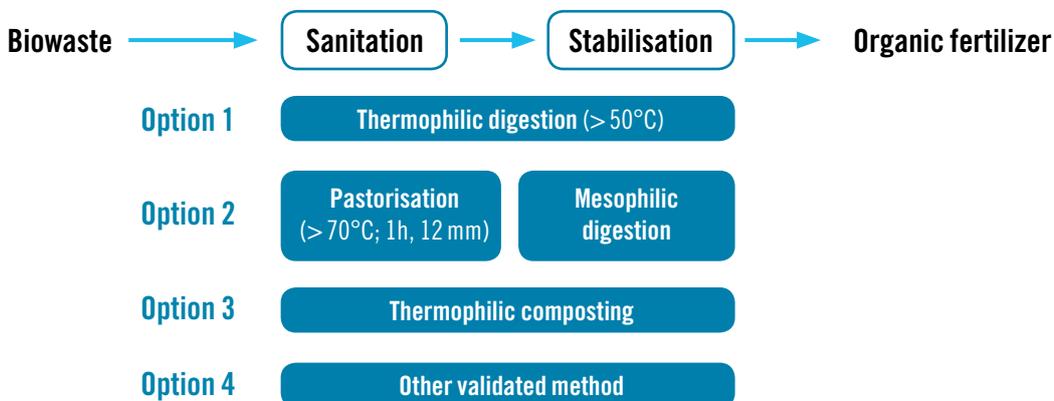
 Most types of biowaste and animal by-products (except manure and some vegetable by-products, which in practice can be spread directly) need to be **sanitised** to eradicate or reduce animal and plant pathogens, or unwanted seeds to acceptably low, sanitary levels. This can be carried out using a full-flow pasteurisation unit, which heats material to over 70°C for one hour. The material (or part of it, if only certain input streams need to be sanitised) can be pasteurised either prior to processing in the digester or after the digestion process. Other possibilities are thermophilic digestion (using temperatures higher than 50°C) if it can be ensured that each particle is heated for at least the retention time of the process, a post-composting step or other methods like liming or damping. Whatever approach is employed, the biological activity in the biogas process will significantly reduce pathogens already at lower temperatures. As stated previously, it is only when complete sanitation is required that either longer retention times or higher temperatures are necessary. Besides sanitation, the anaerobic digestion process additionally guarantees the **stabilisation** of biowaste as an important step to reduce odour, CH₄, laughing gas (N₂O), and other emissions.

The **methane yield** of each feedstock depends on its composition and how much protein, fat and carbohydrate it contains. For example, the high proportion of carbohydrates found in stale bread provides a very high



Vegetable waste delivered at the biogas plant

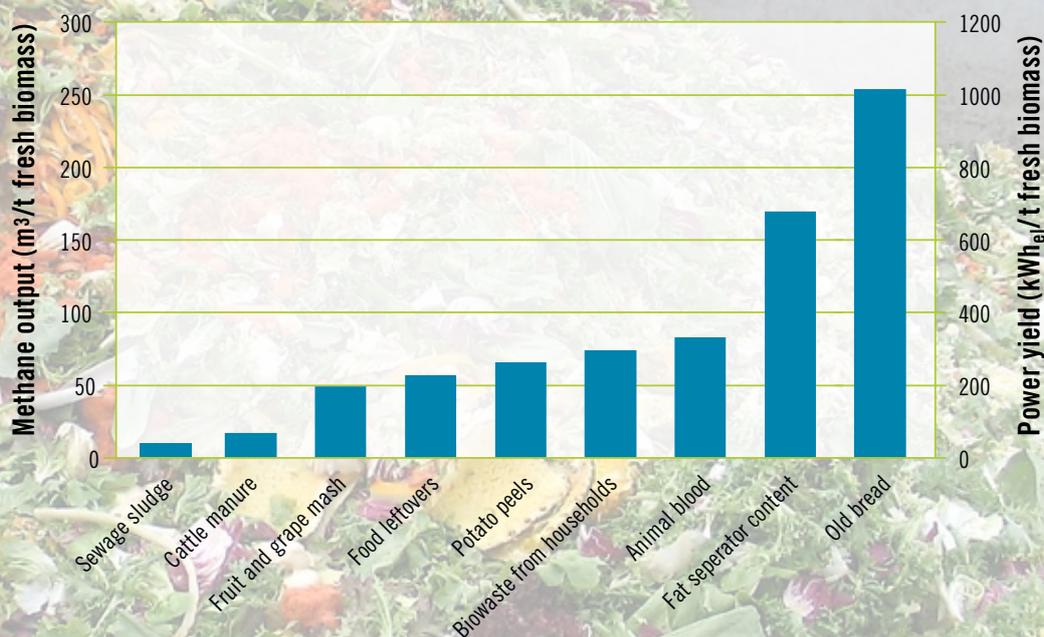
Different methods to sanitise biowaste



CH₄ output per tonne of fresh biomass. Feedstock composition therefore significantly influences the viability of a biogas plant. Conversely, certain feedstock can have a negative impact on the microbiology in the digester. Material with high protein content, such as rape-seed cake, could lead to increased concentrations of hydrogen sulphide (H₂S), which is harmful for biogas-generating microorganisms, machinery and toxic to humans. As such, it is essential to monitor how different types of feedstock have an impact on the composition of gases. In conclusion, feedstock is one of the most important parameters in a biogas project (biologically

and technically). A constant feedstock supply has to be ensured, it determines the technology used and it has a huge influence on the economy of a biogas plant and their associated costs such as collection, transportation, handling, and gate fees, fee-based for those depositing material at the facility. The biogas yield of the feedstock does, however, have an economic value, due to the energy that can be generated from it. Therefore, the whole plant concept should be based around the feedstock it intends to use.

Energy yield for possible feedstock



4 Municipal waste collection

Biowaste collection from households and commercial activities are key to providing feedstock for the biogas process. This chapter gives municipalities and stakeholders the basic elements to correctly structure separate collection schemes aimed at maximising capture rates of biowaste and minimising the impurities.

In the EU, biowaste represents 39 % of all MSW, or approx. 175 kg per capita and year on average; these amounts include both food waste (or kitchen waste) originating from households, restaurants and other catering activities and biodegradable garden and park waste, such as leaves, grass, trimmings, etc. On a global perspective, and in lower income countries, biowaste ranges between 40 % and 65 % of MSW, thus, representing the main fraction to be managed, and also the main contributor to GHG emissions and leachate production at landfills. Waste that cannot be digested or that has a negative influence on the quality of the digestate disturbs the process. Hence, the separate collection of biowaste and its diversion from disposal to recycling represents an obvious win-win situation that allows reduction of MSW disposal, to mitigate GHG emission and to produce renewable fuel (biogas in case of anaerobic digestion) and an organic fertilizer (digestate and/or compost).

EU countries apply different approaches to **collect biowaste separately** and these divert a range of organic

materials towards recycling. For the purpose of producing biogas from biowaste by means of anaerobic digestion, collection schemes, which are able to limit the amounts of bulky, dry garden waste, are generally preferable, since the liquid and fatty content of food waste results in larger biogas production per tonne of fresh matter. Nevertheless, the choice of the specific collection scheme does depend on the final decision of local authorities and MSW companies.

A first source of biowaste in cities is commercial activities of the hotel/restaurant/catering sector; separate collection is relatively easy and consists of equipping each user with one or more wheeled bins exclusively for biowaste and planning convenient frequencies for collection. This approach obtains relatively high amounts of biowaste at a limited number of so-called big producers. As an example, the City of Hamburg (Germany) collects about 22,600 tonnes of organic waste per year (t/a) from commercial activities, representing less than 3 % of all MSW. But the largest producer-group of biowaste in a city or municipality is families. Hence, it is important to design the collection scheme so as to avoid any inconvenience and encourage households to participate in source separation. The City of Milan (Italy) collected about 103 kg per capita of food waste, including the amounts collected from the commercial sector, a total of 140,000 t/a.

The first step and challenge for local authorities organising biowaste collection from households is to make **the separation task easy at home**. Schemes aiming to collect significant amounts of food waste from households use collection tools that are tailor-made to needs in order to intercept highly moist and digestible putrescible waste. Nowadays the standard tools are kitchen baskets (6 – 12 litre) to be used with watertight bags. The small size of the basket stops households delivering bulk impurities (e.g. bottles, cans), while vented kitchen baskets additionally reduce the production of leachate



Separate collection of foodwaste in Milan



A kitchen basket for food waste collection with paper bag



A kitchen basket for food waste collection with a bioplastic bag

and prevent attraction for insects. Watertight bags make it possible to even collect meat and fish scraps along with vegetables and fruit residue, whilst keeping the basket as clean as possible.

Experiences in Europe show that the combined use of vented kitchen baskets and compostable biobags significantly increases the amounts of biowaste collected and reduces impurities such as plastics, metal and glass as shown in the table:

Examples of successful cases that increased biowaste collection by using kitchen baskets in combination with compostable biobags

City of Milan (Italy)	The city has been collecting food waste from households since 2012; families use vented kitchen baskets and compostable plastic shopping bags; separate collection in 2017 exceeded 100 kg per capita with impurities below 5% fresh matter.
City of Kassel (Germany)	The city tested vented kitchen baskets together with compostable bags, resulting in 23% increase of biowaste (and a reduction of impurities of 56%, which was mainly a result of substituting PE bags with biodegradable bags.
City of Sligo (Ireland)	The provision of educational tools, compostable bags & kitchen baskets to households doubled the participation and reduced the contamination levels from 18% to 1%; one year later, the contamination level was still as low as 3%.

Regarding the **types of bags to be used** with kitchen baskets, do not use plastic bags (including oxo-degradable), since these materials tend to clog biogas plants, fragment during the process and may end up as impurities in the digestate. **Compostable** bags made of **paper or bioplastic** are widely used in separate collection schemes for biowaste in many EU countries; yet compostable bioplastic bags are not designed to completely disintegrate during anaerobic digestion, thus they may

end up as rejects of the recycling process in biogas facilities without composting. This can be overcome in biogas facilities that include aerobic post-treatment of digestate (composting), thus, obtaining a complete disintegration of these bags during the aerobic treatment process.

Step two is the selection of a collection scheme that **avoids co-mingled collection**. There are two main approaches for collecting biowaste: Bring schemes and Kerbside collection as shown in the table on the comparison of two types of collection schemes for biowaste. Bring schemes usually use large volume containers placed on the roadside where waste producers deliver their biowaste; these systems cannot check the quality of the waste delivered and, due to anonymity, no feedback to the generators may be available. Kerbside schemes usually equip each household with a type of bin according to specific biowaste production and are scaled to the number of households in the case of apartment blocks. Among the two schemes, **Kerbside collection is usually preferable** since the scheme intercepts larger quantities of biowaste with a lower content of physical impurities.

With Kerbside schemes, collection should be more frequent in summer or during the hot season. Additionally, biowaste collection should always be more frequent compared to residual waste; both measures will result in a more “user-friendly” scheme for households and improve the rate of participation.

The last step is to implement **user guidance and control procedures**. The start-up of a collection scheme for biowaste should always include an awareness campaign, so that waste producers are informed about how to sort biowaste correctly, which collection tools should



Green waste collection as bring scheme directly on the composting plant



Plastic should not be thrown into biowaste bins

Different measures to monitor the quality of biowaste collection for biowaste

Tools	Kitchen baskets and compostable bags	Visual inspection by collection crew	IT detection with electronic tools
Where	Inside the kitchen	Applied to collection with buckets and/or wheeled bins	Applied to collection with wheeled bins only
Actions	Enhances user friendliness	Labelling, feedback, no emptying	Labelling, feedback, no emptying
Costs	Basic (for baskets) Optional (for bags)	Low-cost, based on collection crews or "waste-Inspectors"	High-cost, applied to wheeled bins only

Comparison of two types of collection schemes

Bring schemes	Kerbside collection
Collect a mix of food and garden waste	Can collect food waste-only waste
Logistics are basic	Logistics are complex and more labour-intensive
Impurities cannot be checked and may become critical	Impurities can be controlled and reduced
Lower quantities collected	Higher quantities collected

be used and how often and when the waste will be collected. User guidance should include tools such as calendars for collection, info-leaflets, dedicated web-sites and other tools such as mobile APPs or social network communication.

Levels of physical impurities beyond 5–8% of fresh matter (according to the type of pre-treatment applied before entering the biological process) can negatively affect the correct processing of biowaste at biogas plants, resulting in a loss of biogas production and an increase of rejects that need to be disposed of. Hence, it is advisable that collection companies always apply control procedures to monitor the level of impurities that are collected with biowaste and give feedback to waste producers about errors in sorting. In the following table, different measures to **monitor and control the quality** of biowaste collection are suggested. The free distribution of the appropriate collection tool represents the starting point to enhance participation of households; but procedures for non-compliance situations should also be in place for buckets or bins that contain physical impurities such as glass, plastics and/

or metals. It is important that each user gets feedback about non-compliances. This can be done visually by labelling the bins, leaving the bins unemptied and, in the worst cases, exclude the bins from the collection scheme and apply fines to the households.

Organising a separate collection scheme for biowaste usually requires rethinking the current MSW management scheme of a city or town; technical support can be found at regional or national biogas and/or composting organisations and a significant amount of technical literature about the topic can also be found online (for example, at www.giz.de or www.iswa.org).

In **lower income countries**, the initial investment for equipping households with collection tools such as buckets, bins and bags may be perceived as a limiting factor by local authorities; but these costs should always be considered in connection with the avoided expenditure along the full "supply chain", thus including the effects of the choice of separate collection on the facilities that will recycle biowaste into biogas, into compost or into both.



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- Biomethane
- Biowaste digestion
- Use of digestate as fertilizer
- Security
- Best practice in Europe
- Best practice worldwide
- Innovations



Presentations in German or English
or with simultaneous translation

5 Feedstock preparation

In order to prevent malfunctions in the digestion process and produce high-quality digestate or compost, materials like plastics, glass, paper, metals, stones or oversized components must be removed. To do this, liquid as well as dry removal of impurities can be improved prior, during or after the digestion process in efficient disintegration, preparation and separation stages.

The **quality of input material** is of the utmost importance, especially if the intention is to use the produced fertilizer in agriculture, horticulture or landscaping. It is essential to prepare an optimal feedstock mixture, to ensure operating conditions remain stable, to obtain the best possible biogas yields and to maintain the intended lifespan of the equipment and machinery. Clean feedstock from controlled sources, such as industry or agriculture, is therefore optimal for the biogas process and the quality of the digestate and compost produced. Other biowaste is not always free of non-biodegradable or unsuitable materials and contaminants. Expired food from supermarkets, for example, might still be packaged in glass, plastic or cardboard containers. Catering waste might contain cutlery or bones. As explained in the previous chapter, source-separated biowaste from households can be a particularly challenging feedstock, because its purity depends on the motivation of individuals to properly separate waste at source and not throw inorganic materials (such as batteries or yoghurt pots) into biowaste bins. The quality of this kind of biowaste, therefore, varies considerably according to a number of factors including social structure, education, location (rural or urban) and population density. Hence, public education and a control of waste bins is the first step to control the quality of collected biowaste. Nevertheless,

Waste lorry is unloading biowaste into the bunker



Disintegration and unpacking technologies



Liquid removal of impurities



Dry removal of impurities

there will always be environmentally conscious people who will unintentionally throw away objects properly (e.g. brand-new garden shears), so that controls at the plants will always be necessary.

For the **technical removal of impurities**, different solutions are available depending on the input material, its consistency and the kind of impurities contained. In this brochure, the following symbols for disintegration and unpacking technologies, as well as liquid and dry removal techniques, are used to facilitate the identification of relevant manufacturers of feedstock preparation systems in the company directory. The removal of impurities might happen before, during or after the biological biogas process.

The efficiency of every method depends on technical equipment, energy consumption and the share of impurities separated. Together with the removed impurities, organic compounds are also separated, which have to be disposed of (for example by incineration) and are not used for biogas and digestate production anymore. But even MSW can be prepared to generate a suitable feedstock for anaerobic digestion as also demonstrated in the reference plants, even if the use of the produced digestate and compost is legally not allowed in every country.



The first stage in the preparation process usually involves **disintegration and unpacking technologies**. The aim is to reduce particle size, to remove packaging and to generate a more homogenous material for the digestion process. This can be achieved by squeezing, cutting, milling or shredding the material. During disintegration, light material like plastics can be blown out. Presses and paddles help free the organic material from packaging by applying pressure or centrifugal force through a screen. This approach can

also be used with hydro-mechanical pulpers where the feedstock is broken down and light impurities float to the surface, while heavy impurities sink to the bottom of the pulper similar to sink-float separation, which is described next.

 Technologies for **wet removal of impurities** are applied if the biowaste is delivered in liquid form or if solid biowaste has to be broken down into small particles and mixed with water, recirculated processed water or other liquids for wet digestion. Removing impurities minimises the downtime required to de-silt the digester by opening it and maintaining an effective working volume. Heavy material like stones, bones and sand can be removed through sedimentation in large basins, containers, sand traps, pulpers or directly at the bottom of the digester with scrapers. Grit and sand can be removed using sand traps or hydrocyclones with higher centrifugal forces.

With sink-float separation, light material such as textiles and plastic foils emerge to the surface, where they can be removed. This can also be achieved during the digestion process by skimming plastic foils from the surface of the digester content. By pressing liquid biowaste through a screen, a clean organic fraction can be produced, for example, with separation, screw or piston presses. Small-sized impurities like plastics can easily be removed with separation presses, drumming or curved screens, which achieve high cleanliness depending on the size of the holes. Sieves or presses should be designed as full-flow removal steps at the back end of the process as an end-control for the produced digestate to achieve high-quality fertilizer without relevant impurity content being placed on the market as fertilizer.

 Technologies for the **dry removal of impurities** are implemented to clean and condition the prepared feedstock with an appropriate biowaste content. The removal of oversized components, wood and physical contaminants can be carried out by screening the feedstock (e.g. in rotating drums or stars). Screens are also used to clean and prepare the produced compost into a defined fraction depending on the size of the holes of the sieve (e.g. 0-15 mm). The desired compost fraction depends on further use, customer wishes or mixing with gardening soil. In cases where the anaerobic digestion step is less sensitive to impurities (normally dry digestion processes), instead of a disintegration step, only a sack opener with cutters is installed, in order to avoid cutting plastic foils into small pieces, which is more difficult to remove after the biological process. As a result, impurities may be concentrated in oversized grain captured during the screening of compost. Fractions that are too polluted cannot be used as fertilizer and will need to be disposed of in an alternative way, such as incineration. Light material like plastic foils can be blown out using air separation. Metals



Overlaid yogurt and milk drink still packaged



Fruit waste collected with its plastic packages

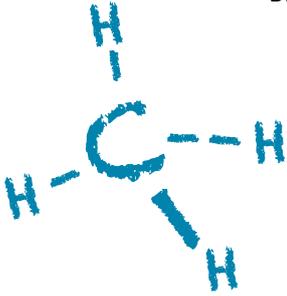
are removed with magnets combined with conveyor belts. Eddy current separators induce an alternating magnet field on nonferrous metals which are offloaded in a different trajectory as other material. Other physical properties like rolling and bouncing, as well as using sensors to identify colour, form and material in combination with air jets, can be used for the technical separation. For heavily heterogeneous biowaste, such as that from households, sorting units can be installed where (human) operatives often work along a conveyor belt, picking out unwanted material.

