SUSTAINGAS

Sustainable biogas production

A handbook for organic farmers

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Content

1 Organic biogas – check it out!

Does biogas production fit in with the idea of organic agriculture and the principle of a natural recycling economy? Can organic agriculture and biogas production be combined for more sustainability and more success? This booklet provides answers to these complex issues and gives information for farmers and others interested in organic biogas.

Organic agriculture and renewable energy production from agricultural biomass are on the rise, both politically supported for reasons of sustainability. Organic biogas production as the combination of both concepts based on agricultural land can have additional positive synergy effects.

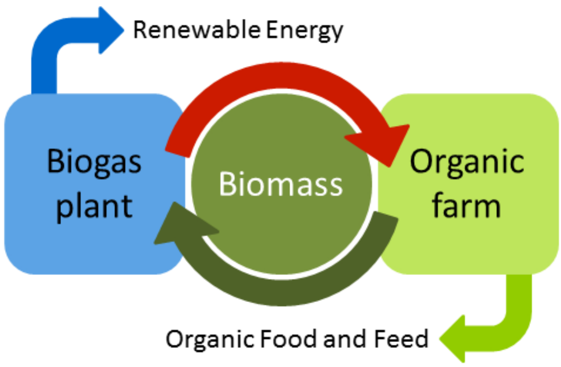

Figure 1: Integration of biogas production in organic agriculture. Source: Tersbøl M., and Malm L. (2013): Financial Performance of Organic Biogas Production. SUSTAINGAS Report D 3.1, online at *www.sustaingas.eu/strategy.html*.

To show why biogas production in organic farming is worth considering for farmers, politicians and sustainability stakeholders, the following list gives an impression of the benefits:

- Renewable energy production
- Climate protection
- No food competition when using legumes, catch crops, conservation material, residues and by-products as biomass sources
- Closed nutrient cycles
- Optimising of crop rotation and cropping system
- Digestate as mobile and flexible fertiliser
- Increased crop yields and quality
- Alternative source of income
- Independent energy supply

This handbook focuses on the specifics of biogas production when integrated in organic farming. Anaerobic fermentation and the basic technology used are similar for all biogas production systems. However, biomass input will usually be different. This requires differences in the process and the technology of biogas production in organic farming. Additionally, the relevance of the biogas system for crop production is much higher in organic systems, resulting in a modified economic approach encompassing the entire farm.

After discussing more general issues in the first five chapters, this guide to organic biogas production will proceed to concrete examples and practical guidance. Following this introduction (chapter one), the basics of biogas production in general are described in chapter two. Chapter three explains what makes biogas production in organic agriculture different from other systems, while chapter four outlines the situation of biogas production in some European countries. Why organic biogas is valuable for the environment as well as for the farmer is explained in chapter five, followed by examples of how others have implemented biogas production on their organic farms in chapter six. Chapter seven explains how to set up a biogas plant. Two service pages in chapter eight provide a link to sources and contacts with further information.

Organic biogas production combines renewable energy production and organic farming. Both are important concepts regarding sustainable development.

2 Basics of biogas production

This chapter outlines some basics of agricultural biogas production in general to help the reader understand the specific issues of biogas production in organic agriculture presented in the following chapters.[1]

The substance

Biogas is a combustible mix of gases produced by the natural fermentation of wet biomass under the exclusion of oxygen (*anaerobic digestion/ fermentation*). The main combustible component *methane* makes up about 50 to 75 volume per cent (Vol.-%). Other molecules present in biogas include carbon dioxide, sulphide, oxygen and water vapour (Table 1). Biogas formation occurs naturally in wetlands when organic matter is decomposed by anaerobic microbes to so-called "swamp gas".

Table 1: Composition of biogas (average figures)

Component	Formula	Concentration
Methane	CH_4	50-75 Vol.-%
Carbon dioxide	CO_2	25-45 Vol.-%
Water vapour	H_2O	2-7 Vol.-%
Sulphide	H_2S	0,002-2 Vol.-%
Nitrogen	N_2	< 2 Vol.-%
Ammoniac	NH_3	< 1 Vol.-%
Hydrogen	H_2	< 1 Vol.-%
Trace gases		< 2 Vol.-%

Source: Fachagentur Nachwachsende Rohstoffe e.V. (FNR) (2009): Basisdaten Bioenergie Deutschland. FNR, Gülzow-Prüzen, p. 35.

The process

For biogas to form, different microbes with differing environmental requirements are active in four consecutive stages:

Hydrolysis: Microorganisms excrete enzymes to break down organic matter like carbohydrates, lipids and nucleic acids into the smaller units glucose, glycerol, purines and pyridines.

Acidogenesis: Fermentative bacteria process products of hydrolysis into acetate, carbon dioxide, hydrogen and volatile fatty acids.

Acetogenesis: Volatile fatty acids and alcohols are oxidised into acetate, hydrogen and carbon dioxide before conversion into methane. This process is closely interlinked with methanogenesis.

Methanogenesis: Specialised single-celled microorganisms (archaea) produce methane from acetate, hydrogen and carbon dioxide. This is the slowest step in the process and severely influenced by operation conditions like feedstock, feeding rate, temperature, and pH.

The biomass

In principle, many types of biomass can be used for biogas production. In agricultural biogas plants, the input material or *substrate* used includes:

- Fresh or ensiled plant material (e.g. maize, grass, cereal, beet or clover)
- Animal excrements (e.g. slurry or manure)
- Residues from agricultural or food production (e.g. feed remains, chaff, whey, glycerine, straw[2])
- Waste materials (e.g. organic household waste)

The technological and microbiological capacities of the plant, the availability of substrate, legal conditions, and the operators' strategy influence the choice of substrate.

[1] For a comprehensive introduction to biogas in agriculture, please consult the literature mentioned in the chapter "Further information".

[2] Straw has high potential biogas yields but is rarely used as biogas substrate as it requires suitable pre-treatment/ disintegration for efficient fermentation.

The technology

Depending on the type of biomass, it is fed into the plant by pumping liquid or viscous material and/or by inserting it e.g. with *feeders* containing sturdy augers. Most biogas plants operate a quasi-continuous process. Several times a day, biomass is fed into the fermenter and an equivalent amount of processed biomass exits the plant at the other end.

As seen in Figure 2, one or more gastight reactors called *fermenter* or *digester* are at the centre of a biogas plant. Here, the substrate is heated and stirred for several weeks at 37 °C or more to enable the microbial activity necessary for biogas production. While all stages of biogas formation usually take place in the same fermenter, some plants provide extra compartments for *hydrolysis*.

Figure 2: Gerald Schulz (right) is farming organically on 650 ha in Stahlbrode/Germany. Despite interruptions at the start of his biogas plant's production, he's convinced of Walter Danner's (left) engineering with separate hydrolysis at high temperatures. Photo: F. Gerlach, FiBL.

The biogas developed during the fermentation process rises to the surface of the substrate – facilitated by regular stirring and/or mixing. The biogas accumulates above the substrate. It is stored in flexible low pressure *gas stores* on top of the fermenter or in external gas stores.

After a *retention time* of several weeks – from less than 20 days for specialised slurry plants to more than 100 days for exhaustive conversion of materials rich in lignocelluloses – the biomass has been transformed into *digestate*, a gooey, brown mixture with a dry matter content considerably lower than the original material.

The digestate is pumped into storage tanks until it is used as fertiliser. For application, farmers use machinery known from slurry application. The digestate contains almost all the nutrients of the input material. Only small quantities of sulphur and nitrogen are lost as components of biogas or by emission. Nitrogen is present in highly plant available compounds with a high proportion of ammonia.

The biogas is cleaned – usually sulphides and moisture have to be removed – and piped to its point of use. Most biogas plants use biogas to produce electricity for the national grid and heat for local use in *Combined Heat and Power* (CHP) units. These combine engines similar to ship's engines with a generator converting the engine's mechanical power into electricity. The useable heat energy produced by this process is equal to or greater than the amount of electric energy. About 5 to 15 per cent (%) of the generated electricity and 10 to 20 % of the heat are required for the operation of the biogas plant.

For specific substrates and circumstances, a large number of variations and additions to this standard process exist. For solid, stackable biomass for example, the fermenter may take on the form of a garage being filled directly by loader or tractor with a discontinuous process of so-called "*dry fermentation*". Particularly, for substrates rich in lignocelluloses such as grass, straw or leguminous plants, useful additions to the standard system of "wet fermentation" are methods of *biomass disintegration* – also called pre-treatment – to speed up the microbiological processes and increase biogas yield. For strongly lignified materials like straw relevant biogas yields are only possible with biomass disintegration.

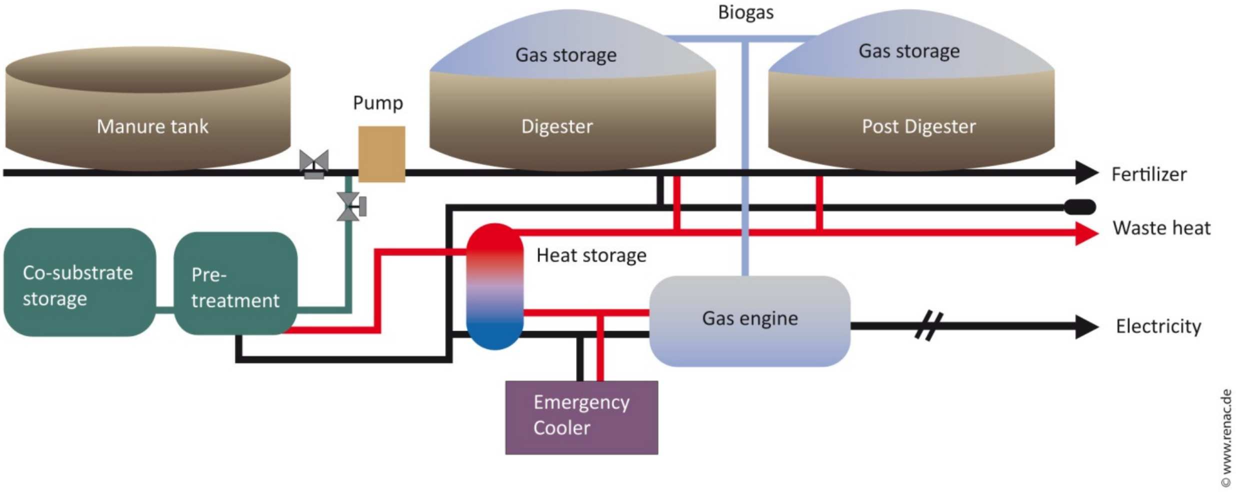

Figure 3: Functioning principles of a biogas system. Illustration: RENAC.

3 What is organic biogas?

At first glance, biogas production in organic agriculture is not very different from general agricultural biogas production: Biomass is fermented to produce energy; the digestate is used as organic fertiliser on the fields. A closer look, however, will show that organic biogas production has a high potential regarding sustainability and synergies with processes in organic agricultural systems.

While effects vary widely between individual projects, the context, structures and effects of biogas production on organic farms in general show a strongly synergistic interaction with organic crop production and livestock husbandry.

Description of organic biogas

Based on a literature study and consultations with organic farmers as well as with other experts, the SUSTAINGAS team derived some essential points for a description of organic biogas:

- Biomass used for biogas generation mainly originates from *organic agriculture*, organic food production and nature conservation material. Material from conventional agriculture is limited.
- *Types of substrate* include mainly catch crops, residues from animal husbandry or crop production, material from conservation areas and/or uncontaminated biological residues (that means free of GMO and problematic levels of heavy metals) from food processing or household waste.
- The use of *energy crops* as substrates is limited since organic biogas aims to have a positive impact on food production, avoiding competition for land use.
- The *digestate* is used as an organic fertiliser in the organic farm's own nutrient cycle. Organic biogas production aims to improve soil fertility in organic farming systems.
- A safe and efficient process with *low emissions*, particularly of methane, is essential for the sustainability.
- Positive impacts are expected on *water quality*, *conservation*, and *biodiversity*.

What do farmers think?

In a SUSTAINGAS study, organic farmers with and without biogas plants were asked what they consider important for a biogas plant on an organic farm to be sustainable.

For most farmers the following aspects were crucial: *Sustaining of soil quality*, *avoiding methane emissions*, *the composition of input materials* and *economic feasibility*. Other important issues included *fair play for all people involved*, *health and safety issues*, and the *efficiency of gas production* (see Figure 4).

While all of these issues are undoubtedly relevant to sustainable biogas production, some aspects – like the origin and nature of the substrates – are closely related to the agricultural system (organic or non-organic) while for other factors – e.g. health and safety issues – the agricultural system is less relevant.