Ensuring the **quality of the fertilizer**, its cleanliness and absence of contaminants and harmful impurities (e.g. sharp objects), is paramount when it comes to marketing the product and fostering public acceptance of biogas technology as a waste treatment option. To create this kind of clean end-product, a combination of both high-quality feedstock with low content of impurities, and the application of appropriate technologies for treating each kind of impurity are essential. This can be strengthened and controlled by quality assurance systems as used on a European level and most member states (see www.ecn-qas.eu).

6 Production of biogas and digestate

Biogas production is based on a very natural process that can be observed in moors and swamps, for example, but also in the digestive tracts of animals, especially the cow's rumen. When organic matter is decomposed by microbiological populations in the absence of free oxygen (anaerobic digestion), high-caloric methane and an organic fertilizer is produced.

Biomethane



Biogas technology makes use of the natural process whereby organic material like biowaste, food leftovers or manure are transformed by different groups of microorganisms in anaerobic (i.e. oxygen-free) situations into methane (CH_4) and digestate. Depending on the type of feedstock that is used, the CH_4 content of biogas fluctuates between 50% and 70%. The second most abundant component is carbon dioxide (CO_2), which makes up between 30% and 45% of biogas. There are also small quantities of other components such as water, oxygen, traces of sulphur compounds and hydrogen sulphide.

Four successive biochemical processes are involved in the production of biogas. In **hydrolysis**, complex and long-chain compounds of feedstock, such as carbohydrates, proteins and fats, are broken down into lower molecular weight organic compounds such as amino acids, sugar and fatty acids. The hydrolytic microorganisms involved release hydrolytic enzymes that decompose the material biochemically outside the microbial cells. In **acidogenesis**, the above-mentioned intermediate products are then transformed into lower fatty acids like propionic acid, butyric acid and acetic acid as well as into CO_2 and hydrogen, which are by-products of the degradation process. In acetogenesis, acetogenic bacteria then convert the propionic and butyric acid into

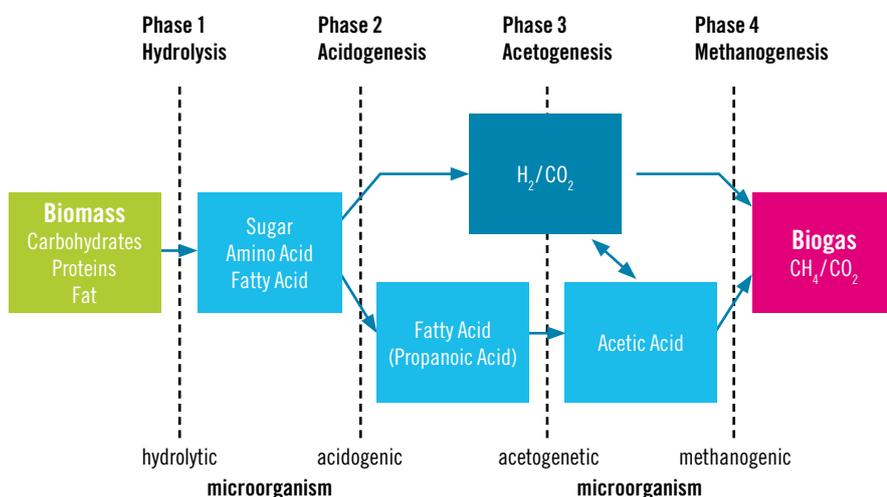
acetic acid, hydrogen and CO_2 , which are the basic materials for CH_4 production. Finally, with methanogenesis, archaea, which are some of the oldest life forms on earth, produce CH_4 by combining the hydrogen with the CO_2 or by cleaving the acetic acid.

Usually, the four processes mentioned above take place at the same time in a hermetically sealed and stirred unit, the so-called digester. The biochemical processes involved are, however, performed by different kinds of microorganisms and each requires different conditions for optimal growth. To create optimal conditions for the different species, the processes can be performed in separate vessels. For example, some biogas plants have a separate hydrolysis tank to prepare biowaste for actual digestion. In this tank the temperature, oxygen content and pH value are optimised for hydrolytic microorganisms, whereas the conditions in the main reactor are optimised for the methane-producing archaea.

Temperature is one of the most crucial factors in biogas generation. A distinction for different operating temperature levels is made between psychrophilic (less than 25°C), mesophilic (from 35°C to 48°C) and thermophilic (greater than 50°C) process conditions. One advantage of low temperatures is that the amount of heating energy that needs to be added to the process is reduced, but the velocity of the reaction is very low.

This leads to lower biogas yields, or a much longer retention time is needed. When digesting waste and animal by-products, higher temperatures also play a particularly important role in neutralising harmful germs, as previously explained. Changing temperatures can, however, destabilise the biogas process and diminish or stop the activity of the microorganisms involved. Other factors can also hinder CH_4 production: for example, high concentrations of free ammonia that soon inhibit the bacteria because the chemical reaction of ammonia and water generates ammonium and hydroxide ions inside the digester, especially at higher pH values. Continuous monitoring of the relevant parameters is therefore essential to prevent problems occurring during plant operation.

Process description



7 Digester technology

The digester is the main component of a biogas system. A number of the technologies available on the market are suited for processing biowaste. Making the right choice depends on the feedstock and the local conditions.

Choosing appropriate technologies depends on many factors, such as the availability and characteristics of the feedstock, its quantity and quality, dry matter content and need for sanitation, energy use and incentives (e.g. feed-in tariffs) and local energy demand, gate fees charged for incoming material, transportation conditions, the intended end-uses of the digestate, operators' skills and knowledge, local climate conditions, and, of course, the financial resources available.

There is no general rule for identifying the best technologies so, before developing a plant, it is essential to get expert advice on the selection of the most appropriate technology. For general guidance, several of the most common options are briefly summarised in this chapter. The technologies and components adopted must be robust and reliable so that the overall system is durable, delivers a high level of performance and is designed to

ensure safe operation. Operator know-how, and good co-operation among all those involved in the biogas project (e.g. the project planners, manufacturers, construction companies and operators) are therefore important factors for delivering a successful biogas project.

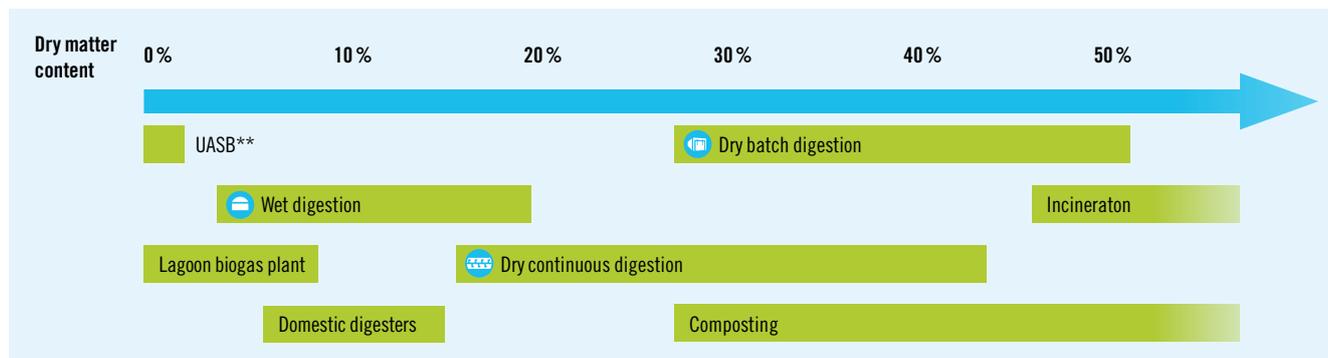
The digester is the main component of a biogas system. In the digester, micro-organisms convert organic material, the feedstock, into biogas. The most important feature of the digester is to provide optimal growing conditions for the microorganisms and, in doing so, to strive for high biogas yields. Biogas systems tend to be categorised according to the type of digestion process they use:



Characteristics of different digester technologies

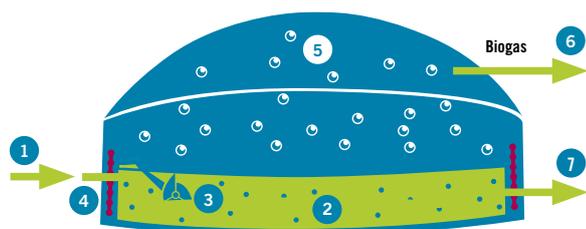
	Feeding	Temperature	Agitation	Feedstock	Reliability	Climate
Wet continuous digestion	Continuous	Mesophilic or thermophilic	CSTR with agitators, hydraulic digester without agitators	Easy pumpable, used for different feedstock	Impurities may cause technical problems	Worldwide, no limitation
Plug-flow reactor	Continuous	Usually thermophilic, but mesophilic also possible	Along or transverses to the flow, vertical systems without agitators	Pumpable, mainly used for municipal biowaste	High tolerance to impurities	Worldwide, no limitation
Garage system	Discontinuous	Usually mesophilic, but thermophilic also possible	No agitators, percolation liquid distribution	Stackable, mainly used for municipal biowaste	Robust reactor without moving parts	Worldwide, no limitation
Lagoon biogas plant	Continuous with long retention time (> 100 days)	Ambient temperature	Usually no agitation	Liquid, typically used for process or waste water	Impurities may cause technical problems	Warmer latitudes like tropical regions
Domestic digesters	Almost continuous	Ambient temperature	Usually no agitation	Locally available biowaste, manure, agricultural residues	Impurities should not enter the process	Temperatures > 10°C

Overview of technologies depending on dry matter content for the possible operating mode*

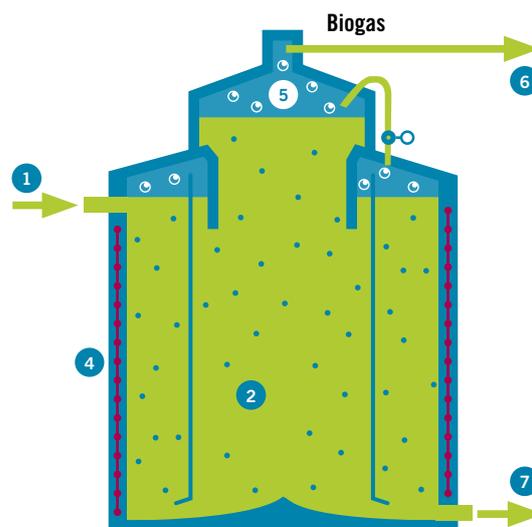


*Almost all feedstocks can be diluted to the needed dry matter content of each digester technology.
 **UASB: Upflow anaerobic sludge blanket technology is a form of anaerobic digestion designed for materials with high water content (e.g. waste water or process water treatment).

Continuously stirred tank reactor (CSTR)



Hydraulic digester



- 1 Input 2 Biomass 3 Agitator 4 Heating system 5 Biogas storage 6 Biogas utilisation 7 Output

7.1 Wet continuous digestion

The most suitable feedstock for **wet digestion** is liquid biowaste such as industrial and commercial wastes or manure. Nevertheless, every feedstock can be wet digested after preparation and dilution with process and recirculation water, or other liquid biomass. Municipal biowaste, in particular, has to be preconditioned because of its heterogeneity, higher percentage of oversized components (e.g. wood) and impurities. The digester is insulated and heated up to mesophilic or thermophilic temperatures to allow best living conditions for the microorganisms. The liquid biomass is stirred inside the digester to bring the feedstock into contact with the microorganisms, to avoid sinking or floating layers and to allow the heat to be dispensed from the heating system into the whole digester volume.

As the digestate is liquid after the digestion, it can also be used to dilute solid feedstock. If a post-composting step is wanted, the digestate has to be separated. Liquid digestate can be spread directly as fertilizer on agricultural areas.

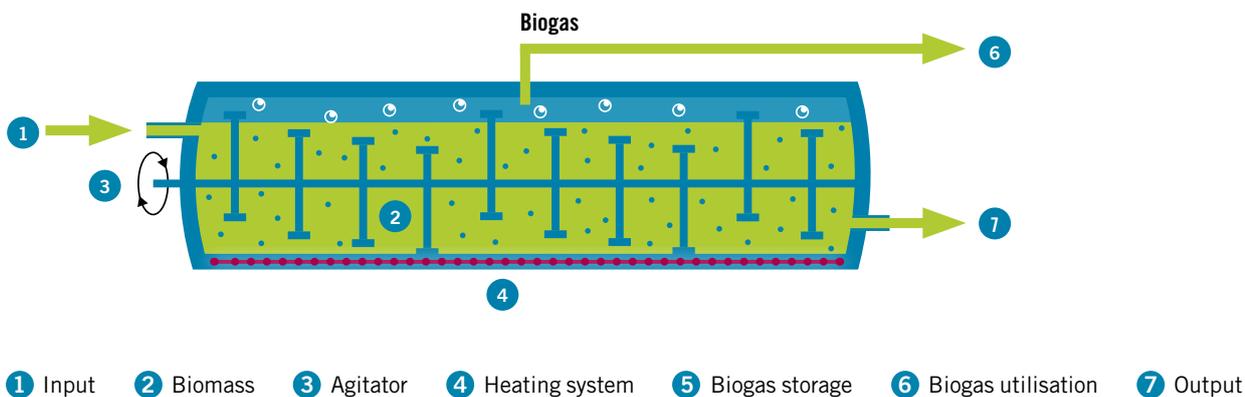
In **Continuously Stirred Tank Reactors (CSTR)**, the material is fed in (quasi)-continuously, with several charges every day. The dry matter content of the feedstock ranges from below 5% up to 15%. Inside the digester, the material is liquid, thus, it should be pumpable. The process can be single or multi-staged (i.e. with a separate hydrolysis tank). One or more main digesters, a

post-digester and digestate storage usually need to be installed.

CSTR is the most commonly used digester technology for agricultural plants. It is a simple but robust technology that can deal with a wide range of possible feedstock. Almost any tank size can be used as long as a mixing process can be carried out. In practice, the size limit of single tanks is thousands of cubic metres. If more reactor volume is needed, several modules of tanks, working parallel or in row, can be constructed.

In **hydraulic digesters**, the material is fed in (quasi)-continuously. Practically any kind of feedstock can be digested, if it is liquid enough to flow. The dry matter content of the feedstock ranges from 6% up to 16%. The digester is constructed in two compartments. Most of the biogas is produced in the main compartment. Due to higher pressure, caused by the biogas production, the liquid biomass in the second compartment is lifted up. When the valve between the chambers is opened, the liquid flushes down unleashing high kinetic energy. Baffles transfer the flush with an agitative effect. No mechanical agitators are required and there are no moving parts inside the reactor. This leads to low electrical consumption of the biogas plant and low maintenance costs. The process temperature is mesophilic or thermophilic. Typically, the tanks are heated up to provide optimal temperatures for the microorganisms.

Plug-flow reactor



 7.2 Dry continuous digestion

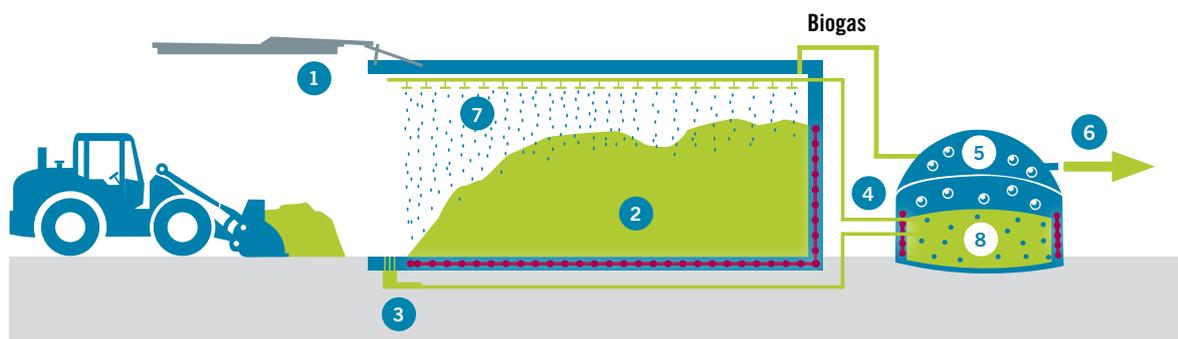
Dry continuous digestion takes place in plug-flow reactors. This concept allows the biomass to be slowly transported (horizontally or vertically) from the inlet to the outlet. Thus, all particles are processed with the same retention time as they pass through the reactor, although some shortcuts are possible, depending on the feedstock and inner construction. Vertical plug-flow digesters operate without agitators, but use gravity and pumps for mixing biomass. To ensure optimal processing conditions, horizontal plug flow digesters are equipped with very robust stirring technology, which operate along or across the flow of the material.

The material is fed in (quasi)-continuously. Suitable feedstocks are practically all kind of organic material that can be digested, but the technology is predestined for heterogeneous municipal biowaste. The dry matter content of feedstock ranges from 15% up to 45%. A high reactor load is possible. Reactor volume is usually limited to between 1,000 and 2,250 cubic metres because of the strong radial forces involved. However, several reactors can be operated in parallel. The process temperature is often thermophilic, but mesophilic is possible as well.

The digestate can be separated, while the solid fraction is normally post-composted and the liquid fraction spread as fertilizer, used for recirculation or sprinkling of the compost.



Garage systems



 7.3 Dry batch digestion

Dry batch digesters are mainly developed as **garage systems**. The feedstock is processed in batches that remain in the digester for a defined retention time, typically for about one month. Afterwards, the digester is emptied and refilled with the next batch. The digestate can be post-composted without a separation step. New incoming feedstock is inoculated with the solid digestate from the previous process which is mixed inside the garage. Leachate from the drainage system is recirculated as percolation liquid and sprayed on the feedstock to inoculate the feedstock with bacteria and to improve contact between the degrading biomass.

The material flow is discontinuous. Feedstock and digestate is moved in and out of the garage using a wheel loader. Feedstock needs to be stackable and thus to contain a large amount of structural material. This technology is adapted for feedstock, with dry matter content higher than 30%. There are no moving components in the reactor, which means the reactor is robust, operations are reliable and maintenance costs are low.

-  Gastight door
-  Biomass
-  Drainage system for percolation liquid
-  Heating system
-  Biogas storage
-  Biogas utilisation
-  Percolation liquid distribution
-  Percolation liquid storage tank

The biogas yield might be lower than that of stirred systems. Since the feeding of the feedstock is done manually, more personnel work is required in comparison to automated systems. The system for distribution of the percolation liquid ensures optimal water content. The process temperature is mesophilic or thermophilic. A minimum of three digesters are required to equalise the gas production level.