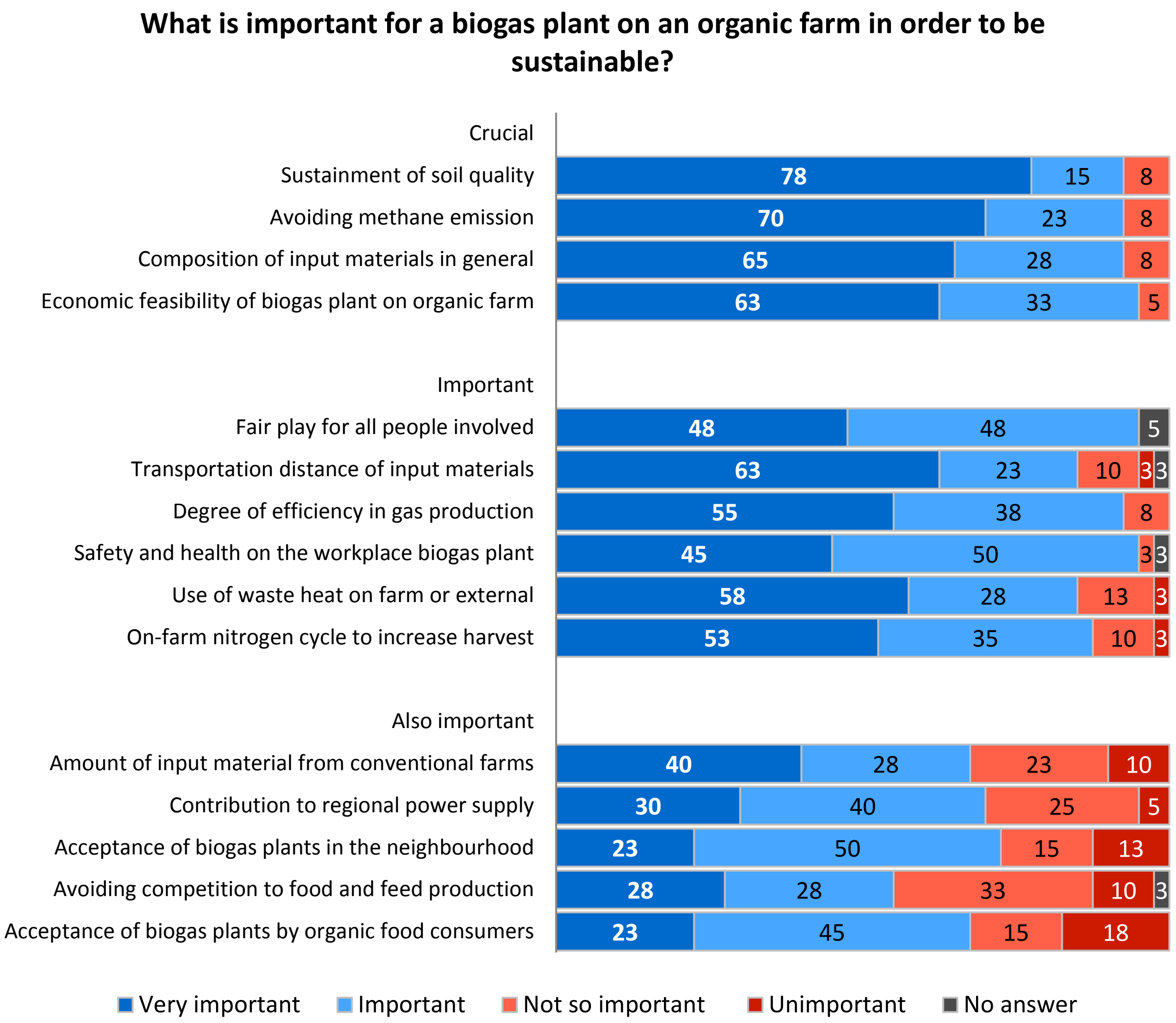

Figure 4: Issues for sustainable organic biogas production. Results from consultations with 40 organic farmers with biogas plants or in a planning phase in six EU countries. After: Baaske W., and Lancaster B. (2013): Product Description of Sustainable Organic Biogas. SUSTAINGAS Report D2.1, online at *www.sustaingas.eu/demands.html*.

Biogas regulations in organic farming

What are the minimum requirements for biogas in organic farming? While indirect EU regulations apply regarding the origin of the biomass used, some organic farmer's associations have developed specific rules for their members.

The *EU Regulation on Organic Agriculture* – as the basic regulation for all organic farmers in the European Union – gives some indirect criteria for the production of biogas on organic farms with its obligation to minimise the use of non-renewable resources and with its lists of substances allowed as fertiliser on organic farms.

The EU group of *the International Federation of Organic Agriculture Movements (IFOAM)* as umbrella organisation of national organic farmers' associations is currently testing with its members a trial version of SUSTAINGAS standards for sustainable biogas production in organic farming. The trial standards include the following recommendations:

- *Objectives:* Biogas production must provide income opportunities for the farm and fit to the socio-economic context of the farm. It must contribute to the overall sustainability of the farm and to the principles of fairness, health, ecology and care. It shall improve nutrient recycling and reduce greenhouse gas emissions. It must not have a negative impact on landscape and biodiversity.
- *Sources of Biomass:* Competition with food production must be avoided; major inputs are farm residues and plant material from nature conservation areas. The use of biomass from non-organic farms should be limited and progressively decreased, local sources should be used. The rules on fertilisers and farm inputs as laid down in the organic regulations ((EC) No 834/2007 and (EC) No 889/2008) must be followed.
- *Digestate as fertiliser:* Sustainable soil fertility is in the focus of organic farming, therefore the digestate should primarily be used on the own farm. In case substrate is imported from outside the farm, this rule may be altered accordingly. EU and national legislation (e.g. slurry directive, hygiene rules, nitrates directive) applies.
- *Energy efficiency and greenhouse gases:* Methane emissions must be avoided (kept well below 5 %) through gas tight tanks and covered storage. Energy efficiency must be optimised, for example by using waste heat.
- *Planning & Construction:* Already in the planning phase, environmental performance must be considered systematically: Transport distances must be minimised to the necessary, maximum energy efficiency aimed at and greenhouse gas emissions avoided.

The SUSTAINGAS project developed more detailed trial standards which were discussed by IFOAM EU members representing the organic sector in Europe. SUSTAINGAS guidelines for sustainable biogas on organic farms will be published in 2015.

For more information on the description of sustainable biogas from organic farms and the SUSTAINGAS trial standards see *www.sustaingas.eu/demands.html*.

Figure 5: No certificate without paperwork.
Photo: F. Gerlach, MEP.

Some national organic farmers' associations have already introduced stricter regulations, especially concerning the use of conventional inputs. Table 2 compares the requirements concerning organic biogas production of the EU Regulation on Organic Agriculture and – as examples – two national farmers' associations.

Table 2: Comparison of the EU Regulation on Organic Agriculture and guidelines of exemplary farmers' associations concerning the requirements of biogas production

Issue	EU Regulation on Organic Agriculture	Bioland (Germany)	Bio Austria (Austria)
General scope	EU Regulation on Organic Agriculture applies as detailed below	EU Regulation on Organic Agriculture applies. In addition, the following restrictions have to be followed by farms certified by the respective organisation	
Share of conventional input	No limitation	Maximum: 30 % Target for 2020: 0 %	0 %
Interim regulations for existing plants		Plants build before 01.05.2009 may be permitted more than 30 % conventional substrate for a period of transition	Plants with planning permission before 31.12.2004: Use of digestate permitted if organic farmer is associate or operator of the plant. Restrictions: No slurry, no pig manure and no poultry manure from conventional farms. From 2020, the share of organic substrate from these plants must be 70 % or more
Restrictions on quality of input material	Free of GMO material, no excrements of industrial husbandry	Conventional dung only from cattle, sheep, goat, horse Conventional maize only from production without use of Neonicotinoid	Conventional dung only from cattle, sheep, goat, horse No limitation for grass silage and biomass produced in compliance with environmental programs[3]
Permitted nutrient import (kg N/ha and year)	170 kg N/ha and year if nutrient demand is proven	40 kg N/ha and year[4]	25 kg N_{jw}/ha and year[5]
Import and export of biogas digestate to and from organic farm	No import of digestate from industrial animal husbandry Nutrient export allowed to suppliers of substrate[6]	Import from purely conventional plants not allowed Import allowed if only permitted biomass (see "restrictions on quality") has been used for six months	Import from mixed biogas plants (conventional/organic) allowed if the farm using the digestate supplies substrate to the plant and grows at least 20 % leguminous plants in its crop rotation

Sources: EU Council Regulation (EC) No 834/2007 from 28.6.2007 and EU Council Regulation (EC) No 889/2008 from 5.9.2008, Bioland: Erzeugerrichtlinien from 18.03.2013, Bio Austria: Produktionsrichtlinien, Revision 2013.

[3] Programme "Verzicht auf ertragssteigernde Betriebsmittel auf Ackerflächen" or "Verzicht auf ertragssteigernde Betriebsmittel auf Ackerfutter- und Grünlandflächen" according to ÖPUL (Austrian Agri-environmental Programme).
[4] The Bioland guideline names 0,5 DE/ha (1 DE has 80 kg N).
[5] Njw: Effective annual nitrogen according to ÖPUL (Austrian Agri-environmental Programme) 2007. It comprises losses at application and a substrate specific factor.
[6] Export of digestate containing fermented slurry/dung from organic animal husbandry to conventional farms is considered forbidden in some countries.

Biogas concepts on organic farms

While biogas plants in conventional agriculture rely largely on energy plants, slurry and – in some countries – industrial waste, organic biogas concepts are more closely linked with the farming system and have strong reciprocal effects. The focus of biogas production therefore will vary with the focus of the farming activities.

Organic intensification

Stockless farms and farms with low stocking rates have problems using biomass from catch crops like clover grass economically. Often clover grass and other catch crops are mulched. As a result, the rhizobia bacteria at the plant roots, which are responsible for fixing nitrogen from the air, will use nitrogen available from decomposing mulch. This in turn decreases their efficiency of nitrogen fixation. When the material is harvested for biogas, the performance of the bacteria and therefore nitrogen fixation increases. At the same time, nitrogen losses are decreased as the digestate that results from biogas production can be spread on productive fields at times when plants need it.

Unused or underused grassland can also be activated for biogas and contribute to an additional input of nutrients. While a productive use of autumn grass harvests will profit grassland condition on dairy farms, biogas from extensive grassland provides additional nutrients for productive fields and makes use of otherwise unusable conservation material.

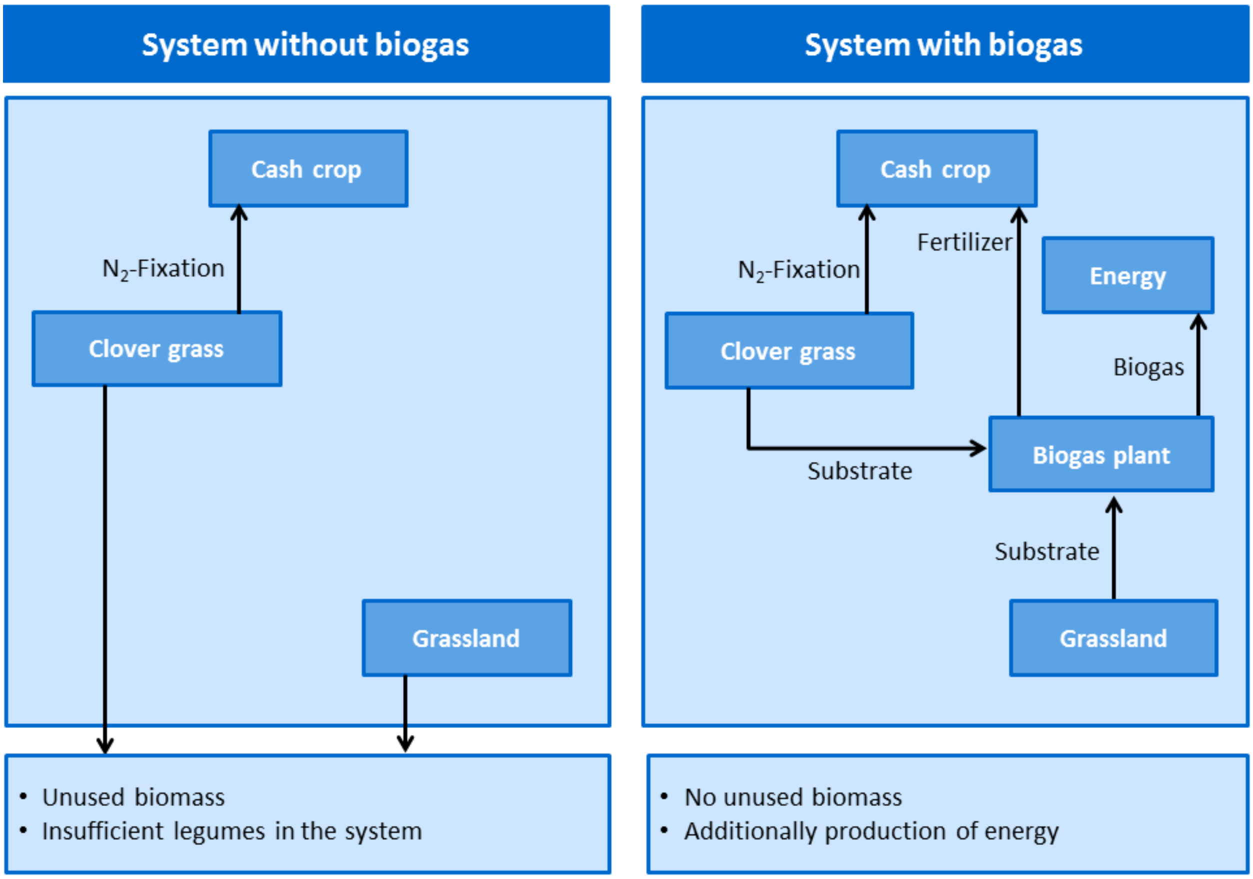

Figure 6: Effect of biogas on stockless organic farming systems. Illustration: FiBL.

Figure 7: Catch crop or cash crop? With biogas it can be both! Photo: V. Jaensch, RENAC.

Energy from manure and bonus for the climate

Livestock farms – conventional as well as organic – considerably improve their greenhouse gas balance by using animal excrements for biogas production. The greenhouse gas methane emitted by manure and slurry is now used to produce energy and no longer emitted into the air. Moreover, energy generation leads to extra revenue without reducing the dung's fertilising abilities.

On organic farms, housing systems based on solid manure are often preferred to slurry-based systems. Compared to direct use of solid manure, the digestate available after biogas production from this substrate is more uniform, versatile and easier to apply with modern machinery.

Nutrient production is vital

For all biogas concepts on organic farms, the fertilising activity of the digestate is a central issue. To assess the suitability of biogas production, an organic farmer will compare the digestate with the organic fertilisers available to him at present. While a monetary equivalent can be assigned to the quantity of nutrients available in the digestate, other qualities of the fertiliser like the potential for long-term humus accumulation are more difficult to assess. Turning material like solid manure or feed residues into readily available fertiliser through the biogas production process makes nutrient management more flexible and enables application even on grassland or in growing crops. Plant availability of nutrients is increased and – when suitable technology is used for application – emissions are reduced.