7.4 Other digester technologies

The most relevant and often used technologies in Europe have already been introduced. However, in many countries other technologies are also used. Two additional types will be briefly introduced here.

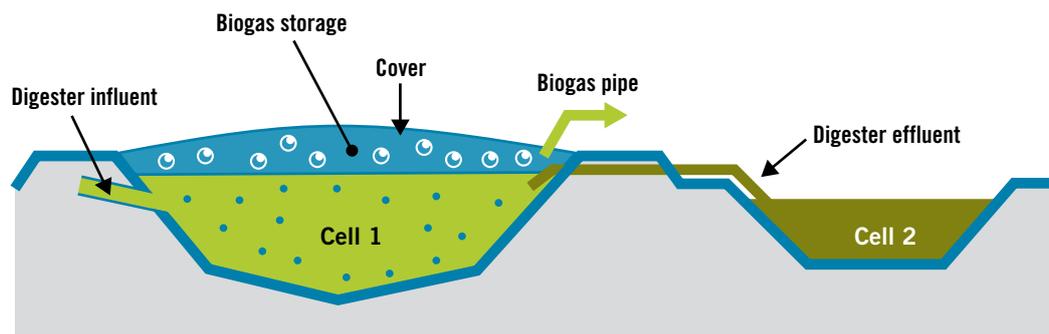
In many emerging economies and developing countries **lagoon biogas plants** are very common. Effluents of industrial processes or farms (e.g. waste water and process water, manure and other effluents) are traditionally stored in open lagoons, which threaten the environment by emitting CH₄ emissions into the atmosphere, and nitrate emissions to soil and ground water.

To face this problem, these lagoons are often covered with a plastic membrane, often a high-density polyethylene (HDPE) membrane to create a simple biogas plant. However, this solution presents some technical

deficiencies, because it is difficult to fix such a big surface of plastic membrane to the ground to prevent it from blowing away. Furthermore, by covering the lagoon, potential emissions to the soil and underground water cannot be avoided. Lagoon biogas plants can have volumes of up to several hundred thousand m³, which makes it difficult to stir the liquid contained in it effectively and efficiently, if not practically impossible. Heating up the lagoon to optimal temperatures is challenging as well. Typically, lagoon biogas plants are operated at an ambient temperature which results in lower and seasonal biogas yields and huge volumes to reach high retention times.

Nowadays, it is possible to operate lagoon biogas plants safely and efficiently, equipping them with mixers and a heating system. However, these increase the invest-

Lagoon biogas plant



ment costs and is only technically possible to a certain point (stirring and heating huge volumes is very challenging).

A **domestic digester** is another form of biogas technology mainly characterised by its size. The daily input is only a few kilogrammes of feedstock (often the amount produced for one or a small group of households). The amount of biogas produced is low, only a few m³ per day. The reactor volume is usually only a few m³, up to 100 m³. The technology is relatively inexpensive and simple. The mechanical parts (if there are any at all) are usually very simple, robust and not electronically driven. The reactor is usually not heated or stirred, therefore, the retention time must be high to allow sufficient biogas yields.

There are three types of domestic digesters:

- ▶ Plastic bag digesters. Feedstock is fed into a plastic bag. Biogas is produced inside the bag. The gas storage is usually made in the form of an external balloon. Advantages: relatively robust, gas- and liquid-tight, corrosion-resistant material.

- ▶ Floating drum digesters. Consists of two drums that are put inside each other. The floating drum indicates the amount of gas stored.
- ▶ Fixed dome digesters. The advantage is that it can be made of local material, e.g. bricks. The disadvantage is that gas tightness (CH₄ emissions!) and corrosion resistance is questionable.

The feedstock used should be liquid or at least diluted (e.g. manure or foodstuff which is diluted in the reactor), free of bigger particles (e.g. no branches of trees). Waste that might be contaminated with pathogen bacteria should not be used because domestic biogas plants don't have a sanitisation unit.

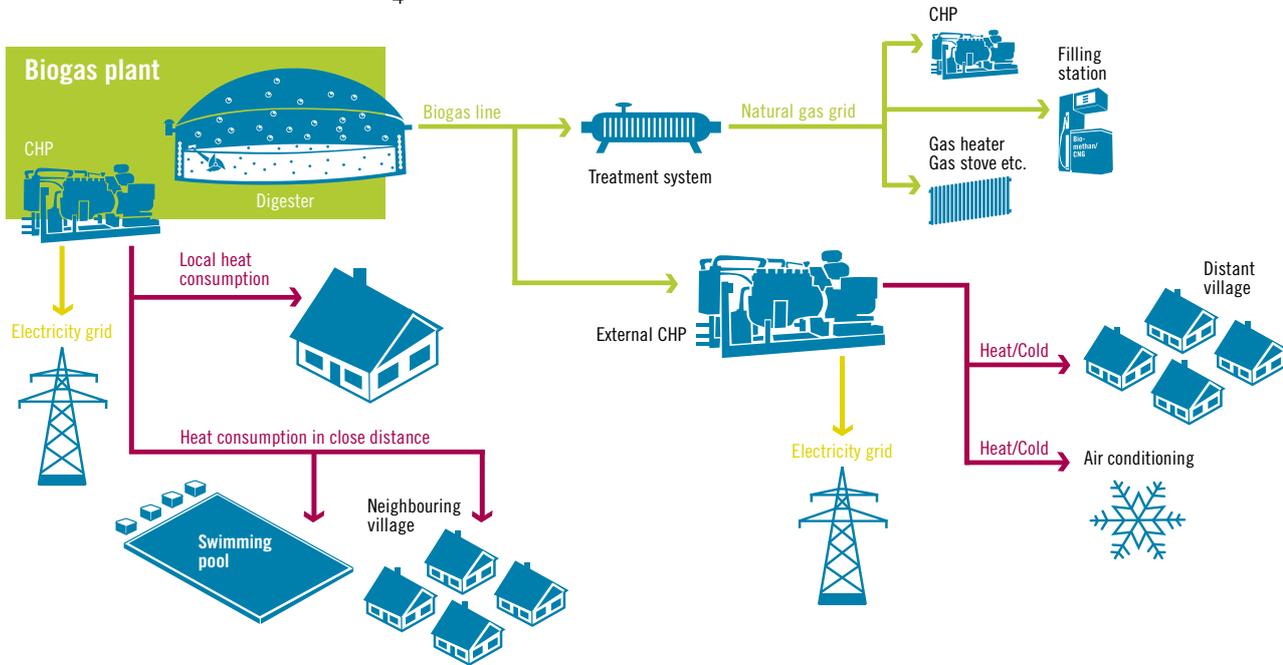
Usually, the biogas is burned in a household stove for cooking. Lightning is possible as well. Small-scale biogas plants produce too little biogas to generate electricity in an economically feasible way. Construction and operation are relatively simple. However, as with industrial plants, knowledge and clear responsibilities are key for a long-term operation.

Floating drum digester in India



8 Biogas use

Among renewable energy technologies, biogas is the genuine all-rounder, providing electricity, heat, gas and fuel for gas-powered vehicles. This flexibility is achieved through the production of a primary energy source, namely CH₄.



The production of CH₄ during the anaerobic digestion process means that the energy contained in the feedstock can be used in multiple ways. One of the most common methods is the conversion of gas into electricity and heat using a CHP (combined heat and power plant). However, before the gas can be used in engines, it must be cleaned. Raw biogas is saturated with water and contains hydrogen sulphide (H₂S), which would end up corroding the plant's engines and other metal, concrete or wood components that are exposed to the

gas. To ensure the longevity of the biogas plant and to protect its components from H₂S, it is essential to **desulphurise** the biogas. This can be performed by

- ▶ adding metal salts into the digester,
- ▶ enabling internal or external biological oxidation (e.g. controlled air injection into the digester), or
- ▶ scrubbing the biogas with sulphur-adsorbing materials (e.g. activated carbon).

Heat and CO₂ from bio-methane upgrading can be used in greenhouses



Drying the gas is another common step in the refining process. A popular method for doing this is condensation drying, which involves cooling the biogas to a temperature where the water content condenses and is captured in a condensation tray.

After this cleaning process, the biogas is suitable for burning in a CHP system in which an engine drives a generator. The **heat** generated in the combustion process can also be collected by heat exchangers. While around a quarter of the heat generated must be used to heat the digesters, the remaining part can be used or sold for multiple applications such as heating farm buildings and homes or drying (e.g. crops or wood). This year-round heat energy is particularly useful for consumers who require heat throughout the year, such as community buildings, swimming pools, greenhouses, breweries or other industrial operations. Heat energy can also be used to run cooling systems, which could prove attractive for countries with hotter climates.

A benefit of producing **electricity** from biogas is the flexibility the gas offers, as it is much easier to store biogas than electricity. Electricity can, therefore, be produced when it is needed. This has a stabilising effect on power systems because any drops in output from fluctuating energy sources (like wind power and photovoltaic systems) can be offset. An increasing number of biogas plants in Germany no longer generate power around the clock but, instead, produce electricity according to demand. This approach also represents a great opportunity for off-grid solutions by enabling producers to generate electricity when needed.



Electricity from biogas plants can be provided on demand

Upgraded biogas, known as **biomethane**, can be fed directly into the existing natural gas grid and be stored in gas reservoirs. To upgrade biogas to biomethane/natural gas quality, the CO_2 contained in the biogas must be removed to ensure the CH_4 content of the gas mixture reaches high concentration, often more than 96%. Various upgrading techniques are available. Once biogas is upgraded to biomethane and is, for example, injected into the gas grid, it can fulfil the same tasks as natural gas. For example, it can be used as a **fuel** to run vehicles, compressed in cylinders (e.g. for domestic use) or used in a CHP at a location where the heat produced can be most efficiently repurposed. Biomethane can have very positive impacts on the sustainability of the transport sector in that CO_2 emissions from a vehicle running on pure biomethane produced from waste, are around 90% lower than those of vehicles running on fossil fuels.

Heating outdoor swimming pool with heat from a biogas plant



Public bus running on natural gas/biomethane



9 Further publications

Safety, biomethane upgrading as well as digestate applications, upgrading and marketing are other very important topics in the field of biogas production. The “Biogas know-how” series provides additional brochures in these thematic fields, which can be downloaded and ordered from the German Biogas Association.

It is essential that a biogas plant is operating safely. In the brochure **Safety first!**, how to construct and operate a biogas plant in a safe way is explained. The main areas of biogas safety are emission control, product safety, water protection, and safety at work, but many other issues and safeguards must be taken into account.

To ensure that biogas plant operations do not lead to health or environmental hazards, manufacturers, planning consultants and operators must work together closely from the outset to avoid problems arising in the plant planning phase. Decades of experience building and running thousands of biogas plants show that biogas facilities can operate safely. Today, reliable technologies, standards and training are available to ensure safe biogas operations. Only when all the required measures are taken can biogas be produced safely. More information under: www.biogas-safety.com.

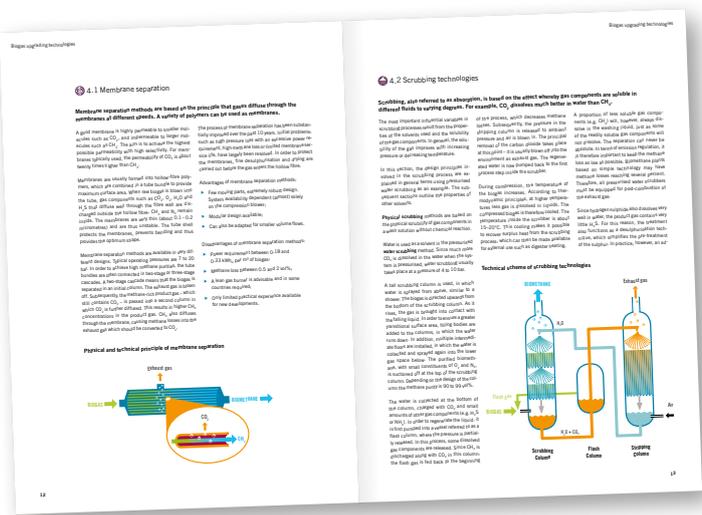
Biogas can be upgraded to biomethane by various techniques of CO₂ separation and CH₄ enrichment (membrane separation, scrubbing technologies, pressure swing adsorption or cryogenic treatment). The possibilities for using biomethane are many and varied. The ability to feed processed biogas into the existing natural gas infrastructure means that gas formed from biomass can be stored temporarily and drawn on as required. This practice allows the highest efficiency levels to be achieved, both in the production of electricity via simultaneously combined heat and power generation, and in direct heat utilisation. In this way, biomethane contributes significantly to the stabilisation of the energy supplies, and balances out fluctuations in renewable energy derived from wind and solar. Certificates that document the sustainable production of biomethane can be traded.

In addition to stationary applications, biomethane can also be used as a vehicle fuel (for passenger transport, heavy duty transport such as lorries and ships, or in industry and agriculture), or as a raw material source for further material applications. Additionally, the by-product CO₂ can be used as the basis for power-to-gas synthesis. This unique flexibility means that biomethane can be generated and put to use in centralised and decentralised applications around the world. More information under: www.biogas-to-biomethane.com.

Digestate is used as high-quality fertilizer, rich in humus and nutrients. It can be used in liquid form or separated as solid digestate directly into agricultural areas. All the nutrients and micronutrients contained in the feedstock for the biogas plant will remain in the digestate. As such, the feedstock fed into the digester directly determines the composition of the resulting digestate.

In general, this technology presents two main types of risk: environmental hazards and health hazards. Environmental hazards may, for example, be greenhouse gas emissions or digestate leakages into bodies of water due to structural or operational failures. Health hazards may involve people who work in biogas plants or third parties (e.g. communities close to the plant) and are categorised as: gas hazards (e.g. explosions), fire hazards, mechanical hazards and electrical hazards as well as noise pollution and the emission of hazardous substances.

The most common risks on biogas plants are not specifically caused by biogas but by falling, cutting, and physical impacts, etc (i.e. they are mechanical in nature). Some of the toxic, harmful and/or sensitising chemicals used or generated in the process, like hydrogen sulphide (H₂S) can be dangerous. Processing aids (essential nutrients), biological agents or compounds to de-sulphurise the biogas can also present a risk to operators and staff.



Essential nutrients for plant growth are predominantly nitrogen, phosphorus and potassium. Nitrogen availability and, hence, plant nutrition, is improved after digestion due to a higher ammonium concentration. Additionally, the digestate's valuable organic carbon content is a key component of humus. To reduce costs (storage, transportation and application) or to establish new markets (e.g. garden centres, home improvement stores and retail markets), a number of techniques can be applied to upgrade the liquid digestate such as separation, composting, drying, pelletising, granulating, vacuum evaporation, membrane filtration (e.g. ultrafiltration or reverse osmosis), precipitation or nutrient stripping, etc.

In general, the use of fertilizer should be promoted to close nutrient and carbon cycles and to reduce the use of inorganic fertilizers, which often have to be transported over long distances. Furthermore, the production of inorganic fertilizers requires vast amounts of energy, which is mainly generated using fossil fuels and thus results in high greenhouse gas emissions. Shortages of phosphorus, a finite resource, look set to affect our society soon and are already heading to critical levels of uranium and cadmium in inorganic phosphorus fertilizers. With the prices of inorganic fertilizers rising, the production of organic alternatives is timely and potentially lucrative.



The use of digestate as a fertilizer is not only beneficial for the environment but also economically essential. For example, it avoids the high waste disposal costs that can result from treating liquid digestate in a water treatment plant. The output quality always depends on the input quality of the feedstock used. As such, the choice of feedstock must be considered when planning the plant in order to guarantee the production of high-quality fertilizer that, ideally, earns increased revenue due to its nutrient and humus content. More information under: www.digestate-as-fertilizer.com

AVAILABLE ONLINE



www.biowaste-to-biogas.com



www.biogas-safety.com



www.biogas-to-biomethane.com



www.digestate-as-fertilizer.com

10 Significance of waste digestion in developing countries

In developing countries and emerging economies, biogas technology can play an important role in integrated waste and resource management. Anaerobic digestion of organic waste provides a unique opportunity to tackle waste management problems, reduce environmental pollution, provide green energy, and to close the nutrient cycles.

Inadequate **solid waste management** in urban centres of low- and middle-income countries is a serious environmental and health problem. Rapid urban population growth and the continual increase in waste generation intensifies the challenge. Often, more than 50%, sometimes up to 70–80%, of waste produced is organic and biodegradable. Suitable treatment options

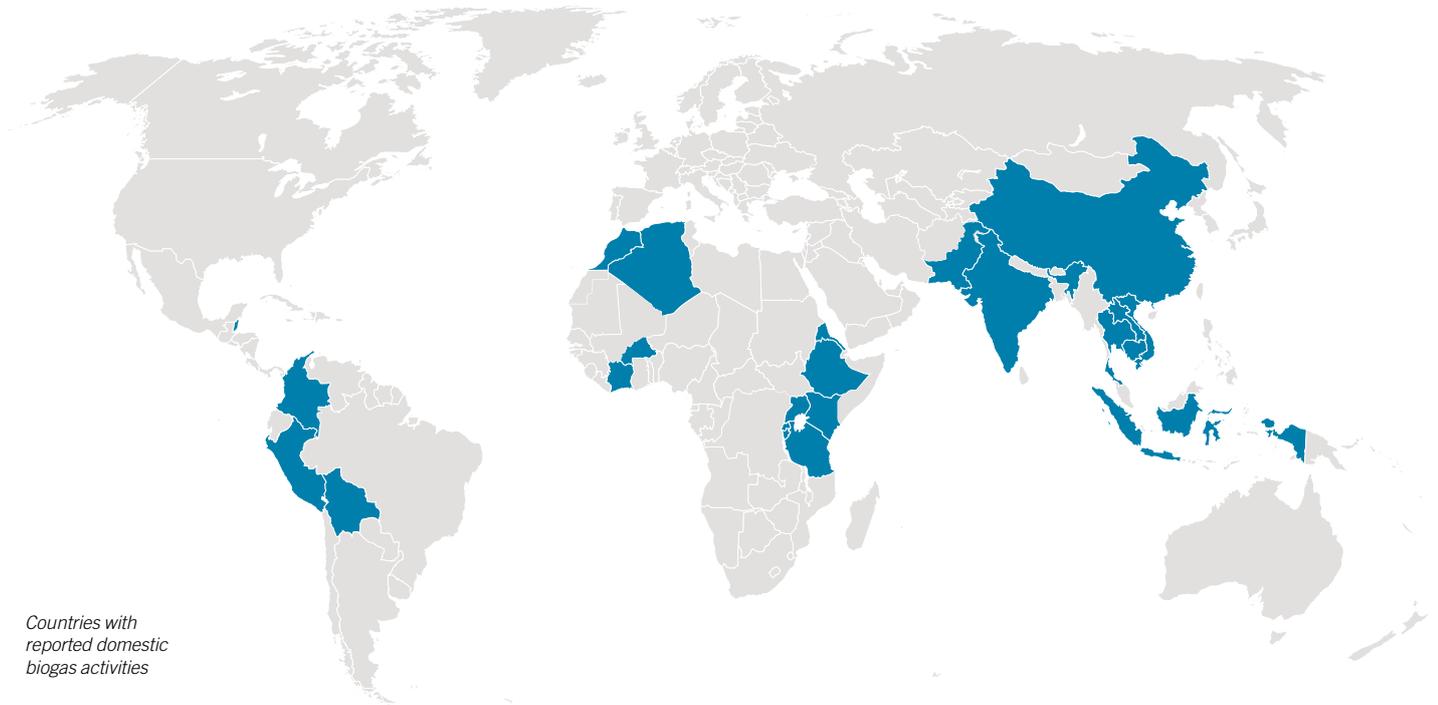
Biowaste collection for biological treatment



for the large organic fraction could help **alleviate the waste problem**. At the same time, the worldwide drive to find clean, **renewable energy sources** remains a main priority. Countries are keen to cut their reliance on fossil fuels due to concerns over the security of supplies and to provide alternatives to wood fuel, the main energy source for cooking and heating which is causing severe deforestation. Banning the dumping or landfilling of organic waste is therefore of great benefit: it reduces the generation of landfill gas, relieves pressure on scarce landfill capacities and mitigates all of the conflicts, costs and social burdens involved.

Anaerobic digestion of organic waste, resulting in the generation of biogas and digestate, which is a high caloric organic fertilizer, provides a unique opportunity to fulfil a number of objectives: tackling waste management problems, reducing environmental pollution, supporting energy recovery and closing the nutrient cycle. There is no need for purpose-grown crops (“energy crops”) for fuel as organic waste supply is abundant. This approach contributes to improved waste management practices and, at the same time, fulfils the goals of sustainable energy generation. Furthermore, using waste biomass to produce biogas creates a carbon-neutral cycle, in which the carbon emitted from burning the gas is absorbed by new crops from which the waste residues can again be used as feedstock: Anaerobic biowaste digestion and the energetic use of biogas is helping to reduce GHG emissions directly, by reducing uncontrolled CH₄ emissions from e.g. landfills and informal dump sites, and indirectly by replacing the use of fossil fuels. Let’s keep this in mind: CH₄ emissions caused by human activities are the second largest drivers of climate change after CO₂.

Biogas waste treatment facilities **reduce the amount of waste disposed** in uncontrolled dumping sites, which, if unmanaged, release pollutants into air, water and soil, endangering the environment and contributing to GHG emissions. Digestate from biogas facilities is a valuable fertilizer for farmers and is particularly useful in countries where soil quality is naturally poor (thin humus layer and organic content) or has become degraded through over-intensive farming and the use of artificial fertilizers.



Countries with reported domestic biogas activities

Moreover, the provision of energy from waste tends to be labour-intensive due to the amount of personnel needed to collect and process the feedstock. Also, the **reductions in odour, disease, soil pollution, and surface and groundwater pollution** that the system engenders, all serve to improve health conditions. All these arguments support the use of biogas as the global growth energy of the future and biogas technology as an appropriate waste treatment option. Consequently, organisations working in international cooperation such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, are regularly integrating waste and resource management, as well as energy recovery components, when implementing their programmes.

Research on anaerobic digestion solutions for low- and middle-income countries has shown that there is a **wealth of knowledge and experience** with small- and medium-scale digesters built in rural areas, where manure from livestock and some household waste is used as feedstock. However, anaerobic digestion still seems to play a negligible role as a treatment option in urban settings for municipal and domestic waste, whether it be organic fraction from yard, kitchen or market waste. The use of this technology over recent years has be-

come increasingly popular on a medium and large scale in industrialised countries, often using sophisticated technology with automated and mechanised control systems. However, transferring this rather advanced technology to a low-income country, without consideration of local conditions, and without specific adaptations, will be predisposed to failure.

In fact, the process of anaerobic digestion has been **practised for decades** in developing countries: reports describe an early anaerobic digester in Mumbai, India, built in 1859 for sewage treatment. Since then, the technology has become widespread throughout Asia. However, the first digesters in Africa were reportedly only started to be built in the 1950s. Different biogas support programmes of international cooperation focused on rural farmers and families with a few cattle, where until today animal manure and sometimes human faeces are used as feedstock, together with the addition of small amounts of kitchen waste. The development drivers for introducing such systems to provide people with biogas, is to reduce consumption of firewood and respective deforestation, decrease indoor air pollution and improve soil fertility.

Biogas production from organic waste in India



As a rule, roughly 10 kg of kitchen and market waste are needed to produce 1 – 1.5 m³ of biogas. This amount of biogas contains approximately 6 kWh of energy which substitutes 0.5 l of diesel fuel.

After roughly 25 years of step-by-step improvements and practical experience, biogas technology is still attracting interest as a **contribution to renewable energy production**, thereby creating independence from fossil fuels. In China, an estimated total of 40 million domestic systems were installed by 2011. India is home to approximately 4 million domestic biogas systems, and Vietnam had installed more than 100,000 systems by 2010. Further Asian countries to be highlighted are Cambodia, Laos, Indonesia, and Nepal (225,000 by 2011). In Africa, where anaerobic digestion is less prevalent due to climatic reasons, countries like Kenya and Uganda (approximately 7,500 by 2017) are amongst the frontrunners regarding domestic biogas installations, while in the Republic of South Africa a significant number of mid- and large-scale biogas plants exist. In Latin America, apart from small biogas plants for rural households, numerous agricultural waste projects have been implemented, and in the urban environment biogas is being extracted from several landfills (landfill gas).

As mentioned, anaerobic digestion of organic household waste in centralised high-technology plants has become a standard in industrialised countries. On the other hand, most regions of developing countries still **lack appropriate low-technology options**. As a result, anaerobic digestion as a waste treatment option for urban settings, predominantly processing kitchen or market waste, still plays a negligible role. There is little knowledge and information available or accessible on technical and operational feasibility, challenges and opportunities.

In developing countries, the **largest share of the MSW consists of organics**, and a relatively small amount of glass, metals, paper and plastics. However, income level, economic growth, lifestyle, and location strongly influence MSW composition. Also, the composition of municipal biowaste can change during the year given seasonal variations and habits.

Organic waste recovery and recycling is still fairly limited in developing countries and emerging economies. Next to direct animal feeding, mulching of gardens, and composting – or burning – the most common practice for disposal of organic waste is dumping into unsanitary landfills or open dumpsites, mixed with other waste streams. However, the recycling of organic waste would significantly reduce the amount of waste that needs handling and thus reduces costs at the disposal facilities. Less organic waste at the disposal site prolongs its life span, and also reduces the environmental impact of the disposal site, as the organics are largely responsible for the polluting leachate, CH₄ and odour problems. The implementation of anaerobic digestion or composting as one step in a city-wide solid waste management programme reduces the flow of biodegradable materials to landfills. Nevertheless, its feasibility depends on the market demand for the end products (gas, digestate or compost), as well as the technical and organisational set-up of the individual facilities. Enabling clear legislation, policy and municipal strategies in terms of organic waste management are further important prerequisites for successful initiatives.

The **characteristics of the waste materials** used for biogas production are highly dependent on the collection system, and one of the fundamental issues is whether the collected waste is contaminated by inorganic ma-



Compacting mixed waste on a landfill

terials. If waste is separated at source segregated at source and collected separately, the quality of this feedstock is increased, and the need for sorting at the biogas plant reduced, thereby reducing infrastructure and human resources requirements. In most low – and middle-income countries, separate collection of household segregated organic waste is rare. Thus the collected waste consists of organic waste mixed with other waste materials, and any planned organic waste treatment will require subsequent sorting of the biowaste fraction. This not only leads to additional costs, but more importantly, results in lower quality biowaste feedstock. An exception to this is waste collected from sources which generate predominately biowaste with few contaminating inorganic substances, such as wastes from vegetable markets, restaurants or food processing industries. Biogas plants should therefore be built or located where large amounts of organic waste are accumulated on a sustainable basis, a demand for electricity and heat – or natural gas as fuel – exists, and organic fertilizer can be used directly or sold to agricultural customers.

When the **main objective of the treatment** facility is to treat waste, with little priority of cost effectiveness or digestate quality, then collection of mixed waste and subsequent sorting before digestion may be suitable. However, if the purpose of the biogas plant is to produce high-quality digestate, then the purity of the waste is very important and biowaste that is separated by the source is preferred.

Source-separated biowaste is generally of higher quality as it contains less non-degradable contaminants such as glass, plastic, rubber, stones, sand and hazardous and/ or toxic substances. This comparatively “pure” biowaste is thus ideal for treatment in biogas plants. A source-separated collection is nevertheless inevitable to ensure that impurities in the feedstock to a biogas plant are removed, as this may lead to clogging of inlet pipes, reduced biogas yield and lower quality and acceptability of the digestate. However, over recent years, revenue-driven waste collection companies’ approaches to waste management could be observed in some countries: mixed domestic waste now sometimes is at least segregated and sorted on top of the collection trucks for further processing and/ or recycling.

Where source-separated collection systems for MSW are deemed to be impossible or limited, **alternative or additional sources** for separated organic waste collection should be considered (e.g. waste from food wholesalers, restaurants and catering, food processing industries). The collection system might also need to be optimised to avoid the loss or premature degradation of organic matter (feedstock), especially in hot climates, e.g. by using sealable bins or containers. A major challenge in countries of tropical, subtropical and arid climates is



Producing biogas in a domestic digester

to minimise the storage time of collected biowaste as organic matter starts to decompose quickly. With longer storage, biogas yield decreases as waste has already degraded and lost some of its energy value.

Additionally, especially when developing a mid- to large-scale biogas project, basic data should be available to demonstrate that a sufficient amount of organic waste is constantly available and is of adequate quality. Securing a guaranteed and regular feedstock supply for biogas plants should not be taken for granted. In practice, this means that all elements of the waste management value chain must contribute to the smooth functioning of the entire system, i.e. the collection, transportation, handling and storage of the biowaste feedstock.

As a matter of fact, a few ‘simple truths’ about integrated waste and resource management need to be clearly stated and acknowledged: **Waste management and energy production** in general, including anaerobic biowaste digestion, **incurs costs**. Generally speaking, high up-front investments for mid- to large-scale industrial biogas systems are the main obstacles for project developers, municipalities and investors in developing countries and emerging economies.

On the contrary, there is an erroneous and widely held belief that the final disposal of waste in sanitary landfills and, even worse, in uncontrolled, sub-standard dumps, costs less than any other waste treatment method. However, this only applies if the major environmental and social burdens these approaches engender are not taken into account, but instead are passed on to future generations.

Biogas facilities require considerably more capital expenditure than ‘simple’ composting or landfill facilities. It often turns out that a significant number of biogas plant projects are not viable under current

economic and organisational conditions, unless favourable framework conditions, e.g. sufficient guarantees, incentives, feed-in tariffs, are provided by local governments. To tackle these challenges, investors and operators therefore need sufficient revenues and price certainties as a basis for their commitment.

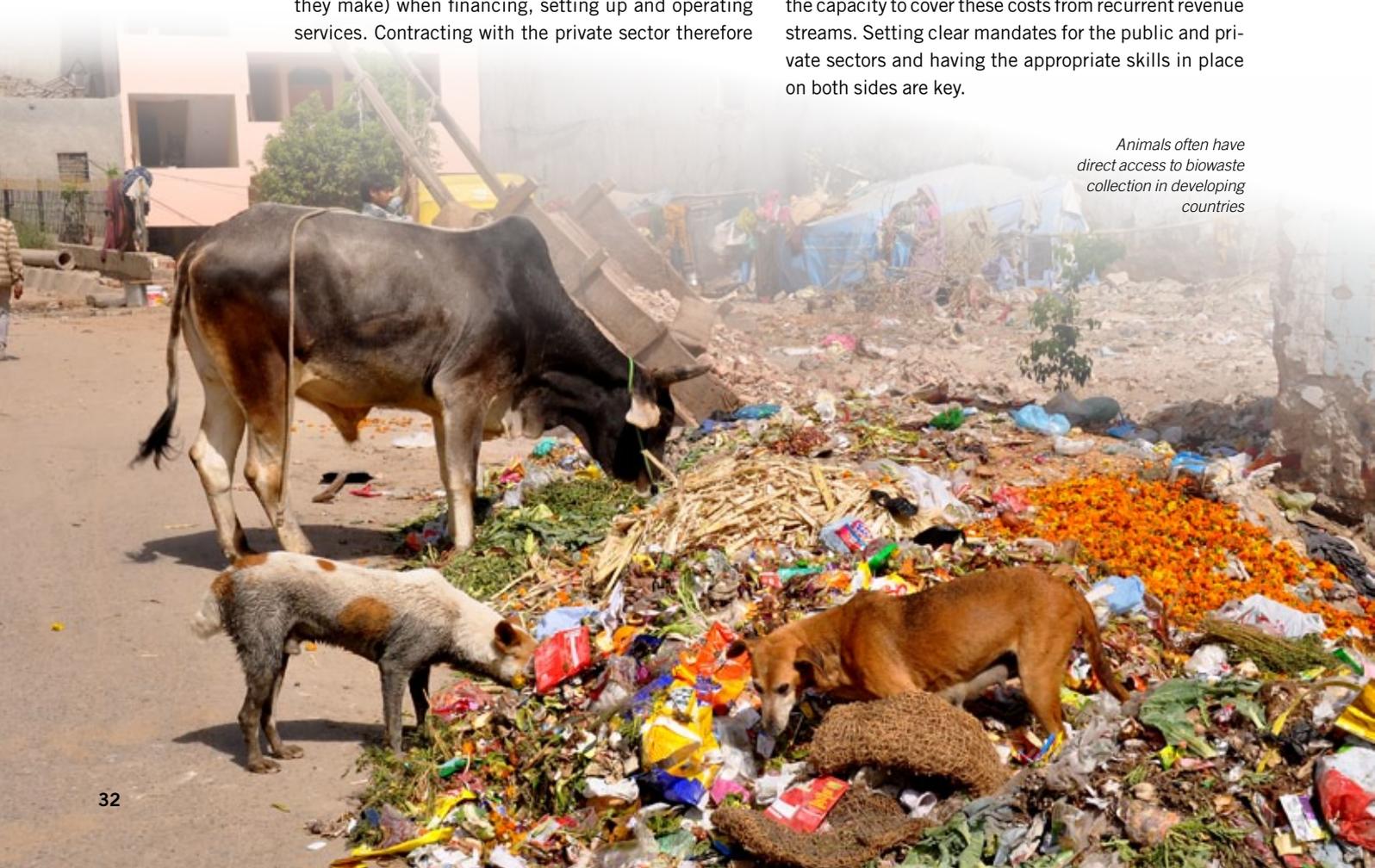
Some **extra efforts** therefore appear necessary and, since waste management is a cross-cutting task, a set of political, institutional, social, financial and technical conditions must be met if biowaste-to-biogas projects are to be successfully implemented. Countries or local and regional authorities that successfully provide such **favourable framework conditions** e.g. by implementing (national) strategies, providing renewable energy incentives, offering long-term contracts and ensuring price certainty for the energy generated, experience substantial increases in investments in biogas production from source-separated biowaste.

In that regard, **private sector participation** is often a key driver in any project that initiates a sector change using new or sophisticated technologies. Business participation is valuable in mobilising investment and bringing in the operational experience needed to provide efficient services. For example, private sector players can achieve improved service efficiency and thereby reduce unit costs. A necessary condition when involving private stakeholders is to guarantee that enterprises can recover all the legitimate costs they incur (and profits they make) when financing, setting up and operating services. Contracting with the private sector therefore

The German Government, and its relevant ministries are providing a number of funding and financing tools for German enterprises that intend to jumpstart cooperation with local partners in developing countries and emerging economies, with the aim of developing and implementing a biogas project. Amongst them are programmes by the Federal Ministry for Economic Cooperation and Development (BMZ) – <http://www.bmz.de/en/index.html>), the Federal Ministry for Economic Affairs and Energy (BMWi – <https://www.bmwi.de/Navigation/EN/Home/home.html>), and the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU – <https://www.bmu.de/en/>). As an example, through the developPPP.de programme, BMZ provides companies investing in developing and emerging countries with financial and, if required, professional support. Since 2008, the International Climate Initiative (IKI) of BMU has been financing climate and biodiversity projects in developing and newly industrialised countries, as well as in countries in transition. DEG as a subsidiary of KfW Group provides financing and consultancy to private companies investing in developing and emerging countries. Furthermore, in order to boost climate-friendly technology, DEG (Deutsche Investitions- und Entwicklungsgesellschaft), a daughter of KfW Development Bank, is running the programme “Climate partnerships with the private sector” on behalf of BMU, which aims at mobilising players from the private sector for climate protection in developing countries and emerging economies, with a focus on the promotion of technology and knowledge transfer to support the development of a climate-friendly economy.

depends on having a reliable understanding of the full costs involved in privately delivered services, as well as the capacity to cover these costs from recurrent revenue streams. Setting clear mandates for the public and private sectors and having the appropriate skills in place on both sides are key.

Animals often have direct access to biowaste collection in developing countries





Low-scale biogas production

Furthermore, financing and funding options available from local governments, as well as the German Development Cooperation, may help to jumpstart a project.

Experience gathered from **redesigning the solid waste management sector**, including not only the formal private sector, but also the informal sector, should be considered. In many low- and middle-income countries, informal players are a key part of the waste management system, working mostly in the small-scale recovery of recyclables. By involving the informal sector, the livelihoods of people in poor and vulnerable communities can be improved, and recycling rates boosted.

Ideally, a **policy and legal framework** for the source-separation of different solid waste fractions and its respective enforcement is in place. National and local legal frameworks should clearly designate the roles and responsibilities of the players involved and it should include provisions on solid waste collection, financing mechanisms, standards for waste treatment and disposal facilities, and standards for the use of biogas plant outputs (e.g. the digestate). Institutions need to have the competencies and capacities to enforce proper waste management and control the appropriate operation of waste treatment plants.

Authorities institute **market mechanisms and economic instruments** to ensure financial sustainability and to quantify and generate market value for the environmental benefits of biogas production. Ideally, they seek information and advice from the private sector, both locally and from abroad. Data collection and assessment of local conditions to ascertain whether sufficient feedstock streams, a market for biogas products (biogas, power, heat/steam, CH₄, digestate etc.) exists is essential. Acceptable, country-specific remuneration arrangements (e.g. feed-in tariffs) need to be put in place: Feed-in tariffs (FiTs) are the policy instruments most commonly deployed for the promotion of biogas projects, including projects to generate electricity from biogas. Energy producers receive a guaranteed price for the energy they supply to the grid over a fixed period of time providing feasibility, income security, and serving to motivate investors.