Cooperation is the key

Organic farmers usually use mainly residues and surplus plant material e.g. from catch crops as substrate. In stockless farming systems, about 20 to 30 % of the area may be dedicated to catch crops/legumes. At farms with animals, livestock will use part of the legumes for feed, so there will be less plant material but slurry and manure available as substrate. In contrast to a conventional farm, organic farming concepts with biogas from surplus material will allow only part of the crop area to be used for the production of biogas substrate. In order to reach economically feasible sizes of biogas plants, organic farms will often need to source biomass from several growers. This is possible particularly in regions where organic farms are numerous. Since biomass supply has to be secured for many years, a reliable cooperation with organic farming colleagues is vital. Successful examples show that a cooperative approach to organic biogas can be a win-win-situation for all farmers participating.

While the specific advantages of biogas for organic farming apply everywhere, suitable concepts will always take into account farm size and structure, natural conditions, the legal framework as well as the relation of prices and returns.

For more on biogas concepts see page 37 (Biomass supply) and page 45 (Use of digestate).

4 Organic biogas production in the EU

As can be seen in the EU countries represented in the SUSTAINGAS project, organic biogas production is increasing particularly in countries with favourable conditions for biogas as well as for organic agriculture. So far, the legal framework with its strong influence on funding, prices and requirements has far greater influence on the development of biogas in organic agriculture than regional differences in natural conditions or farm structures.

Strong tradition

In some countries like Germany and Austria with a long tradition of the organic movement and a political focus on organic agriculture and renewable energy, a number of biogas plants are operating already on organic farms. Some German farmers have already been using biogas on organic farms for some decades. To them, the concept of biogas production primarily from slurry and other farm residues combines well with the organic idea of an on-farm nutrient circuit and an interest in an independent energy supply. Within the last decade, legal privileges for biogas like fixed prices and guaranteed grid connection have made electricity production from biogas also economically worthwhile giving organic farmers an additional incentive to build on the pioneers' work. For example, in Germany about 180 biogas plants with an electrical power of 30 megawatts (MW_{el}) are operated, most of them on forage cropping farms with an increasing number on stockless arable farms. In Austria, about 100 organic farms deliver biomass to biogas plants but so far only two biogas plants are operated by organic farms. However, both countries have experienced unfavourable changes in tariffs for electricity from biogas in recent years. This has discouraged the realisation of additional biogas plants on conventional as well as on organic farms. Bio Austria, Bioland and Naturland, the three largest organic agriculture associations in Austria resp. Germany, have each established production guidelines exceeding the EU regulations on organic agriculture (see Table 2 on page 11).

Figure 8: Gerhard Übleis operates a biogas plant in Schwanenstadt/Upper Austria with a mix of organic and conventional input. The heat is used for drying wood chips as fuel. Photo: F. Gerlach, FiBL.

Potential for the future

In some regions, no or hardly any organic biogas plants are operating yet, but there is growing potential for future development. To some of these countries the organic sector is relatively new and not many organic farms exist. For example, in Bulgaria the first farms were certified organic in 2000 only, and today no more than 0.8 % of the arable area is cultivated organically. Also the biogas sector is new to the country. As organic farming as well as the production of energy from biomass is supported politically in Bulgaria, biogas production on organic farms may well develop in the coming years. Denmark, in contrast, has a well-established organic farming sector and about 60 long-established farm biogas plants, but only recently the focus of political attention shifted to agricultural biogas again. The Danish parliament wants 50 % of livestock manure to be treated in biogas plants in 2020 and has raised feed-in tariffs and funding for electricity from biogas plants.

In the same period, Denmark aims to more than double the area under organic cultivation from 7 to 15 %, while organic agriculture in Denmark is planning to phase out the import of conventional manure until 2021. Today, there is only one organic biogas plant, but with improving conditions interest among organic farmers in biogas production is growing.

Better conditions needed

Other countries have a fair number of organic farms, but farm sizes and/or insufficient incentives for agricultural biogas production from crop biomass restrict the potential for organic biogas. Poland, for example, has about 20.000 certified organic farms but hardly any of them cooperates with a biogas plant. Even though with some 25 hectares (ha) the average organic farm is larger than the average of all farms, this is still small for initiating a biogas project. Moreover, agricultural biogas production in Poland is mainly feasible for large plants processing slurry. Currently, eleven agricultural biogas plants are in operation in Poland, but only two of them have a capacity below 0.5 MW_{el}. Only one biogas plant (30 kilowatt electric power (kW_{el})) based on a small farm exists.

Figure 9: The largest dairy farm in Spain operates one of only 32 agricultural biogas plants in the country with slurry from 2,500 cows. The digestate is dried and sold as fertiliser for organic agriculture. Photo: STUDIA.

In Spain, agro-industrial biogas production is presently based mainly on slurry. Only few agricultural biogas plants are in operation (10 MW_{el} in 2010). The production of energy crops is limited also by the natural growing conditions. Although there are more than 1.6 million ha under organic cultivation, biogas production from organically grown biomass is almost negligible.

Political support is essential

In all European countries considered, the technical potential for biogas on organic farms is many times higher than the number of organic farmers already owning or contributing to a biogas plant. There is considerable scope for an increase in biogas production on organic farms in the EU. However, this requires legal and economic conditions that allow organic farmers a long-term engagement in biogas production as a complex new business with high investment. Biogas production as well as organic agriculture show higher costs than the prevalent natural gas and conventional agricultural systems. Therefore, specific political support is vital to develop this forward-looking combination

Table 3: Agricultural and biogas sectors in exemplary European countries

Country	Number of organic farms	Organic agricultural area (ha)	Share of organic of total agricultural area (%)	Number of biogas plants	Number of organic biogas plants	Share of organic of total biogas plants (%)
Austria	21,575	542,553	19.7	368	7	1.9
Bulgaria	978	25,022	0.8	10	0	0
Denmark	2,677	162,173	6.1	82	1	1.2
Germany	23,003	1,013,540	7.8	7,515	180	2.3
Spain	32,195	1,621,898	6.5	32	1	3.1
Poland	23,430	609,412	3.9	38	0	0

Sources: Number of organic farms and organic agricultural area from Willer H., Lernoud L., and Kilcher L. (Eds.) (2012): The World of Organic Agriculture – Statistics and Emerging Trends 2013. FiBL/IFOAM, Frick and Bonn; Data on biogas plants from own data (SUSTAINGAS) and as follows:
Austria: Energie-Control Austria (2013): Entwicklung anerkannter sonstiger Ökostromanlagen 2002-2012, online at *http://tinyurl.com/qdher6h*; Energie-Control Austria (2012): Ökostrombericht 2012, Energie-Control Austria, Wien.
Bulgaria: own data.
Denmark: own data.
Germany: Fachverband Biogas (2013): Branchenzahlen 2012 und Prognose der Branchenentwicklung 2013, Fachverband Biogas, Freising; Anspach V., Gerlach F., Graß R., Herrle J., Heß J., Siegmeier T., Paulsen H., Szerencsits M., Wehde G., Wiggert M., Wilbois K., Zeller H., and Zerger, U. (2011): Bioenergieerzeugung und Energiepflanzennutzung im ökologischen Landbau. TA-Projekt Ökologischer Landbau und Biomasse, Themenfeld 3, Stiftung Ökologie und Landbau (SÖL), Bad Dürkheim.
Poland: Agricultural Market Agency (2013): Rejestr przedsiębiorstw energetycznych zajmujących się wytwarzaniem biogazu rolniczego, online at *www.arr.gov.pl/data/02004/rejestr_biogazowni_rolniczych_24082013.pdf*.
Spain: European Biogas Association (2012): Biogas in Europe 2011, online at *http://tinyurl.com/ll3o829*.

5 Why organic biogas?

Organic farmers and biogas producers in conventional agriculture will ask the same question: Why should we combine organic agriculture and biogas production? There are several good reasons for this: From a positive impact on organic food production and farm economics to superior performance when it comes to issues of environmental sustainability.

The inclusion of biogas in the farm cycle is interesting to organic farmers, because it results in good fertilisation values and higher economic returns. On a broader view, it can also allow the whole organic farming sector to become more self-sufficient in plant nutrients and further improve its greenhouse gas balance.

More food with organic biogas?

The following chapter deals with questions concerning the potential competition between crop and energy production as well as with yields and quality of crop production in organic agricultural systems with biogas production.

"Food vs. fuel" – not with organic biogas

Food production and energy crops compete for productive land and other scarce resources such as water. Options to reduce such competition include the use of unused land, increasing land productivity (yields) and using residues. Biogas in organic farming to a large extent sources its input materials from residues and by-products. Where energy plants are used, their need for crop area is wholly or partially offset by the yield increases in the crop rotation facilitated by the biogas system.

Biogas on organic farms has the ideal of using only surplus material without competition to food production. To enable a balanced diet for microbes in the fermenter or to reach an economically feasible size of biogas plants, the use of energy plants cannot always be avoided. But generally, the share of energy plants is much lower compared to conventional agricultural biogas plants.

The following table shows how the use of different materials as biogas substrate affects food production. This will be discussed in more detail below.

Table 4: Potential effects on food production of using materials as biogas substrates; (-) negative; (+) positive

Substrates	Effect on food production
Energy crops	-
Catch crops (e.g. clover grass in stockless farms)	+
Animal excrements	+
Organic waste	-/+

- *Energy crops:* Converting land from food production to substrate production causes a decrease in food production rates. Compared to conventional biogas production the share of energy crops is usually lower on organic biogas plants. One reason is the price premium for organic products on the market. If used as substrate for biogas, on the energy market there is no price premium for the organic products. Thus, using energy crops to produce biogas is just the second choice. Also, some organic associations limit the share of energy crops to be used in organic biogas plants.
- *Catch crops:* Harvesting catch crops, like clover grass, instead of mulching can increase yields. Since catch crops have no competition to food production but their harvest improves nutrient availability in the crop rotation, their use for biogas production can help increase food production, particularly on stockless farms where use as fodder is no alternative. Although catch crops are already more common in

organic than in conventional farming, their use can be considerably increased from an agronomic and economic point of view.

- *Animal excrements:* Using manure in the biogas process can have a positive impact on food production as the availability of nutrients for the plants is increased after the biogas process.
- *Organic waste:* By-products from food production or from the harvest as well as other not-marketable units can be used in the biogas plant. In case these substrates had no feed or food use before, their use doesn't reduce food production but contributes to nutrient supply of crops by using the digestate as fertiliser.

Choice of substrate

Biogas on organic farms aims at using non-food material; energy crops are second choice. Preference is given to surplus biomass like animal excrements, catch crops and residues from harvest and processing, as well as organic waste material. Thus, organic biogas production is less in conflict with food production than conventional biogas production from energy crops.

Higher yields and quality with biogas

In 2010, organic farmers running or cooperating with a biogas plant in Germany were asked for their experience with effects of biogas on their farms. 40 % of the farmers reported yield increases of about 20 to 30 % while even higher yield increases were experienced by an 18 % minority (see Figure 10). Farmers experienced large increases in cultures which generally require high nutrient supply. Maize with reported yield increases of 29 % and grassland (24 %) are known to respond well to organic fertiliser. Wheat as the most demanding cereal also profits considerably with 22 % yield increase. For cultures with lower nutrient requirements like rye or potatoes, reported yield increases range below 15 %. This variation between cultures also reflects the practice of organic farmers to apply available fertilisers mainly to the most demanding crops.

Even though these data are derived from the subjective perception of the farmers, they show a positive impact of biogas production on farm yields.

But not just yields increase. Also the quality of the products can be improved since biogas digestate is a highly valuable and flexible fertiliser. In the above mentioned survey, 39 % of the farmers reported quality improvement. Most frequently mentioned was an increase in protein content of grain, leading to a higher baking quality and thus also to a higher market price. Quality improvements were also reported for potatoes and pasture.

Biogas serves the crop

- Growing green manure for biogas production allows more naturally productive crop rotations
- Nitrogen fixation of clover grass or alfalfa is increased with appropriate cutting strategies
- Harvesting green biomass for biogas production supports dual cropping systems with two harvests per year
- Biogas production forwards the cultivation of fodder crops and intercropping. This can suppress perennial weeds.
- Use of residues like feed remains, manure, fruit or vegetable wastes or even surplus straw as biogas substrate facilitates on-farm recycling of nutrients and has a positive humus balance if the digestate is used as fertiliser.
- Nitrogen in animal manure is made more readily available through the biogas production process – a bonus for fertilising when used with diligence.
- Anaerobic digestion kills certain bacteria, parasites and weed seeds that otherwise might have had negative effects on crop production.
- Organic biogas production results in ecological intensification of food production.