Generally, the biggest challenge for the development of biogas projects, may they be small- or large-scale, are **financing options**. Therefore, feasibility is key: the sale of biogas products provides revenue but generally does not always cover the total production costs. Therefore, waste management fees should be imposed, and the possibility to gain additional revenues from the upgrading of digestate as fertilizer should be considered.

Last but not least, **community participation** is of the utmost importance, especially when setting up separate collection schemes, but also when seeking to promote the acceptance and use of biogas plant outputs.

Before this background, in order to **increase integrated waste and resource management**, and to strengthen green energy markets, the commercial biogas sector should be strengthened in developing countries and emerging economies. At the same time, the conjunction of local governments, private sector stakeholders and associations, and international development partners have to be undertaken. This includes sharing best practice examples and intensifying efforts for exchanging knowledge, and collaboration between German and international stakeholders.



Produced biogas can be directly used for cooking

Reference plants



CS BioEnergia S.A.



Gasholder, digester and desulphurisation plant



Manufacturer:
Cattalini Bioenergia S.A. & AAT GmbH

Commissioning: 2017

Waste treatment capacity:
388,600 t/a

Installed capacity:
2 x 1.426 MW_{el.}

Biogas production:
1,100 Nm³/h

Investment volume: 20 million euros

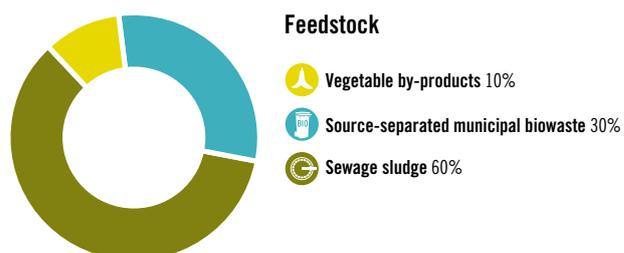


The first AAT-biogas plant in Brazil and the first foodwaste treatment plant in Brazil.

The plant treats about 170 tonnes of market and grocery store waste as well as sludge from the neighbouring waste water treatment plant and produces 2.8 MW of electrical energy. It is the first biogas plant of this kind in Brazil.

Other facts about the plant:

- Input materials: market and grocery store waste and sludge
- Gas production: up to 26,400 m³ a day
- Power: 2.8 MW_{el.}
- Volume of the 2 digesters: 10,000 m³



Operator

CS BioEnergia S.A.

Avenida das Américas SN, Parque náutico -ETE Belém

183.030-640 - São José dos Pinhão - Paraná - Brazil

Contact: Vanessa Cattalini

E-mail: vanessa@grupocattalini.com.br

URL: www.csbioenergia.com.br

Type of digestion: Mesophilic, wet digestion, separate hydrolysis

Feedstock preparation: Milling, shredding, sensor technology, belt press

Digestate upgrading: Separation, waste water treatment

Generated fertilizer: Dischargeable water

Use of the digestate: Treatment in a public waste water treatment plant

VALNOR S.A.



VALNOR, SA in Alter do Chão, Portugal

Manufacturer:
Bekon GmbH

Commissioning: 2011

Waste treatment capacity:
25,000 t/a

Installed capacity:
500 kW_{el}

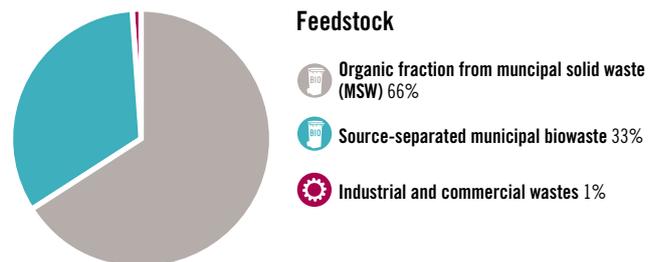
Investment volume:
7.5 million euros



VALNOR, S.A. is the company responsible for the treatment and valorisation of municipal waste, produced in the municipalities of Abrantes, Alter do Chão, Arronches, Avis, Castelo de Vide, Castelo Branco, Campo Maior, Crato, Elvas, Fronteira, Gavião, Idanha-a-Nova, Marvão, Mação, Monforte, Nisa, Oleiros, Portalegre, Ponte de Sôr, Proença-a-Nova, Sardoal, Sertã, Sousel, Vila de Rei and Velha de Ródão. The area of Intervention is 11.980 km², with a residential population of 271,516 habitants.

The biogas plant is designed to treat around 25,000 tonnes per year and receives mostly the organic fraction of the communities. This plant has 8 fairly robust digesters able to treat the organic fraction of MSW of the aforementioned community. The installed power of the anaerobic installation is 500 kW and its temperature for the process is mesophilic.

VALNOR, SA has established an Integrated Management System to take care of the MSW produced in this area of intervention. The system consists of several operational facilities, including biodiesel production, composting plant and anaerobic waste digestion plant.



Operator

VALNOR S.A.

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URL: www.valnor.pt

Type of digestion: Mesophilic, dry batch digestion

Feedstock preparation: Air separation, sorting cabins, metal deposition, sensor technology, cutting

Digestate upgrading: Composting

Generated fertilizer: Compost

Use of the digestate: Marketing compost (vineyards)

Imperial Park (UK)



Imperial Project



The biogas project “Imperial Park” was developed by the UK company AVG Limited. The plant was built in Middlesbrough by BioConstruct who was chosen as the EPC Contractor. It was commissioned in 2017. The input substrates are delivered from supermarkets, bakeries, slaughterhouses, agriculture or any other kind of industry. The maximum total input amount is 108,000 t/a and it has an installed electrical capacity of 4,988 kW_{el}, consisting of four Jenbacher engines (3x 1,487 kW, 1x 527 kW). While the electrical energy is fed into the grid, the produced thermal energy is used to provide heat for the mesophilic AD process at a temperature of approx. 38 °C and the pasteurisation process of the digestate (70° Celsius for 1 hour).

BioConstruct was responsible for the technical design, construction and commissioning of the plant. The plant is characterised by its seven tanks (2 digesters 5,953m³ each, 1 post fermenter 7,953m³, and four storage tanks 7,716m³ each) and its external biological desulphurisation system. In addition, the plant is capa-

Manufacturer:
BioConstruct GmbH

Commissioning: 2017

Waste treatment capacity:
108,701 t/a

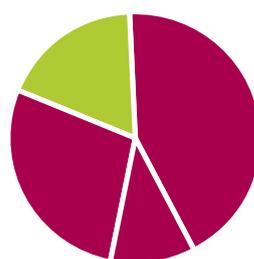
Installed capacity:
4,988 kW_{el}

Investment volume:
£ 20,805,000



ble of receiving and pre-storing nearly 900m³ of liquid substrate in seven tanks with capacities of 5 x 105m³ and 2 x 186m³.

Overall, the biogas plant is able to treat a flexible feedstock menu and is designed for low-maintenance operations. Since its commissioning, the BioConstruct sister company BioConstruct NewEnergy Ltd. has been operating the plant.



Feedstock

-  **Industrial and commercial wastes**
Food production wastes 43%
Bakery waste 11%
Processed mycoprotein waste 28%
-  **Animal by-products**
Cattle slurry 18%

Operator

Imperial Park (UK)

Imperial Avenue

TS6 6BA, Middlesbrough · UK

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Phone: +49 5226 5932 0

Fax: +49 5226 5932 11

E-mail: info@bioconstruct.de

URL: www.b-ne.uk

Type of digestion: Mesophilic, wet digestion

Feedstock preparation: Cutting, sanitation, sensor technology, external biological desulphurisation

Generated fertilizer: Liquid digestate (PAS 110)

Use of the digestate: Spreading as fertilizer (PAS 110)

SEMECS Biomethanization Facility Varennes



Digesters (left) and BTA Waste Pulper (right). Varennes, Canada.

Manufacturer:
BTA International GmbH

Commissioning: 2018

Waste treatment capacity:
40,000 t/a

Biogas production:
490 Nm³/h

Investment volume:
approx. CAD 58 million

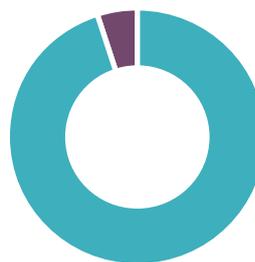


The SEMECS Biomethanization Facility Varennes is designed for a processing capacity of 40,000 t/a of Source Segregated Organics (SSO), grass clippings, septage and liquid waste.

SEMECS (“Societe of Economic mixte de l’est de la Couronne Sud Inc.”) is a PPP established in 2012 between three public Regional County Municipalities (RCM’s) and a private partner, BiogazEG. The facility will count for more than 40% of the organics diversion needs from these RCM’s to achieve the Quebec government’s mandated policy objective in banning organics from landfills by 2022. The technological platform for the facility is the BTA® Process. SSO and grass clippings will be pre-treated via the BTA® Hydro-mechanical Pre-treatment System of pulping and grit removal, others will be fed directly to the two digesters.

Part of the biogas will be used to cover the heat demand of the mesophilic digestion process. Additional biogas will be cleaned up for use at the on-site GreenField Ethanol Facility to offset up to 10% of its natural gas use. The digestate is dewatered with the reclaim and

reuse of the liquid fraction. The nutrient-rich, stabilised and dewatered solids will be hauled to more than 400 farms which grow the corn that supplies the Ethanol Facility. The quality digester solids allows for direct land application in accordance with Canadian Food Inspection Agency (CFIA) requirements as a registered organic soil amendment for agricultural uses.



Feedstock

-  Source-separated municipal biowaste 95%
-  Others
Septic tank sludge 5%

Operator

SEMECS Biomethanization Facility Varennes
3300 Rte Marie-Victorin
Varennes, Quebec J3X 1P7 · Canada
Contact: Jean Roberge (President BioGaz EG)
Phone: +1 450 652-1800
E-mail: J.Roberge@greenfieldethanol.com

Type of digestion: Mesophilic, wet digestion
Feedstock preparation: Grit separation, pulper
Digestate upgrading: Separation, waste water treatment
Generated fertilizer: Solid digestate, dischargeable water
Use of the digestate: Spreading as fertilizer

Yuanping Biogas Plant



The biogas plant in Shanxi province produces 37,680 m³/d from energy crops and animal by-products.



Owner and operator of the biogas plant in Shanxi province, P.R. China is Shanxi Energy & Traffic Investment Co. Ltd.

The plant is designed to receive input materials like corn straw, dry chicken dung and cow manure. The input is shredded, mixed and homogenised by means of the Biogas Kreis-Dissolver[®]. The homogenised input mixture is pumped into the microbiology of the digester. A recirculation shaft especially designed by EnviTec is installed directly on the digester. As per overflow principle, the fermented substrate is fed from the digester into the recirculation shaft. From here, the fermented material is fed back to the Biogas Kreis-Dissolver[®] for the dry matter control during the mixing process. Six digester tanks with a total net volume of approx. 31,500 m³ and with a daily supply of approx. 520.5 m³ of fresh input materials result in a hydraulic retention time (HRT) of approx. 61 days. The immersed, height-adjustable agitators ensure that the substrate and heat are evenly distributed in the digester. The daily produced biogas amount out of the six digesters and the used input materials is approx. 37,680m³/d.

Operator

Yuanping Biogas Plant

Haicun

Yuanping City, Shanxi Province · China

Contact: Anne Selzer

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Fax: +49 2574 8888 800

E-mail: info@envitec-biogas.de

URL: www.envitec-biogas.de

Manufacturer:

EnviTec Biogas AG

Commissioning:

2019

Waste treatment capacity:

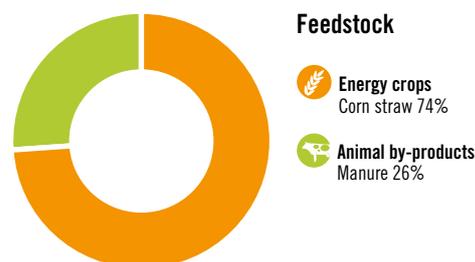
104,025 t/a

Installed capacity:

37,680 m³/d



In order to remove the sulphur from the biogas, atmospheric air is fed into the gas holder of the digester roof with a side channel compressor. Furthermore, the biogas is cleaned and dehydrated by activated carbon filters and a drying/cooling unit before the biogas is handed over to the gas upgrading system. If necessary, excess biogas is flared off via a stationary emergency gas flare. Residues from the biogas process will be fed via a dry installed pump to the fertilizer workshop. The residues are treated to get fertilizer pellets by means of screw press separators, decantation unit and drying unit.



Type of digestion: Mesophilic, wet digestion

Feedstock preparation: Homogenised by Biogas Kreis-Dissolver[®]

Digestate upgrading: Separation, drying unit, pelletising

Generated fertilizer: Liquid digestate, solid digestate

Use of the digestate: Fertilizer pellets

BENC KG – Bio Energie Centrum



Manufacturer:
NQ Anlagetechnik

Manufacturer of paddle depacker:
Mavitec Green Energy

Commissioning: 2000

Waste treatment capacity:
12.000 t/a

Installed capacity:
1.480 kW_{el.}



Food waste depacking with Paddle Depacker



Bio Energie Centrum – sustainable, responsible, innovative!

Since our foundation in 1999, we have made it our business to generate valuable energy from biowaste and thus enable municipalities, companies and private households to dispose of their waste sustainably. In this way, everyone can actively contribute to climate protection.

Our company produces sustainable energy from waste in a careful and environmentally friendly manner and feeds it into the electricity and district heating grid. This energy is generated in our biogas plant by fermenting green waste, food and organic waste. The material is hygienised by heating and methane gas is produced in a downstream fermentation process, which is converted into electricity in block-type thermal power stations. We supply the generated energy to municipalities and companies in the form of electricity and heat.

Due to new German legislation, BENC was looking for a new way of depacking. Together with Mavitec Green Energy, the solution was found in the Paddle Depacker, designed to separate the organic material from the packaging. The Paddle Depacker turns foodwaste into organic soups and delivers a very clean organic output that is extremely suitable for biogas installations, with official lab results of less than 0.5 % plastic & metal packaging in the organic output.

Feedstock



Industrial and commercial wastes
Foodwaste 100%
(supermarket waste & industrial food waste)

Operator

BENC KG – Bio Energie Centrum
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86690 Mertingen - Germany
Contact: Paul Schwehofer
Phone: +49 9078 968550
Fax: +49 9078 968551
E-mail: info@benc-kg.de
URL: www.bioenergiecentrum.de

Type of digestion: Mesophilic, wet digestion

Feedstock preparation: Grit separation, pulper, strain press, press screw separator, Paddle Depacker

Digestate upgrading: Separation, vacuum evaporation, centrifuge

Use of the digestate: Spreading as fertilizer, marketing digestate

Sewage plant for leftovers of own production



Biogas plant for potatoe sludge with own WWTP



The Wernsing company is a globally acting producer of french fries, salads, sauces and convenience food. They intend to bring the pursuit of commercial profit in line with environmental responsibility.

With the implementation of an own biogas plant as well as an own waste water treatment plant, they reach their ambitious ecological goals. The biogas plant has an installed capacity of 4.2 MW_{el} and the only input is 100% biological waste from their own production. As potatoes are a key ingredient of the production, a lot of potatoe sludge emerges along the production process. In general, it is said that potatoe sludge has a gas yield of approximately 50–80m³/t.

The preparation to start the digestion is little: the sludge just needs to be screened. Afterwards hydrolysis takes place in the first tank meaning that polymers are broken down to sugar monomers. The substance is then pumped into the second tank for methanation (wet digestion). After fermentation, the solids are dried and pelletised, whereas the liquids are cleaned in the own waste water treatment plant. The dried digestate and pellets are sold to fertilizer companies.

Operator

Sewage plant for leftovers of own production

Kartoffelweg 1
49632 Addrup-Essen · Germany
Contact: Mr. Elberfeld
Phone: +49 5438 51-01
Fax: +49 5438 51-350
E-mail: info@wernsing.de
URL: www.wernsing.de

Manufacturer:

Erich Stallkamp ESTA GmbH

Commissioning: 2001

Expansion: 2019

Waste treatment capacity:
150,000 t/a

Installed capacity:
4.2 MW_{el}.



The existing biogas plant will now be extended by two tall digesters with a capacity of 3,000m³ each. The digesters will be supplied by the German manufacturer Stallkamp. Completely made from stainless steel, the digesters will enlarge the waste treatment capacity by two thirds.



Feedstock

 **Industrial and commercial wastes**
Biological leftovers from own production 100%

Type of digestion: Thermophilic, wet digestion, separate hydrolysis

Feedstock preparation: Screening

Digestate upgrading: Drying, pelletising, waste water treatment

Generated fertilizer: Dried digestate, dischargeable water, pellets

Use of the digestate: Marketing digestate (horticulture, landscaping, gardening), treatment in the own waste water treatment plant

SAS Bio Méthane Seg



The project Bio Méthane Seg plant in France

Manufacturer:
SAS Bio Méthane Seg

Commissioning: 2017

Waste treatment capacity:
54,000 t/a

Biogas production:
160 Nm³/h



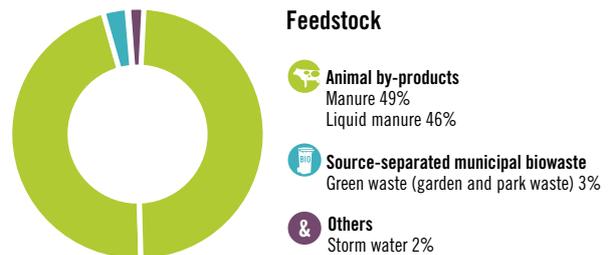
The project Bio Méthane Seg started in 2014 from research into how to improve the value of slurry and manure from the farm.

The project is a collective of 53 farmers who are carrying out a biogas recuperation project using biomethane to feed it into the natural gas distribution network.

The final project includes more than 50,000 tonnes of input from the 27 plants. In order to better control potential odours and improve landscape integration, a building has been constructed for receiving and managing materials.

The plant is constructed by Nasceo Environnement and equipped with SUMA agitators through their service partner Sycomore Services in France. The installed agitators homogenise the substrate to achieve the highest possible gas output. Six OPTIMIX submersible motors on guide masts and six GIANTMIX long-axis agitators from SUMA Rührtechnik GmbH are in operation.

In addition to the biogas produced, 80 % of the remaining product, the digestate, is distributed to the agricultural land. The remaining 20 % is used for composting and recycling for the production of green manure.



Operator

SAS Bio Méthane Seg
Lieu-dit L'Épinette
49 280 La Séguinière - France
Contact: Christian Chupin
Phone: +33 6 82 22 63 63
E-mail: biomethaneseg@gmail.com

Type of digestion: Mesophilic, wet digestion
Feedstock preparation: Milling, strain press
Digestate upgrading: Separation
Generated fertilizer: Liquid digestate, solid digestate
Use of the digestate: Spreading as fertilizer, marketing digestate (horticulture, landscaping, gardening)

TTV EKOGAS (Forsbacka Biogas plant)



TTV EKOGAS (Forsbacka Biogas plant)



The plant produces biogas from 25,000 tonnes of energy-rich household kitchen- and bio-waste using the largest Thöni TTV digester with a volume of 2,250 m³.

Organic waste first undergoes a pre-treatment of shredding (bag opener). The organic input is then stored in a buffer-bunker before being automatically fed via a heat exchanger into the digester.

The digestion process is thermophilic with a residence time of around 36 days to ensure complete hygienisation of the material. Homogenisation and uniformity is guaranteed by the residence time and smooth mixing action of the patented paddle-shaft in the curved-base digester. The design creates a fully controlled plug-flow process preventing sedimentation or the creation of floating layers.

At the end of the anaerobic process, digestate is pumped to the dewatering system. A proportion of the liquid digestate is recirculated in the digestion process to humidify fresh input material, and this inoculation ensures maximum efficiency of both degradation of input material and yield of biogas. Liquid digestate is stored in

Manufacturer:

Thöni Industriebetriebe GmbH

Commissioning: 2017

Waste treatment capacity:
25,000 t/a

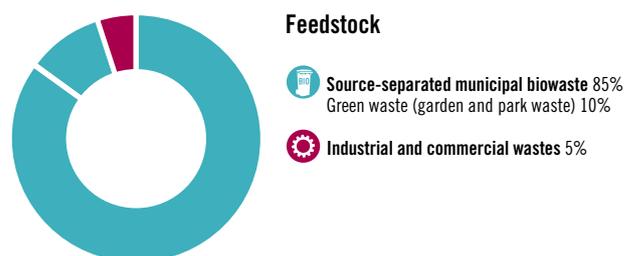
Biogas production:
600 m³/h

Investment volume:
9.7 million euros



tanks under gas-store membranes for use as agricultural fertilizer. The solid digestate fraction undergoes a further aerobic composting process in enclosed composting units to produce high-quality compost certified for organic farming.

Biogas produced in the digester will be further processed into high-grade bio-methane in a biogas upgrading plant by the owner. As there is no local gas grid, biomethane is filled into road-containers and transferred to local gas filling stations.



Type of digestion: Thermophilic, dry continuous digestion

Feedstock preparation: Shredding, screening, air separation, press screw separation

Digestate upgrading: Separation, composting, drying

Generated fertilizer: Liquid digestate, solid digestate

Use of the digestate: Spreading as fertilizer, marketing digestate (horticulture, landscaping, gardening)

Operator

TTV EKOGAS (Forsbacka Biogas plant)

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81842 Forsbacka · Sweden

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Phone: +46 708 23 31 62

E-mail: jonas.stenfelt@ekogas.se

URL: www.ekogas.se

Member of German Biogas Association

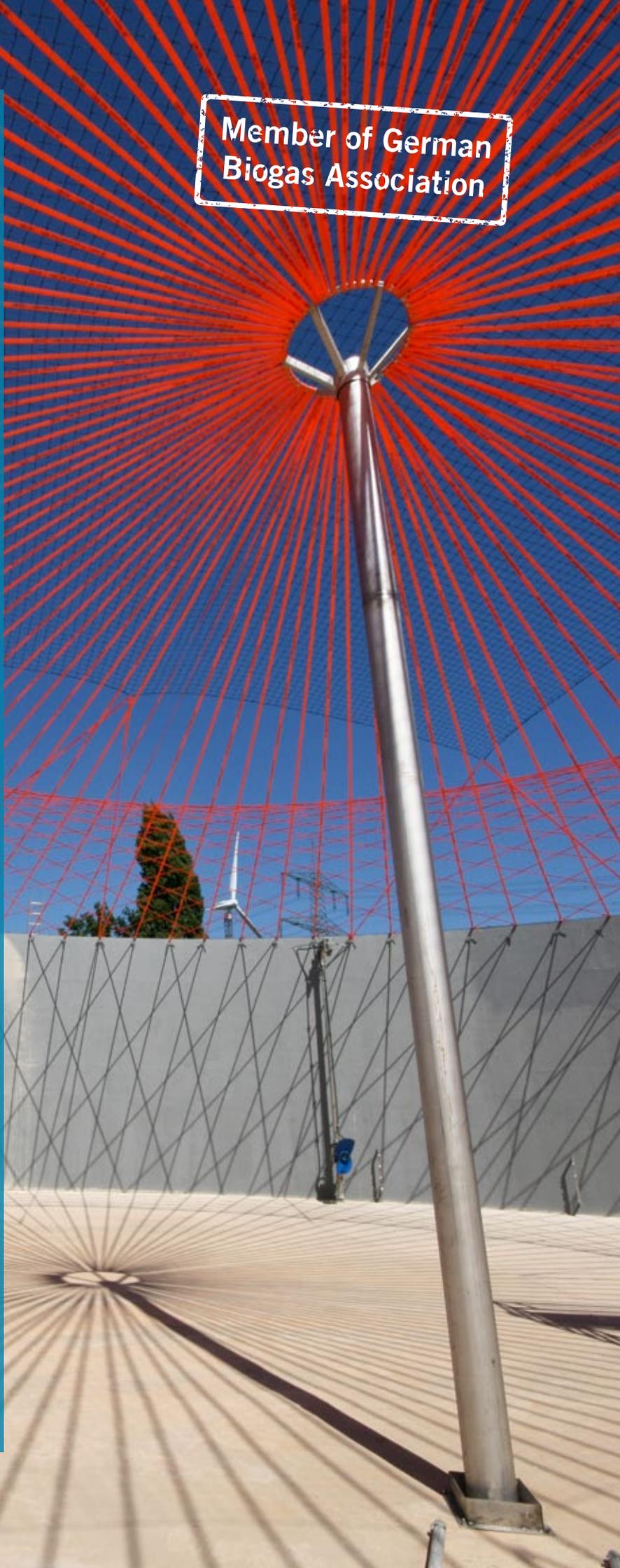
Company directory

SYMBOL DESCRIPTION:

- Wet continuous digestion 
- Dry continuous digestion 
- Dry batch digestion 

- Disintegration & unpacking technologies 
- Dry removal of impurities 
- Liquid removal of impurities 
- Sanitation 
- Process auxiliaries 
- Pumps 
- Mixers 
- Laboratory and measuring 
- CHP components 
- Energy trade and marketing 

The grey icons represent the products or services provided by the companies in this directory, as also shown in the matrix on the following page. The blue icons represent providers of that specific biogas digester technology (wet continuous, dry continuous or dry discontinuous).



Matrix overview of the company directory

Company														Page
1. Turnkey system provider														
AAT Abwasser- und Abfalltechnik GmbH	X					X	X			X				46
Bekon GmbH			X											47
BioConstruct GmbH	X			X			X	X			X			48
BTA International GmbH	X	X		X		X	X	X						49
Envitec Biogas AG	X										X			50
NQ-anlagetechnik GmbH	X			X	X	X	X		X	X				50
Thöni Industriebetrieb GmbH	X	X			X	X				X				51
2. Feedstock preparation														
Werner Doppstadt Umweltechnik GmbH & Co. KG				X	X	X				X				52
Finsterwalder Umweltechnik GmbH & Co. KG	X			X		X	X		X					53
HUBER SE	X					X								53
Mavitec Green Energy B.V.				X	X	X								54
Konrad Pumpe GmbH	X			X										54
Schaumann BioEnergy GmbH								X						55
Tietjen Verfahrenstechnik GmbH				X										55
Wackerbauer Maschinenbau GmbH				X	X	X								56
3. Project developer														
Arcanum Energy Systems GmbH & Co. KG	X	X												56
4. Plant components														
Biogastechnik Süd GmbH	X		X			X				X				57
Lipp GmbH	X													57
MKR Metzger GmbH						X	X							58
NETZSCH Pumpen & Systeme GmbH									X					58
Onergys GmbH												X		59
Fritz Paulmichl GmbH	X	X	X		X	X			X	X				59
SUMA Rührtechnik GmbH										X				60
UTS Products GmbH					X				X	X				60
Erich Stallkamp ESTA GmbH	X					X			X	X				61
5. Services														
Awite Bioenergie GmbH										X				62
bmp greengas GmbH												X		62
Vaisala GmbH										X				63

The companies here shown are classified in 5 categories, namely (1) turnkey system providers who provide complete biogas plants, feedstock preparation companies providers of technologies for crushing, unpacking and separating foreign substances from the feedstock (before, during or after the process) are listed under (2), project

developers (3) are planners of whole biogas plants or of specific plant components. Providers of plant components like tanks, pumps, agitators, CHPs, among other are listed under (4) and finally the companies listed under services (5) provide consulting, laboratory measurements and energy-marketing services.



Biogas plant Recycling Energie AG, Switzerland



Biogas plant Stahlbush Island Farm, USA



RELIABLE SOLUTIONS FOR COMMERCIAL SUCCESS.

Whatever the motivation in building a biogas plant may be, the first priority is a satisfactory return on investment. The basic principles behind the production of biogas are fairly simple; the technology required, however, is complex. Last but not least, biogas production processes also demand a background of highly specialised knowledge.

AAT is not only well known for its state-of-the-art biogas plants but also for successful operation of these during their entire lifespan. More than 1,000 biogas plants built and operating in more than 30 countries verify AAT's success; the result of 30 years of experience and ongoing in-house research and development by highly motivated staff.

Low operating, service and maintenance costs coupled with high availability are the main design targets for each individual AAT biogas

plant, achieved by focusing on the customer's specific demands and input material requirements and supported by reliable in-house developed components and hands-on technology together with profound know-how and efficient service. An excellent example of the application of such expertise is to be found in the AAT-designed maintenance-free digester.

AAT's cumulative philosophy offers the customer the assurance of attaining not only benchmark technology but also complete functional reliability and cost-effectiveness resulting in a high return on investment within a short time span.

Markets and branch offices



- ▶ Biogas plants
- ▶ Pulper
- ▶ Sanitation
- ▶ Agitators
- ▶ Gas cleaning

Year of foundation **1993**
Number of employees **10**

AAT Abwasser- und Abfalltechnik GmbH

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BEKON MINI (Galmiz/CH)



Tunnel filling hall, fermenter and tunnel filling unit (Poznań/PL)

BEKON



Markets and branch offices



- ▶ Biogas plants
- ▶ Garage system
- ▶ Biowaste from households
- ▶ Composting
- ▶ Maintenance

Year of foundation **1992**
Number of employees **23**

BEKON GmbH

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ENERGY FOR THE FUTURE DRY FERMENTATION

Innovative solutions for municipalities, waste management companies and agribusiness

Company profile

BEKON was founded in 1992 in Germany and currently employs approximately 23 people. The company is a worldwide technological leader (> 50 reference plants) in the construction of batch biogas plants for generating energy (electricity or biomethane) from waste. The BEKON dry fermentation process presently features approx. 40 patents which are constantly being amended as a result of ongoing findings of research and development.

THE BEKON TECHNOLOGY

Production of biogas by dry fermentation

The superiority of BEKON technology is already apparent from the wide diversity of suitable substrates. Bulk materials with a high dry-substance content can be digested without need for any complex pre-treatment of the fermentation material. The principle is quite simple: with the absence of air and following inoculation by pre-

viously fermented material, the biological waste begins to digest, immediately resulting in the production of biogas. The BEKON process is a single-step fermentation process that employs batch operation. 'Single step', in this sense means that the various degradation reactions (hydrolysis, acidification and methanisation) constitute one process step.

Filling the digesters using batch operation

The organic waste is collected in a tipping building and taken to the garage-shaped fermenter by wheel loader. Inoculation takes place by mixing the fresh material with material that already has been in a fermenter. Once it has been filled, the fermenter is closed off by a hydraulic hatch and the process of organic waste fermentation initiated. Excess cell fluid (percolation liquid) discharged during the fermentation process is collected by a drainage system and returned to the fermenting material in a cycle to keep it moist. Wall and floor heating is used to keep the temperature of the microorganisms constant. In this way, the conditions in the fermenter are maintained at an optimum level for the bacteria used in biogas production.



Approx. 4,98 MW Anaerobic Digestion Plant at Imperial Park, Middlesbrough, UK



Since its incorporation, **BioConstruct GmbH** has successfully commissioned more than 290 plants with an installed capacity of more than 200 MW.

Our portfolio of realised projects ranges from:

- agricultural plants processing energy crops or co-fermentation plants with liquid or solid manure
- plants with difficult/more complex input materials such as > 90 % grass silage, dung, straw, slaughterhouse waste and packaged food waste
- biogas plants with several CHP units and/or biomethane upgrading technology
- turn-key high-end industrial biogas plants up to 6.5 MW
- high-efficiency plants with heat usages for industry, local heating distribution-companies and greenhouses as well as for electricity providers
- industrial waste fermentation systems

BioConstruct has gained international experience in the realisation of projects in Italy, France, the Czech Republic, the Netherlands, Turkey, Estonia, Latvia, Greece, Ireland and the UK. Only materials able to withstand the strain of continuous operation are used in our plants.

BioConstruct technology meets the most rigorous standards and is permanently monitored

via early recognition and optimisation that is continuously improving our performance, last but not least supported by our broad experience obtained in the shareholding and operation of 21 biogas plants, most of which are majority-owned by BioConstruct. The plants are meticulously planned with a focus on low-maintenance and to furnish the highest gas yields. BioConstruct understands “turnkey plant” not only as a matter of construction, it is rather to explain, consult, support and accompany a project over its lifetime, for example by providing feasibility studies, support in contracting and financing and, of course, not to forget the individual plant design, permitting and planning as well as service and maintenance and, in selected projects, participation in and operation of the built plants.

In a nutshell, BioConstruct's involvement does not need to end with the handover of a plant. BioConstruct defines itself as a partner, not only during the construction phase but rather throughout the whole lifetime of a biogas plant.



A view of BioConstruct's headquarter and own operated anaerobic digestion plant

Markets and branch offices



- ▶ Sewage sludge
- ▶ Biowaste from households
- ▶ Animal by-products
- ▶ Vegetable by-products
- ▶ Hydrolysis

Year of foundation **2001**
Number of employees **100**

BioConstruct GmbH

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Fax: +49 5226 5932-11
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URL: www.bioconstruct.com



5MW_{el} from waste from the food industry – Agrafarm plant in Bury St. Edmunds, UK.



45,000 t/a FORM/biowaste – BTA plant in Granollers, Spain.

BTA 
agraferm



Agrafarm as a provider of complete anaerobic digestion plants has comprehensive knowledge and over 15 years of experience in the international biogas sector. Fuelled by the German boom in energy crops, Agrafarm developed agricultural high-load digestion without adding slurry or other liquids, minimising the recirculation of process water and thus the digester volume needed for a certain retention time. Since then, this process has been patented and extended to any type of solid residuals such as straw, manure, chicken muck, wastes of food industry and agro production in general. The obvious cost reduction is aligned with wide feedstock flexibility and high process liability. Agrafarm's projects are awarded "Best Practice" by the German Government. The German Monitoring Programme emphasised the methane productivity and minimum parasitic consumption.

Both BTA International and Agrafarm continuously develop and further improve their technologies; new patents have been submitted. Meanwhile, over 120 projects worldwide have been designed and realised. BTA waste projects treat about 1.2 million tonnes of organics per year and produce the equivalent of 75 million m³ of natural gas. Agrafarm built biogas plants with a total capacity of over 450 million m³ of biogas per year and is the market leader in the UK with a total capacity of 200 million m³ of biogas per year. Agrafarm also built Europe's largest agro biogas plant utilising over 300,000 tonnes of input per year and providing 35 MW of biogas for electricity and biomethane in parallel.

Our strengths at a glance:

- 30 years of experience, 120 references worldwide
- Wet and dry digestion
- Wet pre-treatment and grit separation
- Production of high quality fertilizer.

Markets and branch offices



- ▶ Biogas plants
- ▶ Pulper
- ▶ Biowaste from households
- ▶ Unpacking
- ▶ Grit separation

Year of foundation **1984**
Number of employees **40**

BTA International GmbH
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URL: www.bta-international.de

Perfected Solutions from One Source

The efficient pre-treatment and adequate subsequent digestion is the key of any successful biogas project and for any type of substrates such as agricultural residues, MSW, biowaste or industrial organic wastes, energy crops or other. This is why **Agrafarm Group** joint together two leading players of the industry and 30 years of experience in one location.

BTA International GmbH is the leading specialist for the wet mechanical pre-treatment of any waste up to the organic fraction of MSW and the subsequent processing of the cleaned organic suspension. The BTA® Hydromechanical Pre-treatment characterises itself by its flexibility and its high efficiency in the removal of impurities out of the organic suspension. This allows for high operational reliability, minimises the disposal costs of the rejects, maximises the biogas yield and ensures the quality of the digestate. The combination of this unique pre-treatment with a subsequent wet anaerobic digestion for the utilisation of the separated organics is called the well-known BTA® Process.



Based in Lohne and Saerbeck, Germany, EnviTec Biogas AG covers the entire value chain for the production of biogas, including the planning and turnkey construction of biogas plants and biogas upgrading plants as well as their commissioning. The company takes charge of biological and technical services on demand and also offers full plant and operational management.

In addition, EnviTec also operates its own biogas plants. In 2011, EnviTec Biogas expanded its business operations with the direct



The biogas and biomethane plant in Dingzhou, China produces 400 Nm³ per hour of biomethane for the transport sector

marketing of upgraded biomethane as well as the marketing of green electricity and balancing energy. With a presence in 16 countries worldwide, EnviTec Biogas AG is represented by its own companies, sales offices, strategic partners and joint ventures. In 2017, EnviTec generated revenue of € 198.8 million and EBIT of € 6.5 million.

The EnviTec Group currently has around 430 employees. EnviTec Biogas has been listed on the Frankfurt Stock Exchange since July 2007.

Markets and branch offices



- ▶ Biogas plants
- ▶ Service
- ▶ Maintenance
- ▶ Biomethane upgrading
- ▶ Biogas cleaning

Year of foundation **2002**
Number of employees **430**

EnviTec Biogas AG
Boschstraße 2
48369 Saerbeck · Germany
Contact: Anne Selzer
Phone: +49 2574 8888 0
Fax: +49 2574 8888 800
E-mail: info@envitec-biogas.de
URL: www.envitec-biogas.de



Waste digestion plant (1 MW_{el}) with an input of 24,000 t per year

NQ-Anlagentechnik GmbH is one of the leading biogas plant manufacturers with over 500 implemented projects in, inter alia, Germany, Switzerland, France, Italy and Slovenia. Due to the great experience we have gained over the last 20 years, we are able to provide a professional workforce that can manage any kind of digestion plant always with the aim of producing clean electricity and valuable resources. We offer an innovative portfolio for plants utilising waste and agricultural by-products for both the commercial and the agricultural sector.