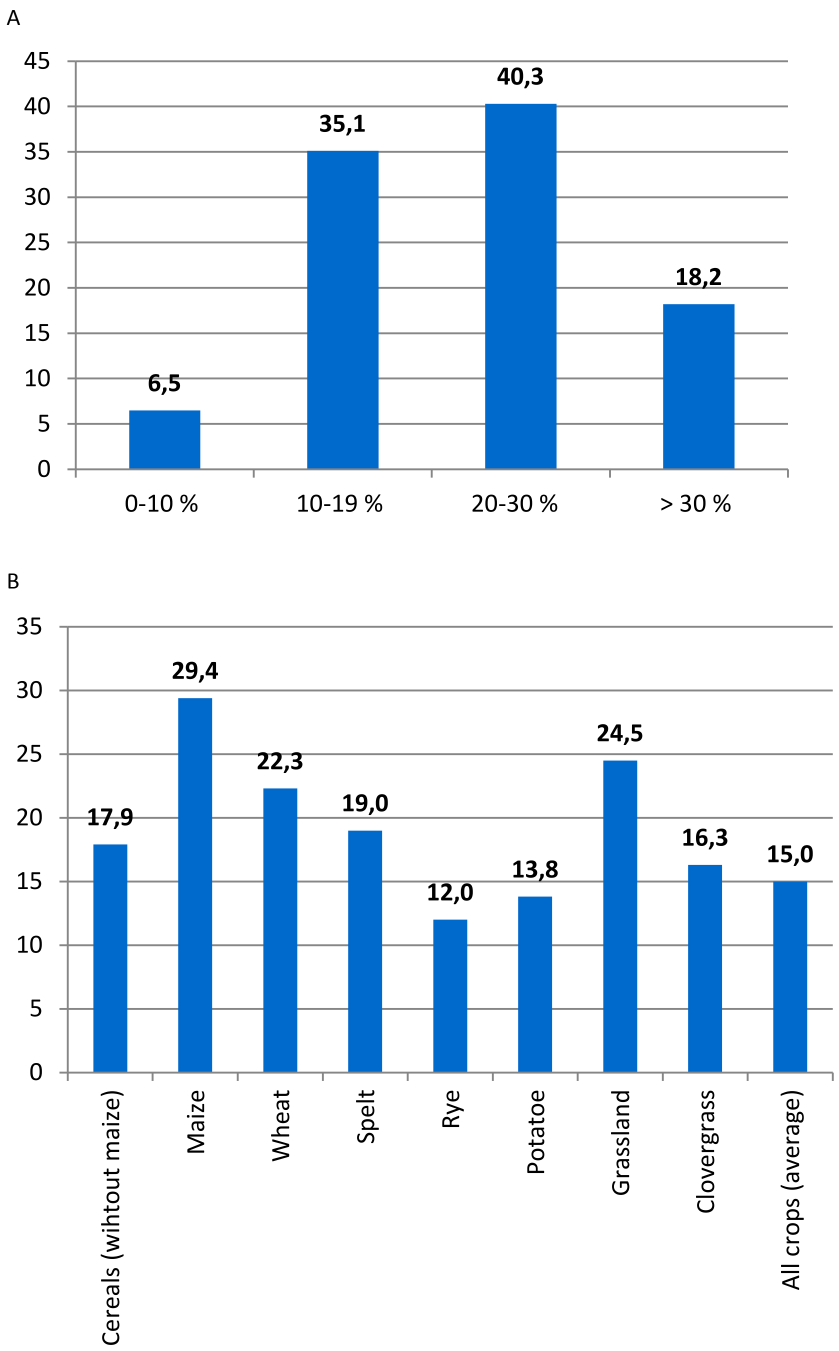

Figure 10: Yield increases reported by organic farmers. (A) Percentage of average yield increase after fertilisation with digestate (n=51), (B) Percentage of average yield increase after fertilisation with digestate, by crop groups (n=51). After: Anspach V., Siegmeier T., and Möller D. (2010): Biogaserzeugung im Ökologischen Landbau – Strukturen und Perspektiven. Kassel University Press, Kassel.

Better economics with organic biogas?

Organic biogas can clearly improve the economics of an organic farm – if the conditions are right and the plant can perform according to plan. Major factors influencing profitability are the costs for biomass and the revenue from the energy produced.

For the economics of agricultural biogas production in general, process efficiency, input costs, and product prices are highly relevant parameters. This is also true for organic production. However, in organic systems biogas production can influence the economics of crop production a lot more fundamentally, particularly in systems with low stocking rates or in stockless systems. Issues of crop rotation and fertiliser management are major reasons for this.

Clover, the new cash crop: In order to provide other crops with nitrogen, leguminous plants such as clover grass are grown as part of the crop rotation. Farms without livestock often have no further use for it and merely use the plants as green manure. When harvested and used as biogas substrate, clover can contribute to farm income as a cash crop.

Natural fertiliser, whenever you want it: The system of fertilising the soil by decomposing green manure on the field is supported by organic biogas residues. The digestate produced in the biogas plant can be applied exactly when and where needed. It contains readily available nitrogen and almost all other nutrients of the original biomass. Considering an often limited availability of manure and the restrictions and high prices for suitable fertilisers, biogas residues in organic arable systems not only spare the budget but also enable higher income since yields and product quality increase (see page 18).

Energy plants: To a lesser extent, profit for crop production can also be gained from growing energy plants to supplement the biogas plant's diet. A suitable choice of plant species or cultivation method can give that extra flexibility the crop farmer needs for his rotation. This might apply to a green ground cover during winter or specific catch crops to reduce diseases. Where agricultural or other suitable residues are used, the value for the farm also lies in the quality of the residues.

Figure 11: Brown jewels: Digestate provides a versatile organic fertilizer. The digestate on the photo is the dry material after separation. Photo: F. Gerlach, FiBL.

Farmers' view: A SUSTAINGAS survey among 696 organic farmers in six EU countries and a workshop with experts has shown influences of biogas production on farm economics. 68 % of farmers interviewed expected increased profit from the harvest or considered it possible. Additionally, they expected reduced costs for fertiliser and soil improvements. Also economical risk spreading by diversification and increased self-sufficiency were mentioned as economic reasons for organic biogas production. Some feared bad economics of the plant, dependency on state subsidies and other economic risks.

> For detailed results of the SUSTAINGAS survey see SUSTAINGAS Report D3.1: Financial Performance of Organic Biogas Production on *www.sustaingas.eu/strategy.html*.

Biogas can help the organic sector

The organic sector in the EU has grown from 3.7 million ha in 1999 to 10.6 million ha in 2011.[7] With the organic food market still growing, organic production has potential for expansion. A study from Denmark[8] shows that lack of access to fertilisers plays a vital role for farmers' choice not to operate organically, particularly in those parts of the country with low stocking rates. Organic biogas with its provision of organic fertiliser may thus encourage more farmers to convert to organic production.

Figure it out!

Will your farm profit from supplying biomass to an organic biogas plant? Can the realisation of a biogas project be a step forward for your farming system?

We don't know. But with the SUSTAINGAS calculator "ECO PLAN BIOGAS" you can estimate the effects of biogas on your farm. ECO PLAN BIOGAS is unique as it goes beyond calculating cost and income merely of biogas production. It also describes economic interactions between biogas production and the farming system. This is particularly relevant to organic farms since the major benefit from biogas production often does not come from biogas itself but from its economic effects on the cropping system.

We suggest you use ECO PLAN BIOGAS with your individual figures – on your own or supported by your agricultural advisor.

To demonstrate results calculated by ECO PLAN BIOGAS, SUSTAINGAS has calculated a case study. It assumes a stockless organic farm in Germany with 70 ha of land. Cereal production is complemented by some pulses and a share of permanent grassland. With 28 % clover grass for green manure and 7 % pulses, our example farm already has a fair proportion of legumes in the crop rotation. Nutrient import is limited to 100 tons (t) of solid manure.

Table 5: Economic calculation with ECO PLAN BIOGAS: Results from a case study (stockless German crop farm)

	Without biogas		**With biogas**	
	Area (ha)	**Euro (€)**	**Area (ha)**	**Euro (€)**
Clover grass (green manure)	20	0	0	0
Clover grass (biogas)	0	0	20	15,600
Grain	35	60,060	35	77,665
Permanent grass	10	3,200	10	3,550
Grain legumes	5	6,500	5	6,500
Earning (farm)		**69,760**		**103,315**
Cost (farm)		**24,070**		**32,338**
Profit (farm)		**45,690**		**70,977**
Profit (biogas)				**4,454**
Increase in profit (farm & biogas)				**29,741**

ECO PLAN BIOGAS calculated an indicative result for the contribution margin of crop production as it is and then proceeded by calculating the possible effect of biogas on crop rotation, yields, cost and income. In addition, cost and returns of a biogas plant are estimated. As the farm is too small for running a biogas plant on its own, the plant in the example processes biomass from several farms. The share of the profit assigned to the farm in Table 5 corresponds to the quantity of biogas substrate from the farm.

While our farm does get some profit from biogas production itself, even a modest loss from biogas production could be acceptable looking at the considerable positive effects it has on crop yields.

[7] Willer H., Lernoud L., and Kilcher L. (Eds.) (2012): The World of Organic Agriculture – Statistics and Emerging Trends 2013. FiBL/IFOAM, Frick and Bonn.
[8] Tersbøl M., and Malm L. (2013): Financial performance of biogas production. SUSTAINGAS Report D3.1, p. 27. Online at *www.sustaingas.eu/strategy.html*.

The main reasons for this positive influence of biogas on the profitability of crop production are:

- The opportunity to sell clover grass instead of merely mulching it.
- Increased yields of the cash crops caused by the application of the digestate.

This calculation is based on an existing farm. It reflects conditions favourable to biogas production: In Germany, electricity from biogas can be sold at special tariffs. Moreover, the clover grass produced so far had no monetary use and grain prices were fairly high resulting in a considerable increase in earnings with yield improvements. Only a calculation based on data relevant for your farm can give an indication on the profitability of biogas on your farm.

> Conditions and results on your farm will be different – check for yourself with ECO PLAN BIOGAS on *www.sustaingas.eu/strategy.html*![9]

Organic biogas – better for the environment?

As organic agriculture aims to protect the natural environment, the environmental effects of biogas on organic farms are highly relevant. This chapter shows the relevance of biogas substrates in this respect and discusses effects on water, biodiversity and the climate.

The right substrate – basis for sustainable biogas production

In order to ensure the sustainability of biogas production, the choice of substrates is of crucial importance.

The increasing cultivation of *energy crops* in conventional agriculture is connected to several concerns including land-use changes, the expansion of monocultures and conflicts between food and energy production. Hence, the use of energy crops in organic biogas production is usually limited. As far as energy crops are used, crops from organic cultivation should be preferred. A deliberate choice of plant species and cultivation methods can benefit the crop rotation e.g. when undersown crops or recovery crops are used.

Catch crops provide a sustainable alternative for biogas production. Leguminous crops such as clover and alfalfa improve soil quality by fixing nitrogen. Non-leguminous catch plants such as mustard, phacelia and rye prevent the washing-out of nutrients and may help prevent crop diseases. After the use as substrate, the digestate is returned to the arable system. Hereby, the effect of the crops on soil and nutrient management is not compromised. As the digestate may be stored and returned to the fields according to nutrient requirements, using catch crops as substrate for biogas production can even increase the system's capacity for nutrient management.

Animal excrements provide another favourable substrate for organic biogas production. Since the methane emitted by excrements is captured in the biogas process, climate-damaging methane emissions from excrements are highly reduced. The fermented manure, which is used as a fertiliser, exhibits reduced odorous emissions; the nutrients are mineralised and the material is transferred into a more fluid consistency. All in all, the environmental cost of the substrate is limited to the transport from the stable to the biogas plant. As long as the distances are low, this variable is negligible.

The use of *organic waste* (e.g. from households or the food industry) also offers an opportunity of producing biogas without additional resource (land, water) and energy requirements. The input of external nutrients to the farm might replace the nutrient loss caused e.g. by the sale of cash crops from organic farms. However, to avoid the risk of importing harmful substances via biogas residues into the arable system, the input of food waste in organic biogas plants is usually limited to specific by-products of the food industry with low risk of

[9] ECO PLAN BIOGAS can be downloaded from *www.sustaingas.eu/strategy.html* and is free to use. For proper operation of the calculator, MS Excel or compatible software is necessary.

contamination (e.g. whey or by-products of sugar production).

Figure 12: Chaff, a valuable substrate with high biogas yields, is a by-product of cereal cleaning and processing. Rich in carbohydrates, it combines well with legumes. Photo: F. Gerlach, FiBL.

What about water quality?

Effects of organic biogas production on water quality and availability may especially occur during substrate production and disposal of digestate. The cultivation of catch crops as biogas substrate can improve water quality by reducing nitrate leakage and enhancing water retention. In stockless farms, catch crops are a key to an optimal nutrient management. The possibility of returning the digestate to the fields based on crop nutrient needs reduces the loss of nutrients from the arable system into the groundwater. Moreover, the substitution of manure by biogas digestate enables an accelerated plant nutrient uptake, thus reducing the risk of nitrate leakage in farms with livestock as well.

Due to lower levels of fertilisation and more complex crop rotations, the cultivation of energy crops in organic farming will normally cause less water pollution than in conventional farming. Using substrates from organic agriculture also reduces the risk of introducing water pollutants (e.g. pesticides) to the system. Negative effects on water quality through eutrophication can be prevented by following the principles of good agricultural practice, thus applying digestate only according to plant needs. Typically, the risk of pollution is lower in organic farms, especially in stockless farms where nutrient deficiency tends to be an issue.

Regular plant operation will not impair water quality as long as runoff water from surfaces is collected and used professionally. Any biogas plant must consider accidents causing loss of substrate or digestate from the fermenters. Runoff into the soil or into surface water must be avoided, e.g. by mounds surrounding the biogas plant.

What about biodiversity?

Maintaining and enhancing biodiversity is a fundamental principle of organic agriculture. If managed properly, organic biogas production can make a valuable contribution to biodiversity.

Land-use changes are a major concern connected to biogas production. Hence, substrate for biogas production in organic farming should never be obtained by transforming land with high biodiversity value (e.g. primary forests or highly biodiverse grasslands) into low-diversity farmland for energy crop cultivation.

The cultivation of monocultures with negative impacts on biodiversity is another possible effect of biogas production observed in conventional agriculture. In contrast, organic agriculture avoids monocultures and relies on crop rotations, thus preventing detrimental effects on biodiversity.

Figure 13: Grasshopper in clover grass. Biodiversity profits from diverse crop rotations in organic farming. Biogas production has the potential to increase biodiversity as it can utilise catch crops and conservation materials. Photo: D. Menzler, BLE.

The fact that no pesticides, herbicides, artificial fertilisers, and genetically modified crops are used presents more advantages of organic energy crop cultivation in terms of biodiversity. Compared to mineral fertiliser, the use of digestate improves the structure of soil – the living environment for soil-based organisms.

The versatility of the biogas process allows a large variety of plants to be used. This leads to different times of blossom and thus better habitat conditions for insects. Different cultivation periods will avoid simultaneous disturbance of all fields and provide refuge for birds and larger animals. Also, weeds can be used in the biogas process. If managed diligently, dedicated biomass production could contribute to an increase in agro biodiversity and weed biodiversity.

Furthermore, the biogas process allows a large variety of plants to be used as substrate. For farmers, this leads to a higher flexibility and opens up new possibilities to improve crop rotations.