The combination of high-quality and field-tested components and reliable, client-focused concepts makes our systems so durable and efficient. Our own approval planning, project management, warehouse, electric service, metalwork facility and assembly team empowers us to plan, manufacture and install almost every element ourselves.

Our Bavarian-based company also offers an after-sales service hotline, which is available 24 hours a day, 365 days a year.

Markets and branch offices



- ▶ Biogas plants
- ▶ Sanitation
- ▶ Project management
- ▶ Pumping technology
- ▶ Approval planning

Year of foundation **2003**
Number of employees **65**

NQ-Anlagentechnik GmbH
Pfliegweg 13
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Thöni headquarters in Telfs



TTV paddle stirrer

thöni



mixing of the substrate and thus a high biogas yield. The Thöni paddle stirrer ensures highly efficient stirring as well as optimum prevention of swim layers and sediments. The dewatering of the digestion residues is effected by Thöni screw presses which are particularly characterised by low energy consumption and durability.

Thöni wet digestion (TNV)

Thöni TNV technology is based on the wet digester which is continuously filled with liquid and solid input material via a special feed hopper system. The patented Thöni paddle agitator creates the conditions for stirring various feedstock mixtures so efficiently that no floating layers arise and ensuring at the same time high gas yields.

Outstanding features of Thöni biogas plants

Robust system technology and the operational reliable design of critical components ensure maximum availability. Thöni delivers turnkey, ultra-efficient plants offering an excellent and trend-setting price-performance ratio:

- High system and input flexibility, robust and durable plant technology
- Operational efficiency, low operating costs and maximum availability
- High biogas yields due to efficient stirring technology

The company has its headquarters in the town of Telfs in the western Austrian province of Tyrol and has further facilities in Landeck, as well as in Tyrol, and in Kempten in the southern German region of Allgäu and in Rovereto, Italy. Besides Environmental Energy Engineering, the Thöni Group is also active in the following business divisions: aluminium extrusion, automotive components, plant engineering, hose production and machining.

Markets and branch offices



- ▶ Biogas plants
- ▶ Plug-flow digestion
- ▶ Digestate upgrading
- ▶ Composting
- ▶ Service and maintenance

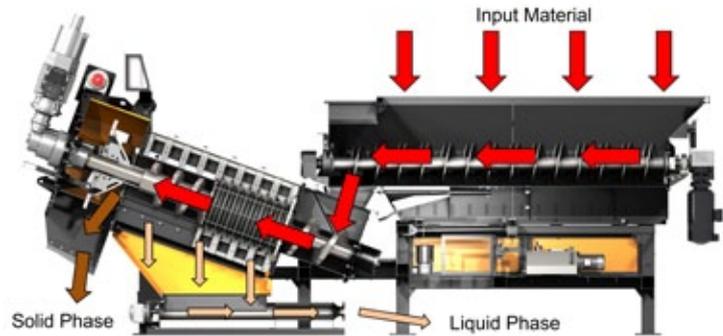
Year of foundation **1964**
Number of employees **600**

Thöni Industriebetriebe GmbH
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URL: www.thoeni.com

THÖNI Industriebetriebe GmbH is an Austrian-based provider of biogas plants for treating organic waste and agricultural by-products. Thöni provides highly-efficient plant solutions, offering an excellent price-performance ratio. These systems are planned and designed by Thöni's own engineering division, and the key plant components are manufactured by the in-house metalworking facility. To date, THÖNI currently has biogas plants in operation in Austria, Italy, Germany, Great Britain, Sweden, Bulgaria and Croatia. The first TTV plant in China is under construction.

Put waste in, draw energy out – high solids anaerobic digestion from Thöni (TTV)

Waste has enormous potential. Thöni Environmental Energy Engineering uses it to produce clean energy and valuable resources. Thöni TTV is a dry digestion process that is especially well suited for organic waste because it has a higher insensibility against impurities than other processes. The heart of the Thöni TTV process is the plug-flow digester equipped with a slow rotating paddle agitator ensuring the optimum



Cross Section of Doppstadt Screw Press with Feeding Hopper



Doppstadt screw press with solid fraction



The Doppstadt Group offers a wide range of recycling equipment for size reduction, screening, mixing and separation. The Doppstadt Screw Press DSP 205 is designed for disintegration and solid-liquid separation of packaged biowaste and food waste prior to biogas production.

During processing via DSP 205, the bio-available organic fraction of the input material is concentrated in the liquid phase. It has high dry matter content for high biogas yield referred to reactor volume. The digestate does not require further processing and complies with German fertilizer ordinance. The solids are then directly disposed of thermally or they can be further dried biologically prior to incineration. The throughput of the screw press averages between 8 and 12 t/h with a maximum of up to 20 t/h depending on the input material.

The machine consists of a feeding hopper with two counter-conveying mixing screws, the screw press itself and optional material handling like conveyor belt for the solids or pump for the liquid product. Household and kitchen waste in bags or shop returns in separate product packaging can be directly loaded into the hopper via wheel loader or digger with grapples. Packaging is opened between the mixing screws in the hopper by shear stress without the need for shredding. In this way, unnecessary reduction of the packaging material into

too small pieces can be avoided. Therefore, the filtrate extracted during the following solid-liquid-separation is particularly clean of plastic flakes.

The pressing screw is dimensioned to tolerate massive solid objects of up to 80 mm in outer diameter. Thus pre-shredding and pre-sorting is usually redundant. The solid bodies agglomerate in the compression zone just in front of the co-rotating cone that opens in set intervals or with rising process pressure to release the contaminants. The cone co-rotates to reduce friction between the material and the outlet gap, enabling more throughput and reducing power demand of the machine. Thanks to the co-rotation, obstruction of the gap is impossible, since it is always in motion.

Thanks to this resistance in regard to contaminants and the redundancy of input pre-treatment as well as digestate post-treatment, the machine lends itself in case of an existing plant being extended for co-fermentation. It is a simple, robust solution that requires little peripherals.

Markets and branch offices



- ▶ Disintegration
- ▶ Screening
- ▶ Air separation
- ▶ Press screw
- ▶ Sink-float separation

Year of foundation **1965**
Number of employees **600**

Werner Doppstadt Umwelttechnik GmbH & Co. KG

Steinbrink 13
42555 Velbert · Germany
Contact: Arndt Bachmann
Phone: +49 2052 889-655
Fax: +49 2052 889-157
E-mail: arndt.bachmann@doppstadt.de
URL: www.doppstadt.com

Markets and branch offices



- ▶ Biogas plants
- ▶ Pasteurisation
- ▶ Biowaste from households
- ▶ De-packing
- ▶ Sink-float separation

Year of foundation **1997**
 Number of employees **12**

Finsterwalder Umwelttechnik GmbH & Co. KG

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Wet fermentation system operated by the "Fitec"-process of the Finsterwalder Umwelttechnik GmbH & Co. KG, Rothmühle AD Schweinfurt Germany



Finsterwalder Umwelttechnik GmbH & Co. KG is specialised in designing wet AD plants. We have developed highly specialised components to cope with all kinds of contraries that are unavoidably collected with organic waste. With 19 years of our own operational experience, our de-packaging and digester equipment has been vigorously tested and optimised. The portfolio of Finsterwalder machine technologies include equipment for pre-treatment (Bio-Squeeze press) as well as for the continuous self-cleaning of digester vessels with the sink-

ing (grit) and floating (plastic) contaminants with our patented floor scraper and skimmer systems. Finsterwalder AD plants can process any kind of organic waste, like restaurant waste, expired supermarket waste or green bin waste from private households. Our process technology is extremely robust and long-lasting.

We have been dealing with organic waste for over 20 years. Numerous reference projects verify the high efficiency of the Finsterwalder process and our components.

Markets and branch offices

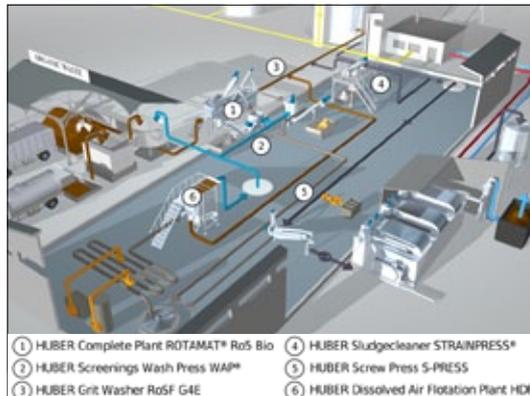


- ▶ Biogas plants
- ▶ Sewage sludge
- ▶ Screening
- ▶ Grit separation
- ▶ Digestate upgrading

Year of foundation **1872**
 Number of employees **1,200**

HUBER SE

Industriepark Erasbach A1
 92334 Berching - Germany
 Contact: Martin Feicht / Torsten Hackner
 Phone: +49 8462 201-264
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 E-mail: industrie@huber.de
 URL: www.huber.de



HUBER Solutions for organic waste processing. For wet anaerobic treatment (fermentation with biogas generation), good mechanical pre-treatment of the supplied bio-waste is essential for the reliability and performance of the entire treatment plant. Most important is not only the choice of effective and efficient processes, but also their implementation with most robust and dependable machines; both are also important for the quality of the generated products. We have developed solutions and products for processing organic waste and for further treatment of residues for their disposal or reuse:

- Coarse material separation: separation and treatment by screening, washing, dewatering and compaction
- Mineral treatment: removal and processing by washing and dewatering
- Fermentation residue treatment: post-treatment for reuse by screening, dewatering, compaction and eventually drying
- Process/wastewater treatment: wastewater treatment and process water recycling with dissolved air



Mavitec Paddle Depacker



Mavitec Green Energy is a Dutch process technology company active in the food/waste recycling industry. We engineer, produce and install high-quality equipment in an efficient and cost-effective way, customised to the needs of our clients.

Maximise the value of your waste! Turn your supermarket, restaurant, hotel, kerbside waste into the cleanest organic soup < 99.5%. We are specialised in food waste recycling and de-packaging solutions with high separation efficiency. Our machines are designed to separate

the organic material from the packaging and deliver clean organic output that is extremely suitable for biogas installations.

Mavitec Green Energy supplies high quality machines with minimal maintenance and low operational costs:

- Reception bins & conveyors
- Depackaging units
- Resizers (shredders, presses, washing drums)
- Complete turnkey food waste handling projects (engineering & production)

Markets and branch offices



- ▶ Biowaste from households
- ▶ Unpacking
- ▶ Feeding technology
- ▶ Food waste recycling
- ▶ Shredding

Year of foundation **2002**
Number of employees **10**

Mavitec Green Energy B.V.

Galileistraat 32
Heerhugowaard · The Netherlands
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URL: www.mavitecgreenenergy.com



2 solid dosing systems type BIG-Mix 118 m³ with a total capacity of 236 m³



Konrad Pumpe GmbH has over 20 years of experience in developing, storing, processing and dosing equipment for biomass. More than 3.000 screw feeders and solid matter dosing units supplied, provide proof of our performance capabilities. Rapid delivery of all spare parts is guaranteed by the customer service, provided 7 days a week. Our solid dosing units of stainless steel are especially developed for difficult substrate materials such as 100% grass silage, solid manure, green- and food waste and slaughter waste.

Our intelligent process control and continued design and development reduce the energy consumption and system wear and tear. Capacity volumes from 2.5–270 m³ are available to suit you plant. Direct feed to digesters or downstream equipment such as crushing and liquid feeding systems are provided by our screw technology. Flexibility, future modernisation and repowering are our specialities.

As a customer, you are welcome to visit our company to convince yourself of our efficiency.

Markets and branch offices



- ▶ Biogas plants
- ▶ Disintegration
- ▶ Biowaste from households
- ▶ Animal by-products
- ▶ Vegetable by-products

Year of foundation **1830**
Number of employees **60**

Konrad Pumpe GmbH

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48324 Sendenhorst · Germany
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Markets and branch offices



- ▶ Biowaste from households
- ▶ Animal by-products
- ▶ Vegetable by-products
- ▶ Digestate upgrading
- ▶ Process auxiliaries

Year of foundation **2010**
Number of employees **15**

Schaumann BioEnergy Consult GmbH

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URL: www.schaumann-bioenergy.com



Continuous biogas model plant with 36 fermenters

SCHAUMANN
BioEnergy
CONSULT



SCHAUMANN BIOENERGY CONSULT – COMPETENCE IN BIOGAS

Schaumann BioEnergy Consult GmbH offers know-how and tailor-made additives for the increasing biogas market.

Schaumann BioEnergy Consult is the leading company concerning the optimisation of anaerobic digestion facilities and conservation of organic substrates. Next to the profound process consultancy and accredited lab services, Schaumann BioEnergy Consult offers tailor-made additives to increase efficiency of AD processes. The portfolio of Schaumann

BioEnergy Consult comprises trace elements mixtures, several specific additives to reduce inhibition effects, enzymes and bacterial products for conservation purposes.

With a high degree of experience, Schaumann BioEnergy Consult also supports investors during the realisation of their projects by means of neutral/independent project evaluation, opinion letters, market studies and training courses.

Markets and branch offices

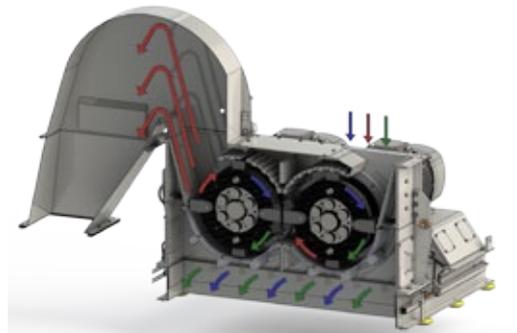


- ▶ Disintegration
- ▶ Grinding
- ▶ Biowaste recycling
- ▶ Unpacking
- ▶ Feeding technology

Year of foundation **1959**
Number of employees **51**

Tietjen Verfahrenstechnik GmbH

Vor der Horst 6
25458 Hemdingen · Germany
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E-mail: info@tietjen-original.com
URL: www.tietjen-original.com



Effective separation of organic and inorganic waste

TIETJEN
— DAS ORIGINAL —



TIETJEN – FOR EACH TASK THE RIGHT APPLICATION

Good solutions require experience and innovation. Since 1959, Tietjen Verfahrenstechnik GmbH has been developing and manufacturing grinding systems for a variety of biomasses.

With the Double Rotor Mill (DRM) system, Tietjen provides a cost-efficient system design to separate organic fractions into biowaste from a single source. In contrast to conventional pro-

cess technologies, the DRM allows high-precision separation of organic substances from all foreign substances at the beginning of material preparation. The processed organics can then be used optimally for energy and material production, while the foreign substances can be used for thermal utilisation.

Feedstock preparation



WACKERBAUER – INNOVATIVE TECHNOLOGY FOR THE PROCESSING OF BIOWASTE

Separation mill TM 75

Developed in 2009; since then, more than 65 worldwide installations in only 10 years

- Honoured with the Bavarian State Award 2013
- Patented design
- Throughput capacity: approx. 25 m³/h

The separation mill is based on a specifically developed principle which unifies different processes in one machine (mechanical unpacking, milling of the biowaste to substrate, separation and washing out of the extraneous materials,

Separation mill
Wackerbauer
TM75



mechanical transport of heavy extraneous materials to the discharge chute and air separation of light fractions). The unpacked bio-waste, which was freed from the extraneous materials, is milled with hammers and screens and flows into substrate containers from which it can be pumped off directly. The extraneous materials are ejected. The discharge chute has an integrated screw press which separates still contained liquids from the extraneous materials. Apart from the adjustable liquid flow, which is necessary for the regulation of the dry substance content of the substrate, the separation mill regulates the water and material supply by itself.

Markets and branch offices



- ▶ Disintegration
- ▶ Screening
- ▶ Air separation
- ▶ Unpacking
- ▶ Grit separation

Year of foundation **1938**
Number of employees **25**

Wackerbauer Maschinenbau GmbH

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Project developer



ARCANUM Energy is leading as an engineering, consulting and project company in the biogas and biomethane field

Arcanum Energy is one of the leading engineering, consulting and project developing companies specialised in all subjects concerning biogas and biomethane production. Besides its engineering services, ARCANUM Energy operates its own certified mass balancing system "BIMAS". Highly specialised support can be provided for:

- Evaluation of local and regional potential of waste and residual materials
- Planning and calculation of profitability for biogas- and upgrading plants choosing the best suitable technology

- Independent quality assurance and control during the planning, construction and implementing phase of waste-based projects
- Safety protection
- Approval procedures for plants/gas grid connection and feed in
- Initiation and realisation of investment and corporate financing projects
- Maintenance and operational management of plants

Markets and branch offices



- ▶ Service
- ▶ Energy concepts
- ▶ Maintenance
- ▶ Biomethane upgrading

Year of foundation **2001**
Number of employees **40**

Arcanum Energy Systems GmbH & Co. KG

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Markets and branch offices



- ▶ Manure
- ▶ Press screw
- ▶ Service
- ▶ Pumping technology
- ▶ digestate upgrading

Year of foundation **2002**
Number of employees **50**

Biogastechnik Süd GmbH

Am Schäferhof 2
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Vapogant digestate evaporator



The digestate evaporator Vapogant processes the digestate of the biogas plant to produce a usable, concentrated fertiliser with reduced water content. We remove most of the water from the digestate through vacuum evaporation using waste heat from the CHPS. At the same time, volatile nitrogen is bound so that any emissions during spreading will be minimised, making the nitrogen available as ammonium sulphate solution (ASS).

The goal is to use the available waste heat to thicken or enhance 100 % of the digestates produced in the biogas plant. This is achieved with a very high evaporation rate of 2.5 litres per kilowatt of thermal output. At 500 kW plant capacity, this is equivalent to a volume reduction of about 10,000 m³ per year. The plant is available in a module size of 400 kW or 500 kW.

Markets and branch offices



- ▶ Biogas plants
- ▶ Manure
- ▶ Sewage sludge
- ▶ Service
- ▶ Thermal storage tanks

Year of foundation **1958**
Number of employees **50**

Lipp GmbH

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73497 Tannhausen · Germany
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URL: www.lipp-system.de



LIPP digesters and process tanks at St. Hyacinthe, Canada – producing biogas from sludge and biowaste.



As a tank construction specialist, we offer quality tanks and system solutions in stainless steel for industry, communities and agriculture.

LIPP offers a wide range of digesters and tanks especially for anaerobic digestion of sludge, food waste, biowaste and agricultural waste but also for industrial and municipal waste water treatment. This means that LIPP is always the right partner for the planning, designing and installation of small and large scale biogas systems.