Moreover, biogas plants on organic farms are often equipped with robust components, so that substrate with high shares of fibres and cellulose can be processed. This allows for making use of biomass accruing from conservation measures (e.g. mowing meadow habitats). Hence, organic biogas production can contribute to the maintenance and good management of such valuable habitats as well as facilitating nutrient export from conservation areas where this is desirable.

In general, running an organic biogas plant leads to a high motivation to make full use of residues and waste from plant and animal production, thus reducing the risk of uncontrolled eutrophication of natural habitats by reducing the passage of nutrients into the environment.

What about the climate?

At all stages of the biogas production greenhouse gases are either emitted or saved. Important steps are the cultivation and extraction of biomass, the storing, transportation and distribution of raw materials, diffuse emissions, methane leakage in the CHP generator, use of external heat, and the avoidance of methane emissions from manure. Here, the questions arise, which steps are critical and what is the overall balance?

Figure 14: District heating with biogas energy improves efficiency and can be a bonus for rural infrastructure. Photo: N. Hölzer, MEP.

In a SUSTAINGAS study the climate balance of biogas production was analysed to clarify these questions. Twelve model biogas plants of different size and with different substrate inputs were defined to represent typical European biogas plants.

As a main result of the study, it was shown that all examined plants hold a large potential for emission savings compared to the fossil EU-Mix for electricity production (see Figure 15). Moreover, the study revealed the most important sources for emissions and possibilities for saving emissions:

Manure treatment has by far the most relevant effect on the reduction of emissions. On a livestock farm without biogas plant, methane emissions occur when manure is stored. Within a biogas plant manure is degraded and the forming methane is captured. As a result, the biogas plant greatly lowers methane emissions. Since methane has a greenhouse effect 23 times higher than carbon dioxide, such emission savings are highly relevant. The use of external heat was identified as another important contribution to saving emissions, since heat production from fossil fuels can be substituted in this way.

However, biogas plants not only save but also produce emissions. Relevant factors are diffuse methane emissions through leaks in the biogas plant as well as methane emissions from the CHP generator as a result of incomplete combustion. Due to the strong greenhouse effect of methane, it is crucial to minimise such leakages. In case of high methane leakages, the overall greenhouse emission might rise to levels comparable with energy production from fossil fuels.

Cultivating energy crops is another factor contributing to greenhouse gas emissions. Emission sources in this context are e.g. the production of fertilisers and pesticides as well as machinery-use for cultivation and harvesting. Organic biogas production aims to reduce the share of energy crops. Even if biogas production is based mainly on plant material specifically grown for biogas production, the organic alternative still produces less greenhouse gases than a conventional alternative. In this case, the non-use of pesticides, herbicides and mineral fertilisers as well as the use of clover grass as part of crop rotation lead to a lower climate impact.

Land-use changes are a further source of greenhouse gas emissions. The transformation of land with high carbon stocks (e.g. grassland) to arable land for energy crop production can lead to immense carbon dioxide emissions and must therefore be prevented.

Finally, transporting and storing raw material will also emit greenhouse gases. However, these emissions are clearly lower than those described before.

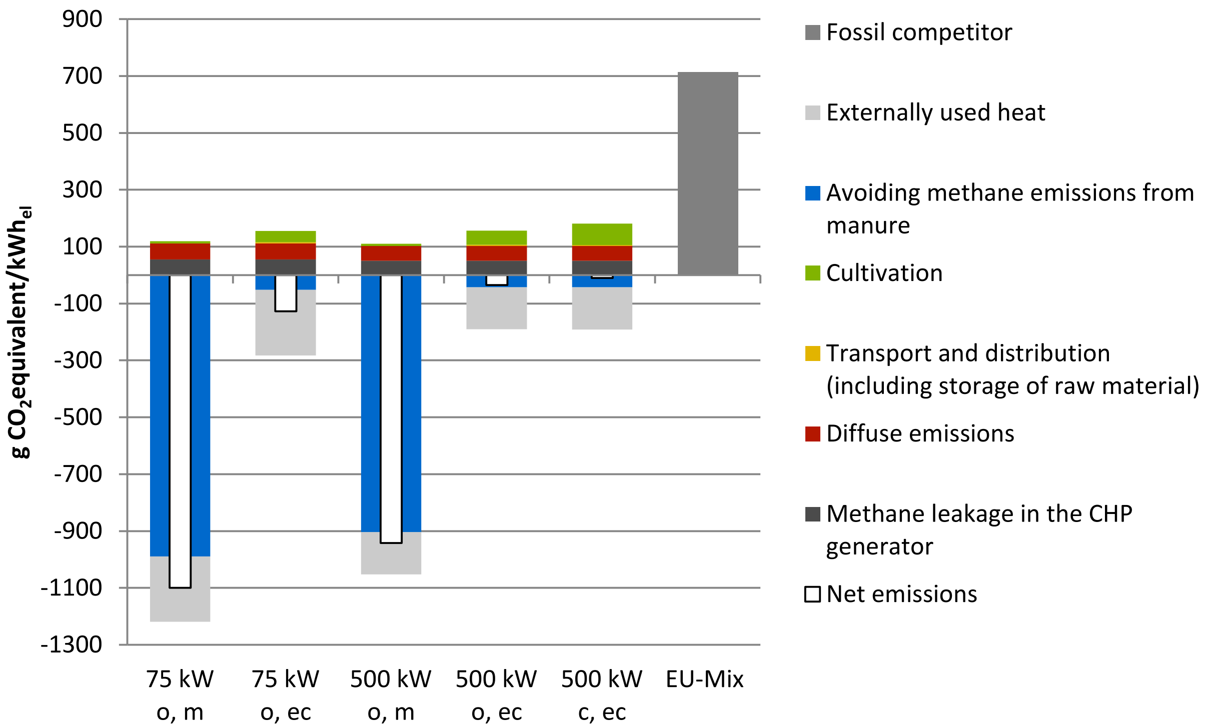

Figure 15: Greenhouse gas effect of electricity production from organic and conventional biogas.
Greenhouse gas (GHG) emissions of five model plants normalised to electricity output. o: organic; c: conventional; m: input mainly based on manure; ec: input mainly based on plant material; Negative number = GHG savings; Positive number = GHG emission, white column: sum of all influence factors. Manure substrate holds the highest potential for emissions savings, but also plant based biogas production allows for net emission savings, especially when external heat is used and in case of organic production with its high shares of catch crops and the non-use of pesticides and mineral fertilisers.
Source: Hofmann F., Gamba L., Weddige U., Gerlach F., Wilinska A., Jaensch V., Schneider C., Baaske W.E., Lancaster B., Tersbøl M., García F., and Kölling A. (2013): Report on analysis of sustainability performance for organic biogas plants, SUSTAINGAS Report D4.1, p.72, online at *www.sustaingas.eu/sustainability.html*.

Optimising sustainability of biogas production

The environmental effects of biogas production discussed result in recommendations for organic farmers to optimise biogas production in terms of sustainability:

- Give priority to manure treatment. It holds the biggest potential for emission savings.
- Using residues and wastes offers a further opportunity to convert biomass into energy with very low carbon emissions.
- Reduce the share of energy crops. Catch crops such as clover grass provide a good alternative with beneficial effects on soil, water, biodiversity and greenhouse gas balance.
- If energy crops are used, they should be cultivated on previously unused areas (to prevent indirect land use change), using organic farming methods and taking measures to prevent negative impacts on soil fertility and water availability.
- Using material from conservation areas (e.g. residues from mowing meadow habitats) contributes to landscape and biodiversity protection.
- Avoid methane leakages from the biogas plant. Methane is a highly potent greenhouse gas.
- Cover the digestate storage. Most methane emissions in a biogas plant emit from this source.
- Prevent impacts on biodiversity and water during construction and operation of a biogas plant. Depending on the size and the type of the plant an environmental management plan might be appropriate. Measures to prevent uncontrolled outflow of slurry/digestate during operation should be developed and implemented.
- Make use of the by-produced heat. CHP-generators provide the opportunity to heat facilities on the farm or in the neighbourhood, thus substituting fossil fuels for heating.
- The application of digestate has to follow the requirements of organic farming and environmental regulations.

Figure 16: Slurry injection technology reduces ammonia emissions, thus improving nutrient recycling and reducing air pollution. Photo: N. Hölzer, MEP.

As life is more complex than theory, not all biogas projects in organic farming will be able to follow the suggestions above completely. The experiences of the SUSTAINGAS project team show that most biogas production facilities in organic farming already present a particularly sustainable form of energy production. At the same time, most initiatives offer some scope for further improvement.

6 Best practice

Successful biogas projects on European organic farms demonstrate how this farmer friendly form of energy production can be implemented in organic agriculture.

The projects in this chapter show that biogas plants vary depending on the structure and size of farms, on the type of agricultural production and on the farmers' aims. The focus is on biogas systems based on clover grass and catch crops as these concepts show more synergistic effects of biogas and organic crop production than others. At the same time, the plants used as substrate are fairly demanding input materials concerning technology and fermentation processes. Manure-based systems – extremely valuable also for climate protection – have been realised successfully in organic farming as well, but their set-up and effects are often less specific to the farming system.

The conditions related to feed-in tariffs strongly influence size and arrangement of biogas plants. The following examples are situated in Germany and Austria – countries where tariffs have allowed biogas plants to be operated economically.

Bioenergie Schmiechen: Just clover grass and solid manure

Biogas from 100 % clover grass was the aim of the long-term organic farmer Hubert Miller from the village of Schmiechen in Bavaria/Germany when he teamed up with four colleagues in 2005 to venture into biogas production. The biogas plant of the Bioenergie Schmiechen GmbH & Co. KG was individually planned and built on one of Miller's fields in the open countryside.

A focus on the use of clover grass as substrate led to the use of technical components rarely used in agricultural biogas facilities: A slim fermenter with the impressive height of 13 metres (m) is equipped with suspended central axial stirring to cope with viscous substrate. Instead of heating spirals inside the fermenter which may be blocked by fibrous material, the substrate is pumped through external heat exchangers. This keeps temperatures at a level of more than 40 °C and supports the mixing of substrate. Electricity from the 350 kW CHP unit is sold to the national grid at prices fixed for twenty years of operation.

After several years of optimising the method of operation, the plant managers succeeded in producing biogas energy from a biomass mix with up to 98 % clover grass. About 40 organic farmers supplying the clover grass accept transport distances of up to 50 kilometres (km) to gain biogas digestate as fertiliser. With mainly stockless crop farming in the region, for many partners the digestate is the only opportunity to obtain a flexible organic fertiliser. For the biogas farmers, maize silage as substrate is only a makeshift short term option when biomass suppliers drop out or fail to deliver the necessary quantities: "Biogas has to serve food production via improved nutrient supply", Miller says.

Figure 17: Hubert Miller, organic crop farmer in Schmiechen/Germany since the 1980s, has been running a 350 kW biogas plant with extra high fermenter and vertical stirring for six years. He uses a substrate mix with up to 98 % cover grass from about 40 organic farms. Photo: F. Gerlach, MEP.

The robust technology enables Bioenergie Schmiechen to remain open for processing other surplus biomass as it becomes available. After years of using only plant materials, the biogas plant is presently operated on a mix of substrates including up to 40 % solid manure.

Using the heat produced by the CHP unit so far has been only moderately successful. Plans for a large drying facility for agricultural and other biomass have been blocked by the community. It will remain an open question if a dislike of industrial development outside the built-up area or scepticism towards biogas farming were the decisive reasons. However, heat is used for the biogas process and to dry wood chips and grass.

Miller, who manages the plant, admits that it took considerable experience to reach normal operation. Since the biogas plant was the first of this type focussing on clover grass only, extensive alterations and adaptions were necessary to solve technical and biological difficulties in the first two years of operation. Today, Miller who is still testing and optimising, can base his work on a performing production system. He is convinced that organic farmers could take a faster route to successful biogas production by learning from experienced colleagues.

Krumbecker Hof: A working mixture

Since 1991, organic crop farming with low stocking rates has been the focus of the Krumbecker Hof, a north German farmstead cooperating closely with the neighbouring organic market gardener.

Since 2010, the activities on 230 ha have been supplemented by a biogas plant with 160 kW_{el}, supplied ready-made from a general contractor specialised in processing fibre-rich substrates.

The main factor influencing the decision of farm manager Gerhard Moser to start biogas production has been its effect on soil fertility and nutrient management. He explains: “The choice was to either step up cattle husbandry or to venture into biogas production.” Even as a biodynamic farmer who particularly values the quality of cattle dung for soil fertility, Moser sees biogas production as a valuable alternative to livestock farming.

Table 6: Characteristics of Bioenergie Schmiechen and Krumbecker Hof

Characteristics	Bioenergie Schmiechen	Krumbecker Hof
Location	86511 Schmiechen, Germany	23617 Stockelsdorf, Germany
Corporate structure	GmbH & Co KG[10], cooperation of five stockless farms	Single farm enterprise
Start of production	2005	2010
Investment	1.3 million Euro	0.9 million Euro
Plant size (CHP units)	350 kW_{el}	160 kW_{el}
Biomass input	60-98 % clover grass, 0-10 % maize silage, 0-2 % rye grain, 0-40 % cattle manure	60 % clover grass, 25 % cattle manure, 15 % horse and poultry manure, milling by-products
Biomass supply from other farms	Clover grass from up to 40 organic farms (max. 50 km radius); manure from organic and conventional farms	Organic poultry manure, conventional cattle manure, organic milling by-products
Energy yield per year	2800 MWh_{el}, 1360 MWh_{th}	1200 MWh_{el}, 1400 MWh_{th}
Heat use	Drying: Wood chips & grass	District heating, cereal drying

[10] Limited partnership with limited liability company as general partner.

About 60 % of the substrate is made up of the farm's own clover grass. Cattle and horse manure stabilise the fermentation processes. The ration in the fermenters is complemented by organic poultry manure from other organic farms and by-products from the organic milling industry. Moser relies on robust standard technology with some specific adaptions. After damages and standstills during the first year, partly caused by poor workmanship, the biogas plant is now running quite reliably.

While the electricity is used in the national grid, surplus thermal energy is used to heat farm buildings, about ten households and a drying facility for cereals. The electricity the biogas plant needs for operation is produced by the farm's own wind turbines.

Figure 18: A biogas plant from a general contractor does the job at the organic Krumbecker Hof of farm manager Gerhard Moser (small photo). Photos: F. Gerlach, FiBL.

Bannsteinhof: Growing organically

Set in the hilly German region of Palatine, the Bannsteinhof is a classic organic farm with 150 ha arable land, grassland, about 40 cows, a few pigs and some poultry as well as a small farm shop. For the family farm of Achim and Margit Ruf, the decision to run their own on-farm biogas plant was a process that started back in the 1990s, when they first read about biogas in an agricultural magazine.

Eight years after converting their farm to organic agriculture, the Ruf family established a small biogas plant with 75 kW_{el} on their holding. As it soon became clear that workload and investment would only moderately increase with a larger capacity, the plant was extended to 180 kW_{el} three years later.

The Bannsteinhof biogas plant is a classic single-farm installation: More than two thirds of the biomass comes from the farm, most of the digestate is used on the farm's own fields, and the heat is used by the farm houses and the grain drying facility. The fermenters are supplied with slurry, clover grass and silage from conservation farming on grassland with high biodiversity value. No energy plants are used.

Achim Ruf is confident with the technical operation of the plant and with the financial returns. However, it becomes clear that the family farmer's outlook is long-term: Since he will be running the plant for at least 20 years, he considers it too early for an overall assessment of his biogas project.

Figure 19: Bannsteinhof: Separating the digestate (on the left) offers the organic farmer the choice of solid digestate and a liquid digestate with very low dry matter content suitable for application in growing cultures. Photo: A. Ruf, Bannsteinhof.

Graskraft Steindorf: Cooperative success

How about running a sustainable biogas project with a business volume of 430,000 Euro together with 54 farmers without displacing food production or using maize? The registered cooperative Graskraft Steindorf has been doing this successfully since 2010. From the yield of 250 ha grassland the partners – some of them organic farmers for more than 20 years – produce 1.2 million cubic metres (m^3) of biogas. "Especially the 3rd and 4th cut often can't be used for hay production because of instable weather conditions. Using the grass in the biogas process is a real alternative", reports a farmer.

The basis for this cooperation is open communication between all partners, for example concerning the coordination of harvesting times. Another important issue is quality management. Analysing the content of all incoming biomass is a standard process. This way nobody feels treated wrongly.

In addition to 16 t of grass, 5 m^3 of slurry are daily fed into the two tank biogas plant. Even with 54 partner farms, the average transport distance is just 3.1 km. Thus it is easy to close the nutrient cycle by returning the 6.000 m^3 digestate per year to the biomass suppliers.

70 % of the methane produced is upgraded and injected into the gas grid. The rest is used in a 330 kW CHP unit. The CHP is running just enough to produce the energy required for operating the plant.

The associates of Graskraft Steindorf are still enjoying the cooperation. When asked about their future perspectives, they show that they are still open for more farmers in the region providing

biomass to produce products people need – such as biomethane as car fuel replacing imported fossil fuels.

Figure 20: The Graskraft Steindorf cooperative shows how an economically feasible plant size can be attained by cooperation of many farmers. Photo: P. Stiegler, Energiewerkstatt.

Would you like to know more about biogas production on organic farms? Read the SUSTAINGAS Best Practice Handbook featuring more than 20 projects all over Europe. The handbook can be downloaded at *www.sustaingas.eu/bestpractice.html*.

Table 7: Characteristics of Bannsteinhof and Graskraft Steindorf

Characteristics	Bannsteinhof	Graskraft Steindorf
Location	66482 Zweibrücken, Germany	5204 Strasswalchen, Austria
Corporate structure	Single farm enterprise	Cooperative: 54 farmers and 4 non-farmers
Start of production	2009	2010
Investment	1.2 million Euro	2 million Euro
Plant size (CHP units)	180 kW_{el}	330 kW_{el} + biogas upgrading
Biomass input	60 % organic clover grass, 40 % manure	70 % grass (mainly organic), 30 % manure
Biomass supply from other farms	30 % from regional organic farms	100 % of cooperation members
Energy yield	1500 MWh_{el},	1.2 million m^3 biogas p.a. (equals 7.000 MWh)
Heat use	District heating, cereal and spice plant drying	70 % of the biogas is fed into the gas grid

7 Getting started

This chapter follows a practical approach. After considering the planning of a project, issues of implementing biogas production in organic agriculture are explained. Starting from biomass supply, biogas production as well as biogas use and the use of residues are discussed. Throughout the chapter, the focus is on aspects specific to the practical establishment of biogas production on organic farms.

"'Begin at the beginning,' the King said gravely, 'and go on till you come to the end: then stop.'"[11]

Well…yes, but where exactly is the beginning?

Most biogas projects start with one or more of the following ideas on how to improve the present farming unit:

- Making better use of farm residues
- Improving the supply and quality of manure and nutrients
- Producing renewable energy
- Diversifying production on the farm
- Diversifying crop rotation
- Avoiding odours from manure and slurry
- Investing available funds

Successful biogas projects can provide all or most of the above advantages, but a lot of different aspects have to be considered in detail before starting the project. This chapter will mainly outline issues specific to organic farms which are important for the planning and operation of a biogas plant. Newcomers to biogas will need to gather additional general information on biogas production from other sources.[12]

[11] From: Carroll L. (1865): Alice's Adventures in Wonderland. MacMillan, New York.
[12] For more information see chapter "Further Information".

First steps

Is biogas the right project for me? Before even starting the planning phase of a biogas project, farmers should reflect on this question. It may help to see how other organic farmers see the advantages and problems of their own biogas projects. Some may overlook the social relevance of biogas production in the local community. Choosing the right partners and a suitable scale of biogas production can be decisive for a successful project.

Will it really work?

Paper is patient, but nothing is as tricky as reality. SUSTAINGAS has asked biogas farmers and other biogas experts for their experiences. What worked out? Where are the pitfalls? The results speak a clear language: Organic biogas has many advantages for the cropping system and increases crop yields. Sourcing biomass at reasonable prices and ensuring a smooth running of the process are the two main challenges. The farmer's experiences can be translated into suggestions on how to set up a successful biogas project:

- Only start if you get *decent returns* for your energy. This will largely depend on the tariffs for biogas energy in your country.
- The *market situation* will determine to a large extent what plant size, concept and biogas use is feasible in your particular situation.
- *Seek advice* with people experienced with organic biogas.
- *Permissions and regulations* will cost time and energy.
- *Size does matter:* Small biogas plants are expensive to build and run in relation to their capacity and output. Also, do-it-yourself concepts are limited by risk considerations and increasing safety and legal obligations. On the other hand, the plant size is restricted by the

biomass quantity available at reasonable conditions. Demand and price schemes for heat, electricity and/or gas should also influence your choice of plant size.

- *Keep biomass costs down:* Securing sufficient substrate in the long term needs to be at the beginning of every project. Running the project in cooperation with other farmers may be one way; contracts with stockless farms for exchanging biomass and digestate are another option. Making sure the plant will process a wide range of crops and residues lowers the risk of rising biomass prices. Don't disregard harvesting and transportation costs – they may weigh heavily on the budget.
- *Don't let trouble shooting kill your leisure.* Technical and organisational problems may cause expensive standstills and can sharply increase operation costs. Reduce the risk by careful planning, professional operation and documentation as well as some buffer time for unexpected mishaps. A plant which – running smoothly – requires less than half a day's work may turn into a full time job as soon as there are problems.

Figure 21: The biogas plant needs to be working 365 days a year. Photo: N. Hölzer, MEP.

- *Consider biomass disintegration:* A variety of strategies exist to shorten fibres and open up plant cells, e.g. by crushing, heating, electrokinetic and biological treatment alone or in combination. This can speed up the process of fermentation, increase biogas yields and reduce technological problems, particularly when using viscous material rich in fibre. In the survey, most farmers with an opinion on disintegration methods were highly satisfied.

Figure 22: For medium sized and large biogas plants, disintegration techniques like this combination of hammer mill and specific microorganisms, can improve efficiency and reliability. Photo: F. Gerlach, FiBL.

- *Don't copy other farms' concepts:* The conditions of organic biogas concepts are often very specific to the individual farm. Learning from experienced projects is vital, but each project will need to suit local conditions.
- *Keep an eye on power consumption:* Between 5 and 15 % of the electricity produced will be needed for the running of the biogas plant – particularly stirring and pumping use a considerable quantity of energy. Careful planning and continuous improvement during the production phase are needed to curb power use.
- *Make it last:* Technology needs to be robust and suitable to handle solid biomass rich in fibre. Many existing plants have upgraded the equipment for feeding biomass into the process, for stirring the substrate in the fermenters and for pumping. Here, robust and functional technology is vital.
- *Digestate:* More storage – more plant power. Digestate storage is mandatory to meet legal obligations. More storage room may further improve arable yields. In arable systems,

digestate needs to be stored for up to nine months or more to ensure spreading at times of optimal nutrient use. Pay for storage once and get that extra yield every year!

- *Power generation:* Use your heat. On-farm power generation from biogas only makes sense if the by-product heat is used. Make sure there is need for the heat in the neighbourhood before fixing the location.

Figure 23: Heat distribution in biogas plant. Professional concepts may utilise a large proportion of heat produced. Photo: MEP.

Biogas – a social project

Communication comes first – long before technology and microbiology step in. For most biogas projects, you will need the cooperation, support or at least acceptance of suppliers, authorities, farmer colleagues, your neighbours and/or the local media. Even if your project is small and self-sustaining, you might want to sell surplus heat to neighbours and you will need planning permission for the project. Local support can bring considerable advantages, while opposing neighbours or the local council can endanger the viability of the entire project.

Many communities understand that organic biogas can be a real bonus for the neighbourhood. Apart from the general advantage of having a producer of sustainable renewable energy in the village, communities will receive additional taxes – providing that the project is profitable. If there is an opportunity to process local residues in the biogas plant or to set up a district heating for homes or public buildings, there are even more tangible advantages for the community. Biogas plants with on-farm use of manure will substantially decrease odour – a strong argument for pig and poultry farms.

On the other hand, many people believe that biogas plants will be an additional source of bad smells although this is only true for plants processing bio wastes or for badly managed projects. In some countries, widespread use of energy plants such as maize has fuelled fears of unwanted changes in land use even where organic projects are concerned. Also, an increase in heavy load traffic on small roads connected to transport of plant biomass and slurry will be unpopular, particularly if it touches residential areas. Biogas as an explosive substance causes fears of dangers to the neighbourhood and the water. Noise and landscape changes caused by the building phase should also be considered. Adding a general scepticism of change and individual economic activity in some communities and you will know why you ought to convince your relatives, friends, neighbours, colleagues and the entire community early that the organic biogas plant in their neighbourhood will not only profit your farm but also the community. Keep in mind: There is no such thing as “biogas in general”. Advantages and disadvantages will always be connected to your specific project.

Addressing the community: With sustainable organic biogas, a coherent concept and professional management, you’ll have the facts on your side to convince the community. The road to successful communication is similar in most projects, but biogas often is the first intensive need for public communication on a farm. Here are a few issues to keep in mind when addressing your community:

- Break the news before rumours spread
- Stay with the truth
- Only promise what you can keep
- Some neighbours will be confronted with your biogas activities more than others. They need specific attention

- Think ahead: Consider solutions before your neighbours contemplate the problems
- Try to genuinely understand people's viewpoint even if you don't share it
- It's a lot about feeling and experience: Talk positive and show your enthusiasm
- Make sure the local media really understand what you're planning

Public information: On a local scale, a lot of trust and support can be gained from using informal channels: There's nothing as effective as the talk at the local shop or over the farm gate, the discussion on the market or the conversation at the pub. In addition, some formal initiatives may be useful and necessary:

- Early in the planning: Presentation and discussion of the project with the community council, followed closely by a public presentation/discussion
- Project website and/or public notice informing about the state of the project
- Organised visit to other (organic) biogas plant with members of the community
- Discussion forum with external experts (esp. if specific issues are at the focus of local discussion)
- Contact to the media: Press release, information to local reporter, invitation to visit the farm
- Open days at the start of production and during operation

Experiences: Community support is a decisive factor. Here's what biogas operators have experienced:

- "When we discontinued operating the biogas plant after many years, the neighbours again smelled the chicken manure as it was no longer fermented. They asked us to restart biogas production."
- "The decision for our district heating was political. For public consent with biogas production, we need our neighbours to participate in the benefits of our biogas production."
- "The planning was discontinued after three years since the community was opposed to the project of an organic biogas plant."
- "The permission to expand our biogas production was tied to the obligation to provide energy to the community."

Figure 24: Visiting best practice biogas plants with colleagues and local citizens will help to communicate your biogas project. Photo: W. Baaske, STUDIA.

Choosing partners, sourcing information

Traditional family farmers have learned the bulk of their knowledge from their parents and grandparents. This is different with biogas: While knowledge on mechanics, technology, biology and economics is definitely useful for anyone venturing into biogas production, specific biogas knowledge in the family, with colleagues or consulting partners is often scarce. There is a need for information, training and advice. Farmers interested in biogas ought to acquire additional knowledge and make sure they have competent partners to help with decisions and to find solutions when problems arise.

Prefer consultants who have experience with organic biogas and/or facilities to convert biomass rich in fibre and dry matter. These may be biogas advisors, organic agriculture advisors or experienced organic biogas operators. Not always will you get all the information you need from only one person.

Together may be better: Consider entering into biogas together with organic farming colleagues in the region. This may cut costs, secure an adequate biomass supply and increase know how for the management. Before committing yourself to cooperation, check if you and your partners have clear and compatible aims, a similar attitude to cooperation, and a common understanding of the task. Seek legal and financial assistance when fixing the details of cooperation.

Make sure construction companies and providers of biogas technology are experienced in the type of plant you intend to build. Visit projects in operation and talk to the operators. Choose one general contractor or seek experienced and competent advice regarding the compatibility of components for a smooth process.

Engage legal assistance in drafting and confirming the contract with suppliers of biogas plants. The contract should contain warrants to ensure the working not only of separate parts but also of the entire system (heating, stirring, pumping, hydraulics, control of swimming layer etc.).