The Lipp System for automated on-site manufacturing guarantees the same high level of quality at any location in the world. The advantages of the LIPP construction technology combined with the professional communication, cooperation and execution from the design stage to manufacturing, installation and testing has made LIPP a preferred supplier for numerous contractors and plant constructors worldwide.



cleaning systems for liquids



As a family-run company in the second generation, we have been offering vacuum evaporators for treating digestate since 2010, and can rely on over 25 years of experience in industrial fluid treatment. All the key components are manufactured at the Monheim site.

Service performances at short notice are always ensured via our service network. We cover a wide range of digestates with the RT and DV model ranges. The evaporators can be operated flexibly, have a modular design and can be subsequently expanded.



MKR vacuum evaporator DV1000

With a heat consumption of 190 to 600 kW and a distillation capacity of up to 4.4 l/kWh, up to 70 % water can be extracted from the digestate. At the same time, up to 80 % of the ammonium-nitrogen is converted into an ammonium sulphate solution (ASL) and an odour-free, dischargeable distillate is produced.

Over 25 evaporators already prove our efficiency. We would be happy to also be your partners in treating digestate.

NETZSCH



NETZSCH product group in biogas production: NEMO® Progressing Cavity Pump, TORNADO® Rotary Lobe Pump and the grinders N.Mac® and M-Ovas®.

NETZSCH – Experts in pump solutions

The range of applications for NEMO® progressing cavity pumps, TORNADO® rotary lobe pumps and grinders in biogas production vary from mixing and conveying to grinding.

At the start of the process, the unique design of the B.Max® mixing pump helps to feed the fermenter with a mix of dry and liquid substrates that are optimised for bacteria. After fermentation and with a dry matter content of approx. 5–15%, the pre-fermented substrate is conveyed to the secondary fermenter which allows

the output of additional biogas in the process thanks to the longer dwell time. The NEMO® progressing cavity pump can contribute to the flexibility of the plant by reversing the direction of conveyance of substrates and recirculated substances between various containers, even with higher solid contents. An upstream installed grinder allows for an even higher gas yield to be achieved.

The TORNADO rotary lobe is used for high-volume flows.

Markets and branch offices



- ▶ Service and maintenance
- ▶ Flexible waste heat utilisation
- ▶ Nitrogen reduction
- ▶ ASL production
- ▶ Digestate reduction

Year of foundation **1990**
Number of employees **55**

MKR Metzger GmbH
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Markets and branch offices



- ▶ Biogas plants
- ▶ Manure
- ▶ Disintegration
- ▶ Feeding technology
- ▶ Pumping technology

Year of foundation **1952**
Number of employees **2000**

NETZSCH Pumpen & Systeme GmbH
Geretsrieder Straße 1
84478 Waldkraiburg - Germany
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URL: www.pumps.netzsch.com

Markets and branch offices



- ▶ CHP
- ▶ Engine parts
- ▶ Biogas spark plugs
- ▶ CHP spare parts original & OEM

Year of foundation **2013**

Onergys GmbH

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47608 Geldern · Germany
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URL: www.onergys.de



ONERGYS.de



www.ONERGYS.de – Your engine parts specialist for genuine CHP spare parts and accessories. Our product range of CHP spare parts for your combined heat and power unit extends from starter to spark-plugs. We offer high quality OEM parts and genuine OE parts at competitive retail prices.

In addition to a comprehensive stock of ORIGINAL PARTS, ONERGYS also offers a high-quality private label. A large stock of spark

plugs (Denso, Beru, Federal Mogul, Bosch, Jenbacher, MWM, 2G, Champion, Deutz) and filters (UPF, air, oil and gas filters) offers you enormous cost-saving potential with the highest OE quality. As an official sales partner, MANN-FILTER is also part of our product range at www.onergys.de. As a registered customer or key account (reseller), you will receive the best prices in our member area! Open a customer account online now and enjoy the price advantages → www.onergys.de

Markets and branch offices



- ▶ Biogas plants
- ▶ Manure
- ▶ Heating technology
- ▶ Unpacking
- ▶ Pumping technology

Year of foundation **1907**

Fritz Paulmichl GmbH

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E-mail: info@paulmichl-gmbh.de
URL: www.paulmichl-gmbh.de



Biogas plant Yanquetruz, San Luis Province, Argentina

**FRITZ
PAULMICHL
GMBH**



Fritz Paulmichl GmbH has been offering high-quality components for biogas plants for many years. Whether new equipment, plant expansion or repowering, the reliable technology has been appreciated for many years. This is why our customers include not only plant operators but also plant manufacturers and research institutes.

Longevity and comfortable operation are further features of our components. Our large propeller agitators Mammut, Multimix and MaMix are used worldwide with great satisfac-

tion especially for repowering, large digestors and changing filling levels due to their stirring performance. The individual installation option guarantees reliable homogenisation in all tank variants.

The product range includes pump and separation technology for a wide variety of applications. Visual inspection is a basic prerequisite for safe plant operation. The PAULMICHL panoramic sight glasses were developed precisely for this application.



Stirring needs to be effective, efficient and sustainable.



SUMA has been designing and manufacturing agitators for a variety of applications and industries since 1957.

Our long-axis agitators and submersible motors for biogas are especially designed for fermenters, secondary fermenters and end storages. We can provide an optimal distribution of temperature and nutrients within the tank. In the past 60 years, we have produced and shipped in excess of 94,000 units to our customers.

Our dedication, knowledge and experience coupled with our in-house manufacturing and production facility make us capable of adapting to customers' specific needs, industry standards and technical certifications. Common to all our doing is our unwavering commitment to quality.

Consistently meeting our customers' needs is our goal and therefore, we can proudly state: **OTHERS STIR – WE SOLVE.**

Markets and branch offices



- ▶ Agitation technology
- ▶ Biogas plants
- ▶ Sewage sludge
- ▶ Manure

Year of foundation **1957**
Number of employees **92**

SUMA Rührtechnik GmbH

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PSM Mixer – efficient technology made in Germany



UTS Products GmbH is based in Germany and produces innovative technology for the biogas, agricultural, food and waste water industry. UTS is a subsidiary of Anaergia Inc., a global leader in solving waste problems by recovering energy, water and fertilizer from virtually any waste stream.

With more than 1,600 equipped biogas plants, UTS can refer to many successful projects in

which waste is converted into useful resources.

If you are looking for innovative mixing technology that adapts to the conditions of your biogas plant, mature pump technology, separators for various applications or the latest addition to our range of products – the NRScompact, a system to process slurry and nutrients, at UTS you will find reliable technology to help you get the most out of your biogas plant.

Markets and branch offices



- ▶ Biogas plants
- ▶ Press screw
- ▶ Pumping technology
- ▶ Digestate upgrading
- ▶ Pump technology

Year of foundation **2009**
Number of employees **25**

UTS Products GmbH

Oestinghausener Str. 12
59510 Lippetal · Germany

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Phone: +49 2923 61094-0

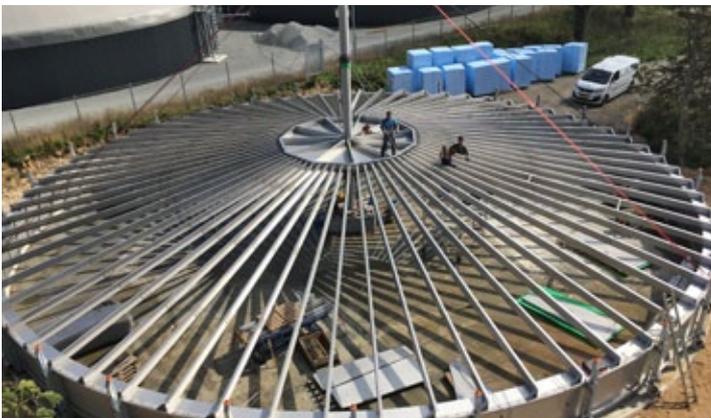
Fax: +49 2923 61094-100

E-mail: products@uts-biogas.com

URL: www.uts-products.com



Stainless steel digester with insulated stainless steel roof for glycerin



Stainless steel roof in construction

Stallkamp



Digester interior

Stallkamp also produces pump and mixing technology for reliable application in the digester or fermentation residue storage. The submersible motor agitators have an efficient mixing power because they reach a high circulation quantity at a low level of energy consumption. Above standard, they can be ordered in full stainless steel or with a ceramic coating in order to prevent corrosion. With regard to the pump technology, the portfolio covers submersible motor pumps, displacement pumps (rotary lobe pump, eccentric screw pump) and long-shaft pumps.

Separation technology

The end of fermentation leads to the beginning of digestate upgrading. Therefore, the press screw separators from Stallkamp are designed to divide digestate or other waste water into a solid and liquid phase. The medium is supported through the stainless steel sieve where an armoured press screw permanently cleans the sieve from the inside. The separated liquid phase flows out of the sieve. The solids are supported to the throw-off. The counter pressure of the hydraulic ball head adjusts the desired content of dry matter.

Approved applications

The separators have already been applied in various industrial and biowaste plants:

- Food processing industry: pressing out potato sludge
- Biowaste plant: pressing out digestate of ice cream fermentation
- Breweries: pressing out pulp
- Plastic industry: pressing out plastic residues
- Wastewater treatment plants: pressing out sewage sludge
- Animal truck washing plant: pressing out dung residues

Markets and branch offices



- ▶ Biogas plants
- ▶ Manure
- ▶ Sewage sludge
- ▶ Press screw
- ▶ Pumping technology

Year of foundation **1973**
Number of employees **230**

Erich Stallkamp ESTA GmbH

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49413 Dinklage, - Germany
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E-mail: info@stallkamp.de
URL: www.stallkamp.de

Stainless steel or nothing

As a specialist in construction and assembling of stainless steel products such as digesters, pumps, agitators and separators, Stallkamp is the competent partner for agriculture, biogas and wastewater industry. Its wide portfolio is successfully applied all over the world.

Digester for biowaste

Biowaste often requires corrosion resistant materials since it has specific pH-values which react aggressively against the digester and other components. Corrosion means maintenance and repairing costs. This is the reason why Stallkamp produces stainless steel digesters. Thus, corrosion is put to an end before it has a chance to arise and the digester is ready for long-lasting application.

Complete digester

The stainless steel plates themselves do not manage the fermentation process on their own. But with heating, insulation, double membrane roof or stainless steel roof with insulation options, Stallkamp is able to provide the whole digester.



Configuration of a gas analysis system

Quality has always been the focus of **Awite**. We have been manufacturing gas analysis systems and creating process automations of the highest quality according to individual requirements since 2000. To date, more than 2,700 of our gas analysis systems and more than 140 automation systems have been installed worldwide.

We have been offering our proven Awite quality also as a development service in the fields of Smart Home, electromobility and other renewable energy sectors since 2018.

With our subsidiaries and long-term partner companies worldwide, we at Awite are your competent partner for the sale and service of our products. Our network enables us to offer suitable solutions in many countries and continents.

Your process requirements take centre stage. Through our commitment and continuous further development, we can offer tailor-made and high-quality gas analysis and automation systems with or without measurement technology all the way through to the laboratory facility.

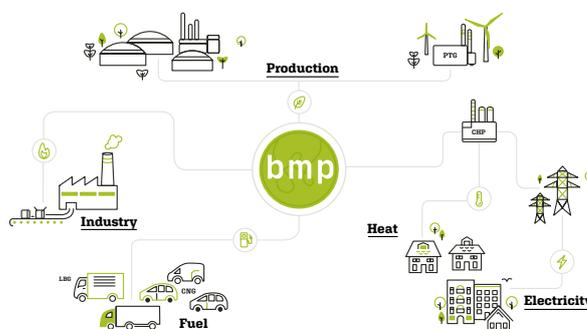
Markets and branch offices



- ▶ Biogas plants
- ▶ Gas analyses
- ▶ Automation
- ▶ Desulfurisation
- ▶ Biomethane upgrading

Year of foundation **2000**
Number of employees **40**

Awite Bioenergie GmbH
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bmp greengas – your partner for green gases
Acting together for a green future!

bmp greengas is one of the market leaders in the marketing of biomethane and the expert for green gases. For more than 10 years, the company has been a partner for the reliable transport, smooth balancing and fail-safe supply of green gases. bmp greengas buys, bundles and sells biomethane from a wide variety of producers and of differing qualities. In this way, the company has established a diversified biomethane portfolio and supports its customers

with conversion to regenerative gases for use in combined heat and power generation, thermal or material use, or in the field of mobility, while offering fail-safe delivery and every available gas quality.

bmp greengas is a founding member of dena's biogas register, and provides its customers with a record of the quantities and qualities of green gas fed into the natural gas grid. As a subsidiary of Erdgas Südwest GmbH, it is an EnBW Group company, with its declared corporate goal which is to work together for a green future.

Markets and branch offices



- ▶ Energy trade and marketing
- ▶ Balancing group management
- ▶ Portfolio management

Year of foundation **2004**
Number of employees **35**

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URL: www.bmp-greengas.de



Vaisala MGP261 is the only probe which measures CH₄, CO₂ and H₂O



Vaisala MGP261 probe for the smart control of biogas quality

VAISALA



Markets and branch offices



- ▶ Gas analyses
- ▶ Industrial measurement solutions

Year of foundation **1936**
 Number of employees **1850**

Vaisala GmbH

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Vaisala is a global leader in environmental and industrial measurement. Building on over 80 years of experience, Vaisala provides observations for a better world. We are a reliable partner for customers around the world, offering a comprehensive range of innovative observation and measurement products and services. Headquartered in Finland, Vaisala employs approximately 1,850 professionals worldwide and is listed on the Nasdaq Helsinki stock exchange. vaisala.com
twitter.com/VaisalaGroup

Industrial measurements

The industrial measurements business area serves customers in multiple industries with over 40 years of industrial knowledge. Our products improve quality, productivity, energy efficiency, and help our customers fulfil regulatory compliance. Industrial Measurements customers operate in different types of environments from semi-conductor factories and high-rise buildings to power plants and small incubators where reliable measuring and monitoring of the

ambient conditions are a prerequisite for successful operations. Customers use our products and systems to measure and monitor temperature, humidity, dew point, pressure, carbon dioxide, moisture in oil, dissolved gases in transformer oil and methane.

Industrial measurement solutions

Vaisala's measurement products are used by a variety of industries, such as electronics, automotive, maritime, lithium battery and food processing. The stable real-time measurements extend equipment lifetime, and improve processes, productivity and end-product quality.

Organisations

German Biogas Association

The German Biogas Association (GBA) unites operators, manufacturers and planners of biogas plants, representatives from science and research and all those interested in the industry. Since its establishment in 1992, the association, which currently has more than 4,700 members, has become the most influential independent organisation in the field of biogas worldwide. It campaigns for the increased use of biogas and biomethane technology through political lobbying at EU, national and state levels. Furthermore, it encourages the exchange of biogas-related information and knowledge, for instance by collecting, evaluating and spreading knowledge of scientific findings and practical experience, or by means of conferences, exhibitions and other events.

The German Biogas Association works closely with international organisations such as the Deutsche Gesellschaft für Internationale Zusammenarbeit [German Association for International Cooperation] (GIZ), the United Nations Industrial Development Organisation (UNIDO), the International Solid Waste Association (ISWA) as well as the European Biogas Association (EBA), where it also acts as a founding member. As a consequence, Fachverband Biogas e.V. actively promotes and stimulates the exchange of international experience.

The German Biogas Association has excellent expertise and knowledge in all biogas-related topics and cooperates with almost all official German bodies as well as many international ones where standards for biogas plants are discussed, developed and defined.

Year of foundation **1992** | Number of employees **41**



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Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is a global service provider in the field of international cooperation for sustainable development. GIZ has over 50 years of experience in a wide variety of areas, including economic development and employment, energy and the environment, and peace and security.

As a public-benefit federal enterprise, GIZ supports the German Government – in particular, the Federal Ministry for Economic Cooperation and Development (BMZ) – and public and private sector clients in around 130 countries, to achieve their objectives in international cooperation. With this aim, GIZ works together with its partners to develop effective solutions that offer people better prospects and sustainably, and improve their living conditions.

Year of foundation: **2011** | Number of employees: **16,400**



Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Indian Biogas Association

The Indian Biogas Association (IBA) is the first nationwide and professional biogas association for operators, manufacturers and planners of biogas plants, representatives from public policy, science and research, in India. Currently, the association has members from all across the biogas community and related fields involved in promoting biogas. They represent industry, individuals from academia, institutes, government and non-government organisations contributing directly or indirectly to the biogas vision of India, set forth by IBA.

The efforts of IBA have been towards building a strong platform, which would prove to be instrumental in the growth of the biogas sector. IBA aids its members and the biogas community in exploring the sector at a national and international level. Through political advocacy at the Centre and State level, IBA promotes drafting and the adoption of, conducive policy and programmes pertinent to the biogas sector. Furthermore, it actively disseminates awareness through participation in workshops, conferences, trade shows, and seminars, organises training programmes across India, and engages in experience sharing and sectoral updates via its periodic newsletters, magazines and brochures.

Established in 2011, IBA presently has its headquarters in Gurgaon, India, and is represented by a four-member board, all having significant experience in the renewable energy sector. It has around 130 members from across India, with representatives from the international community as well.

Year of foundation: **2011** | Number of employees: **6**



Indian Biogas Association

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ISWA – the International Solid Waste Association

The International Solid Waste Association (ISWA) is a global, independent and non-profit association, working in the public interest, and is the only worldwide association promoting sustainable, comprehensive and professional waste management and the transition to a circular economy.

ISWA is open to individuals and organisations from the scientific community, public institutions as well as public and private companies from all over the world working in the field of, or interested in, waste management. ISWA is the only worldwide waste association that enables its members to network with professionals, companies and institutional representatives.

ISWA's mission is **to promote and develop sustainable and professional waste management worldwide**. It achieves this by:

- ▶ promoting resource efficiency and a transition to a circular economy through sustainable production and consumption;
- ▶ supporting developing and emerging economies;
- ▶ advancing waste management through education and training;
- ▶ promoting appropriate and best available technologies and practices;
- ▶ promoting professionalism through its qualifications programme

Year of foundation **1970** | Number of employees **11**



ISWA – the International Solid Waste Association

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Filling vehicles
with biomethane



SYMBOL DESCRIPTION:

Organic fraction from Municipal Solid Waste (MSW)		Disintegration and unpacking technologies	
Source-separated municipal biowaste		Liquid removal of impurities	
Municipal sewage sludge		Dry removal of impurities	
Industrial and commercial wastes		Wet continuous digestion	
Animal by-products		Dry continuous digestion	
Vegetable by-products		Dry batch digestion	
Energy crops		Fuel	
Sanitation		Heat / Cold	
Process auxiliaries		Biomethane	
Pumps		Electricity	
Mixers		Digestate	
Laboratory and measurement			
CHP components			
Energy trade and marketing			

The depicted symbols are used repeatedly throughout the brochure and as a classification system of the different companies in the directory.



Fachverband
BIOGAS

German Biogas Association
www.biogas.org



www.biowaste-to-biogas.com