For all the necessary and valuable advice you will get, the first and foremost expert on your individual plant will have to be you as plant manager. This is particularly true for biogas in organic farming as conditions vary more than with most conventional plants, and biogas specialists usually have only limited experience with such projects. Only those who know the operation in and out from daily experience will be able to take into account all the parameters. Eventually, even the most qualified expert's advice can only be as good as the information the plant manager gives him. Therefore, you can't do better than working on your own biogas know-how. Training, qualification and the continuing search for better and current information is a big step towards a successful biogas operation.

Big or small?

The appropriate decision on the capacity of a biogas plant is crucial for its success and a lot more complex than just multiplying investment, input, and output. The following examples illustrate the variety of opportunities and challenges of different plant sizes (see Table 8):

While *small plants* with less than 100 kW_{el} can be run as single farm units even from moderately sized farms, the relatively high investment costs even of plants with simple technology may cause severe difficulties for the plant's economics. But despite low electric efficiency of small CHP engines, an intelligent integration of substrate provision, digestate use and heat use within the farming system may provide an excellent overall efficiency.

For *medium sized plants* of up to about 500 kW_{el} the main challenge will often lie in securing enough organic biomass in long-term agreements. Heat use may also be challenging as the plant provides more heat than most farms will need, but district heating at this scale is only feasible if the plant is close enough to other heat users. Biogas constructors offer a range of tried and tested turn-key plants which may need adaption to the substrates used.

Large plants are typically managed in cooperation with other farmers. Planning approval may be a challenge since these plants are sometimes no longer considered as part of the farm. Management and transportation costs may rise for this scale of plant, but developments like upgrading biogas for injection into the gas grid, extensive heat use or direct marketing are feasible on this scale.

A definite limitation to plant size is the quantity of biomass available in the long run. While a small plant may be able to find new sources for additional biomass, a large plant with too optimistic calculation on biomass needs may run into severe problems. After all, a small biogas plant of 75 kW needs biomass from about 30 to 50 ha while a plant producing 1.000 kW_{el} will process biomass from some 350 to 650 ha – an annual quantity of biomass from organic farms which ought to be secured before embarking on a large biogas project

Table 8: Strategies for biogas plants with different capacities

Biogas plants	Small < 100 kW	Medium 100-500 kW	Big > 500 kW
Suitable for	Small farms Farms with only animal production Farms with mainly perennial cultures like fruit and wine	Big farms Farms with more arable crop production (with green manure) Larger horticulture production	Several bigger organic farms with short distances in between Potential for a common biogas plant in cooperation
Disadvantages	High specific cost for biogas plant (€ per kW) Management lies on the farmer him selves Lower electric efficiency in CHP	Dependency of external biomass supply Waste heat utilisation can be a challenge Transportation cost may occur Appropriate cooperation agreements with biomass suppliers must be foreseen	Higher cost per kW Transportation costs More costly and time demanding approval process Cooperation agreements must be developed Enough biomass necessary in relation to plant size
Advantages	Closely integrated with the farm setting Only own biomass (no dependencies) No transportation cost Waste heat allocated locally	Lower specific cost for biogas plant (€ per kW) Higher electric efficiency in CHP Employed people can take part in the operation	More optimal energy sales can be developed, like upgrading for the gas grid Specialized operator can be employed
Strategies	Do-it-your selves' concept appropriate or simple turn-key concepts	Turn-key plant appropriate Organic biomass must be secured through agreements from suppliers Import of conventional biomass for a transition period Convert neighbouring farms to organic	Customized biogas plant setting can be afforded Alternative marketing strategies can be analysed

Source: Tersbøl M., and Malm L. (2013): Financial Performance of Organic Biogas Production. SUSTAINGAS Report D 3.1, online at *www.sustaingas.eu/strategy.html*.

Funding: Staying in the driver's seat

With a biogas plant, farmers establish a semi-industrial facility on their holding. The investment required is considerable (usually between 200.000 and several million Euro depending on size etc.).

For projects in organic agriculture, the use of foreign capital from investors should be considered critically. Often, the advantages of biogas in the organic agriculture system are too complex to enter the calculations of partners investing merely for financial reasons. Particularly, if investors are not connected to organic agriculture, their control of the project could compromise the synergy between biogas and organic farming. Farmers should therefore look for project partners with a common understanding of the biogas project and its aims.

Biomass supply

A decisive challenge for setting up a biogas unit is to get enough organic biomass for an affordable and stable price. As the availability of biomass will determine the capacity and technology of the project, this sensitive issue should be addressed in the early planning phase and before establishing the plant. Unless the biomass is sourced entirely from the biogas producer's farm, long-term agreements are crucial. It is vital to the economy of organic biogas plants to agree with biomass suppliers on mutually binding and mutually beneficial long-term conditions for exchange of biomass and fertiliser.

Surplus biomass from organic farms

For organic farmers, supplying surplus biomass to a biogas plant means exclusive access to organic premium fertiliser (digestate). Particularly, for farms with low stocking rates, this can improve the performance in the entire crop rotation. Operators of organic biogas plants, on the other hand, need reliable organic sources of sufficient quantities of biomass at stable and reasonable prices. This is why farmers must work together and decouple biomass supply from market prices with long-term agreements including affordable biomass prices for the biogas plant as well as a reliable supply of digestate for the crop farm.

Organic growers benefit from optimising their crop rotation. Therefore, they have an interest in selling green manure to biogas plants in exchange for digestate as fertiliser.

The focus of biomass sourcing should be on residual biomass like green manure, catch crops/intercrops and livestock manure. Additional disintegration for better digestibility makes other biomass like material from conservation measures and straw available for the biomass process.

Figure 25: Clover grass harvest for biogas. Photo: agrarfoto.at.

Clover grass: Mix and enjoy

Clover grass is an ideal biogas substrate for organic farms. Beneficial to the soil and the entire crop rotation, its use for biogas turns clover grass into a cash crop – even on stockless farms. However, the high fibre and nitrogen content of the substrate are a considerable challenge to biogas plants when clover grass is used as the predominant substrate. A minority share of slurry, suitable residues, or – where not available – energy plants like cereal silage or even maize silage may allow for a smoother and more efficient operation of the plant.

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Off-farm residues and bio waste

Using organic waste material like kitchen waste or residues from the food industry works towards a circular flow economy but is to be considered with caution: The risk of introducing diseases, harmful substances or genetically engineered organisms into the farming system must be avoided. Also, national legislation, feed-in tariffs, or organic regulations often prohibit waste use in agricultural biogas plants or on organic farms. The properties of many waste materials vary greatly between lots, making them very difficult to handle in the fermentation process. At present, therefore organic biogas plants usually prefer by-products and residues form the (organic) food industry with a low risk of contamination and predictable biogas potential such as chaff or whey.

While sources and handling of off-farm residues will differ greatly depending on your region and the type of material concerned, some of the following suggestions and questions may help you to get an idea what to check if you consider using these substrates:

- Find out which surplus materials are available in your region. Helpful contacts might be the (organic) food and feed industry and waste management authorities.
- Check the legal conditions for processing the residues and waste materials in question and – equally important – for using the digestate as fertiliser on organic fields.
- Which materials are feasible for processing in an agricultural biogas plant? Digestibility, nutrient content, handling specifications, the uniformity of the substrate's qualities and the risk of contamination with harmful substances or diseases need to be checked.
- Is your planned or present biogas plant equipped to process the substances technologically (feeding, stirring, etc.) and microbiologically (temperature, biomass mix, safety equipment, analysis equipment)? What extra investment would be necessary to process the substrates?
- Can you acquire the know-how to manage the substrates successfully?
- What quantities are available at what conditions? Will the producer of the waste pay for its disposal or will there be a charge to the biogas plant? This very much depends on the alternative disposal strategy of the producer.
- Will the substrate in question increase the risk of bad smells in the neighbourhood? Would this be a problem on your plant?
- Will the nutrients imported with off-farm biomass contribute to a balanced nutrient situation on your farm or should you consider selling surplus nutrients as organic fertiliser?

Figure 26: Poultry manure enables high biogas yields and will lose its smell after fermentation. The high nitrogen content limits its use as a substrate. Photo: R. Newman, BMLFUW.

Second choice: Energy crops

Energy crops grown primarily for biogas production are only second choice: They use land where food crops can be grown. Keep in mind: In contrast to organically produced food or feed, there is no premium pay for organically produced biomass on the energy market. Some organic associations limit the share of energy crops in organic biogas plants.

Energy plants might, however, play a role when advantageous to the cropping system or necessary to enable a balanced "diet" for the fermenter. Like cows, biogas plants need nutrients in the right proportion. Using only residues and surplus biomass available may result in an imbalanced biogas process. In this case, the addition of suitable energy plants can increase the productivity of the biogas production.

One hundred per cent organic?

Organic agriculture aims at developing a self-sustaining system. Biomass from conventional agriculture should therefore only be seen as a short term solution when not enough organic biomass is available. However, supplementing the biomass input with residues from conventional farms (e.g. manure, cover crops or landscaping material) might be an alternative to using energy crops.

To improve biomass supply, conversion of farms near the biogas plant to organic agriculture should be promoted – with the additional argument of a secure supply of fertiliser.

The issue of suitable input for organic biogas plants is still in discussion. Depending on the focus (energy production, soil fertility, climate change, land use, contamination, resource efficiency and/or nutrient cycles) and on regional conditions, approaches differ regarding the use of energy crops, biomass from conventional agriculture and bio wastes.

For more information on the share of organic biomass in biogas plants see the SUSTAINGAS description of organic biogas on page 8 and Table 2 on organic regulations on page 11.

Substrate quality

For many substrates, estimations of the potential methane yield exist for material from conventional agriculture. You may use these figures for rough estimations. Since water produces no methane, always make sure you compare biomass with defined (organic) dry matter content. As you will know from analysis of feedstuff and organic fertiliser, you need to have your farm's own material analysed for accurate information. Whether you (out)reach the estimated yields will then depend largely on the efficiency of your biogas process.

Table 9: Typical substrates for organic biogas production (selection)

Substrate	Approx. annual generation (t fresh matter per ha or per dairy cow)	Dry matter content (%)	Biogas yield (Nm^3 per t fresh matter)	Methane content in biogas (%)
Cattle slurry	19	10	30	55
Cattle manure	13[13]	25	96	55
Conservation grassland	5-12	50	128	50
Rye silage (harvested green)	10-15	25	135	53
Clover grass silage	16-27	30	157	55
Maize silage[14]	28-40	35	216	52

Source: Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL)(2013): Wirtschaftlichkeitsrechner Biogas, online at *http://daten.ktbl.de/biogas/startseite.do*.

[13] deep litter
[14] Maize silage as the main substrate in conventional agricultural biogas production is included as a reference.

Biogas and the crop farm

On farms focusing on plant production, biogas can greatly benefit crop yields, crop quality and the possibility to grow certain demanding crops (see chapter 5 ("Why organic biogas?)). Responsible for this are:

- The utilisation of otherwise underused plant products
- The return of nutrients to the fields as readily available and storable fertiliser

If you want to really use the benefits of biogas, we recommend you revise your cropping and fertilising system:

- Cultivate a sufficient share of green fodder legumes such as clover and/or alfalfa. A proportion of 20 to 30 % will usually provide enough nitrogen for the crop rotation. Where feasible, cultivating legumes for two years will cut costs and help soil life and weed control.
- Consider catch crops, intercropping and other systems with two harvests per year: Since biogas substrate can be harvested while still green, this is possible under many conditions.
- Improved nutrient availability may allow you to experiment with more demanding crops than before. Having the alternative of using disappointing harvests for biogas production will lower your risk of crop failure.
- Rethink your management of harvest residues. Instead of leaving them on the field, you now have the option of processing them in the fermenter and using the digestate the coming spring.
- The seeds of many weed species become infertile when processed in biogas plants. You may use this advantage to reduce weed pressure in infested fields.

Biogas on livestock/poultry farms

Your focus is on livestock, pig or poultry? Biogas can turn your animal manure and slurry into energy without reducing its value as a fertiliser. Fodder of poor quality and feed leftovers may also be used for biogas instead of inadequately feeding livestock (but: mouldy material is unsuitable even for biogas).

Looking at the effect on the climate, there's not much you can do wrong: Capturing the greenhouse gas methane from manure which would otherwise be emitted into the atmosphere is a big bonus for your farm's climate footprint! An important side effect for pig and poultry farmers and their neighbours: The digestate left after fermentation will smell a lot less than untreated manure.

Figure 27: Pigs, producers of fine manure and slurry for biogas production on the Scharlhof/Germany. Photo: V. Jaensch, RENAC.

Unless you run a large farm and use the excrements of several hundred livestock units and/or extensively use plant biomass from your fields, your own substrate will be sufficient only for a small plant. Cooperation with other organic farmers can enable you to start a larger biogas plant which usually is more economic. Make sure you know the regulations from your veterinarian authorities, if manure from more than one farm is used. Preconditions might include sanitation of the substrate, analyses for harmful substances and/or separate routes for transport of slurry and digestate.

Biogas production

An organic biogas manager once explained it drastically: "Producing biogas from maize silage and slurry is like driving on a motorway, fermenting mainly clover grass is like driving along a mountain track." This means: Before setting off, make sure to get the right gear, the right guide and the right training! While technology is a central issue when dealing with substrates rich in fibres, careful process management also needs particular attention.

Technology

Why does suitable technology for organic biogas plants have to differ from conventional solutions? Compared to biogas plants operating on the basis of maize and other cereal silage, the substrate in organic agriculture typically has:

- *More fibre* (lignin, cellulose) from grass, clover grass, landscaping material, and straw. The dry matter content in the fermenter is also high with 13 to 15 %. Impacts are higher strain on moving parts and pumps.
- *More protein* from clover grass, other legumes and in manure. Impacts are the building of swimming layers.[15] The activity of microbes – particularly during methanogenesis, is impaired.

In principle, the technology is quite similar with differences for some parts. In the following the special needs of organic biogas plants are described.[16] The technology used should be robust and proven, and the following issues should be kept in mind when choosing the right technology:

- Unwanted parts (like stones and sand) should be removed before the process and/or in the sediments of the fermenters.
- Feeding technology is the most liable part. It must be durable, reliable and energy efficient.
- Mechanical (or other) biomass disintegration or hydrolysis (an additional compartment for the first phase of biogas production) helps in degrading high fibre content and can be an option for more biogas and better substrate consistency.
- Pipelines for substrate pumping should be short with a large diameter, and pumps have to be robust (e.g. eccentric worm pump) and near the digester.
- Stirring equipment should have large and slow moving paddles and blades that can move the biomass and avoid a swimming layer. The stirring units should be selected with caution. They contribute considerably to the operating costs of biogas plants since their energy consumption is high and the moving parts have to be replaced after four to six years.
- External heating of the fermenter may cause problems as the high protein content of the substrate leads to a higher risk of proteins adhering to heating coils.
- High fermenters with low diameter facilitate stirring and help avoid swimming layers.

The process and the technology not only have to be designed to operate with the types of biomass available, farmers should also make sure that there is sufficient experience with the technology on working plants to ensure an efficient and reliable operation for many years. Your technology will process large quantities of inhomogeneous material every year causing considerable wear and tear. At the same time, the product biogas requires reliable and safe handling as it is highly flammable, explosive when mixed with oxygen and active as greenhouse gas when released into the atmosphere.

For all of these reasons, regular competent inspection and overhaul of the relevant parts are necessary. For machinery like CHP engines, manufacturers define intervals for inspection and overhaul, others like augers or pumps need to be routinely examined for actual wear and tear.

[15] Swimming layers are compactions in the fermenter on the top of the substrate causing problems with stirring and with the exit of methane from the substrate.
[16] For literature on general technical issues please consult the chapter "Further Information".


Figure 28: Vital for reliable operation is the regular overhaul of the CHP unit. In the picture: Engine cylinder pistons. Photo: F. Gerlach, MEP.

When asked by SUSTAINGAS, most organic farmers already running biogas plants were fairly satisfied with the operation of their project. However, repairs was the one issue which practitioners were most unhappy with – followed by the issues of daily operation costs and workload closely connected to the issue of frequent and costly repairs. Consequently, many farmers mentioned failures and repairs as a negative influence on the plant's economic situation.

When asked about plans for additional investment on the plant, several farmers mentioned the addition or extension of components such as substrate disintegration, heat utilisation or digestate storage. However, repeated mentioning of planned investments in stirring and feeding technology reflects the experience that the technology used didn't always meet the requirements of organic biogas production.

Process management

The "look, feel and smell"-approach of many farmers to quality management is a good start also for biogas production. No matter if the smell of your biomass, the structure of the substrate in the fermenter, the gas bubbles in the fermenter or the sound of your CHP engine are concerned: Use your senses and you'll get to know your biogas plant.

However, for high and reliable gas yields and for more insight into the "black box" of fermentation, you will need to know and document a considerable amount of data regularly:

- What goes in? (Substrates: Quantity, dry matter content, if possible expected gas yield)
- What comes out? (Digestate: Quantity, dry matter content, nutrient content)
- What happens in between? (Temperatures, content of acids, biogas production, methane and carbon dioxide content)

Daily documentation of input, output and process parameters is an absolute must if you intend to attain decent biogas yields!

To avoid fermentation problems e.g. due to nitrogen inhibition, the biogas process must be monitored closely by analysis of substrate properties in the fermenter as well as analysis of the biogas produced. A regular monitoring of free and total organic acids combined with a daily analysis of methane content in the biogas will give you a clear indication if biogas production in the fermenter is doing well. If problems arise, you can react early and avoid a drop in production.

Biogas use

Only rarely will biogas producers find a market for the biogas as it comes from the fermenter. Usually, the product "biogas" will be processed further and be sold as energy. While fuel production and biogas injection into the national gas grid are promising concepts, the combined production of electricity and/or heat at the site of biogas production so far remains the most widespread use for biogas.

CHP: Biogas for Electricity and Heat

In most cases biogas is used for the production of energy in Combined Heat and Power units (CHP units). Depending on individual strategy and the structure of costs and energy prices, the CHP unit will run only when heat and electricity are required, or it will also be operated when only the more valuable energy source is needed.

Figure 29: CHP: Biogas for Electricity and Heat. Photo: V. Jaensch, RENAC.

Often, biogas CHP units are operated without interruption to feed electricity continuously into the national grid. This will allow investment costs to be spread out over many hours of total running time. Alternative concepts restrict CHP operation to conditions when heat as well as electricity is utilised. This makes most efficient use of the energy contained in biogas. The geographical position of a biogas plant can very much limit the options for heat use. Advanced concepts allow for short term or regular interruption of electricity production when there is less demand for it or electricity production e.g. from wind and solar energy is high, thus contributing to a balance of supply and demand in a rapidly changing energy market.

Efficiency: From a given quantity of biogas as input, you intend to produce the maximum amount of valuable energy. For CHP plants, electricity and usable heat are relevant forms of output energy, with the focus usually on electricity. Please consider that smaller units generally produce less electricity per m³ biogas than larger units. A decent CHP unit of 100 kW_{el} will turn 35 to 37 % of the energy into electricity and some 45 % into heat, while a CHP of 500 kW_{el} may have an electric conversion of 38 to 41 % and a thermal conversion of about 45 %.

The standard CHP unit consists of a gas engine – an adapted Otto engine – and an electricity generator usually connected to the grid via current transformer. Small biogas plants tend to favour pilot injection gas engines. These follow the principle of adapted diesel engines and allow significantly higher electric efficiency, particularly where lower capacities are concerned. However, pilot injection gas engines are not run on biogas alone but need a proportion of about 5 to 10 % expensive liquid fuel like diesel, biodiesel or pure plant oil. Also, they have a reputation for needing more care and maintenance. This trade-off makes the decision for pilot injection less clear than it appears at first glance.

For economic viability as well as for reasons of efficiency, the heat generated by the CHP unit must be utilised to a high degree. Depending on legal conditions and contracts (e.g. organic farming associations' regulations or conditions for receiving grants), a certain amount of heat use may be mandatory. For small biogas plants there might be enough need for heat on the farm. Additional options are sales to residential areas, institutions or industry. A significant challenge even for small plants will be the use of surplus heat in the summer months. Examples for summer use of heat include drying processes, for example of grain, grass, wood chips, the digestate's fibre fraction, furthermore heating of production facilities, like greenhouses, or heating of public swimming pools. Producing cold from heat opens up a variety of additional uses like cold stores and air conditioning. Some plant operators consider advanced heat use concepts as an additional enterprise with considerable investment and the opportunity to participate in the unregulated market for heat energy.

Biogas for fuel

The idea of using the biogas as fuel for vehicles may attract some farmers. The biogas formed in the fermenter usually contains around 50 to 60 (sometimes 75) % methane. Engines running on generic biogas are technically possible but not generally available. Biogas as fuel is therefore used in engines adapted to the use of compressed natural gas (CNG). For this, more or less pure methane is needed. Therefore biogas has to be upgraded, that means cleaned from carbon dioxide, water, hydrogen sulphide and particulates.

There are several methods for biogas upgrading, having one thing in common: they require expensive investment. Under advantageous circumstances, fuel production may be economically feasible for biogas plants producing more than 50 m³ methane per hour (this is equivalent to an eclectic power output of the CHP of 200 kW). However, most related projects process considerably larger quantities. In many European countries, using natural gas for mobility is developing on a rather small scale. Therefore, a considerable challenge is the necessity to establish not only biogas upgrading and distribution of the fuel but also to kick-start a regional market for natural gas/biogas as fuel.[17]

Figure 30: The first Biogas-powered tractors attract attention at trade fairs and on the fields. Upgraded biogas is stored in tanks under floor and optionally at the front. Photo: F. Gerlach, MEP.

Biogas in the national gas grid

Upgraded biogas – also called biomethane – can be injected into the national natural gas grid. In some countries, a gas quantity equivalent to that fed into the grid can be sold as "biogas".

So far, this option is being practiced mainly by larger plants producing 100 to 1,000 m³ methane per hour (equivalent to 400 kW_{el} to 4 MW_{el} in a CHP engine). This has several reasons:

- Upgrading requires extensive investment. Depending on the requirements of the network operator, gas grid injection may need more elaborate upgrading than fuel production.
- For feeding in, additional steps (odorising, adaption of pressure and methane content etc.) have to be carried out with a high level of precision.
- Permission, contracts and verification for feeding in, conveying and discharging biogas are very complex issues. Rules and legislation for decentralised projects vary between countries.
- Even if national legislation makes feeding in possible, network operators are not always happy to accept biogas in their grids. Negotiations seem to be particularly hard for small-scale agricultural projects.

Once fed into the national gas grid, biogas can be transported nationally or even across borders to any user of natural gas connected to the same grid. Often, biogas in the national grid is used by CHP engines for efficient production of electricity and heat. However, its use in gas heating or for fuelling vehicles is also possible and depends very much on market conditions. Biogas plants feeding into the national gas grid may even choose to diversify their markets and establish an on-site biogas fuel station at moderate additional cost.

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[17] Several projects of biogas farmers cooperating with municipal utilities and gas station operators can be found in the IEE project GasHighWay: *www.gashighway.net*.

Use of digestate

What goes in – must come out! As a farmer, your soil nutrient management will change with the integration of biogas. What will be the main effects? Three examples will show the main changes.

Livestock farm with single-farm biogas plant

While the quantity of nutrients available will not change greatly since nutrients are little affected by the biogas process, you will gain a different quality of fertiliser. Instead of slurry and/or solid manure as main fertiliser, you will be provided with biogas digestate. This organic product from the fermentation can be compared to slurry, but (when originating from a wet fermentation process) shows the following significant differences:

- Lower dry matter content
- Higher content of plant available nitrogen (ammonia)
- Lower fibre content
- Significantly less odour

Existing slurry tanks on the farm may be used to store digestate. However, if using solid manure as input material, you will now have more liquid fertiliser than before and may therefore have to provide more storage tanks for sufficient storage space. Grassland farms will notice that digestate will run off the plants and infiltrate into the ground more easily than untreated slurry.

Since most weed seeds will have become infertile in the biogas process, spreading weeds is less of a problem than it used to be with manure.

Higher plant availability of nutrients means that you may now provide your plants with nutrients at the right moment more easily. But due to the high ammonia content, application techniques reducing nutrient losses are even more necessary for digestate than they are for slurry. Applying the digestate at low temperatures and without direct sunlight directly on or into the ground will keep the nutrients where you want them - in your cropping system.

Stockless crop farm with single-farm biogas plant

You will have a storable and mobile fertiliser available which you may use whenever needed – maybe for the first time since your conversion to organic agriculture. While the effect of legume cultivation on nitrogen content in the soil will still be similar (roots and nitrogen fixing bacteria remain in the soil), you'll have the digestate as an additional source of nutrients.

As stockless farmer you will need to refocus your soil nutrient management: Due to its high ammonia content even compared to slurry, digestate as a fertiliser is ready-to-use with nutrients highly plant available, but must be applied corresponding to plant needs to minimise nutrient losses.

Biogas plant with input from outside the farm system

A biogas plant may receive input not only from one farm but also from cooperating farms or – in the case of waste – non-farm partners. In addition to the effects mentioned above, these systems will experience additional effects on nutrient management.

The digestate storage can now be seen as a joint provision of fertiliser for several farms and will need to be shared in relation to nutrient input. Shifting nutrients from one farm to the other is restricted by the need for fertiliser on all farms and by organic regulations. However, some input of additional nutrients into the system is possible, e.g. in the case of grass from conservation areas, off-farm residues or organic waste, where the partners typically don't have any need for digestate. If conventional substrates supplement the input of a biogas plant that also uses manure/slurry from organic farming, organic agriculture regulations prohibit the return of digestate to the conventional partner.

If a plant uses waste materials, legal restrictions concerning the use of digestate may apply. Depending on the type of material, this may include more extensive documentation, hygiene measures, regular analysis of contents and limitations on the quantity of digestate to be distributed.[18] You may still welcome the additional nutrient input of waste materials as long as the digestate remains an asset and does not turn into a liability.

For more about organic farming rules on digestate use see Table 2 on page 11.

Humus: The Cropping system counts!

Neither livestock nor stockless farmers have much to worry about changes to their soil's humus content following the use of digestate. The carbon fraction responsible for humus generation largely remains in the digestate.

While it is too early for definite long-term results on the use of digestate, research suggests that humus content is mainly influenced by changes in crop rotation, not by the use of digestate.

Biogas offers additional options for more sustainable crop rotations – it's up to you to use them!

Making the most of it: Biogas digestate as fertiliser

Digested biomass has a high proportion of nutrients readily available for the plant. This can increase nutrient availability and give the plants that head start they need in early spring. In order to let the nutrients benefit plant growth, careful management – like known from the management of liquid animal manure – is vital. Minimising Nitrogen losses from digestate is a win-win-situation for economics and sustainability since it will waste no valuable plant nutrients and at the same time will avoid emissions of ammonia and nitrous oxide. Therefore you should aim to:

- Cover storage tanks
- Let digestate cool to outside temperature before application
- Only apply at the appropriate season and in suitable weather conditions (cool, no or low wind, no direct sunlight)
- Analyse nutrient content and apply according to plant needs
- Apply digestate close to the soil and cultivate the soil directly after application or insert into the soil

Efficiency

At the end of the day, you will need to compare input and output of the entire biogas process. Is the production of the biogas plant efficient? Does the production of energy and digestate make the biomass input, the investment and the work worthwhile? Can the process be improved?

We advise you to

- beware of simple answers,
- regard your individual plant rather than comparing average figures of plants unlike your own, and
- take into account that efficiency is a result of the interplay between technology, biomass, biological processes and management. This will need to evolve over the years of operation.

What's wrong with benchmarks like the efficiency of biological conversion (m^3 biogas per t of biomass) or of technical conversion (kilowatt hour electric power (KWh_{el}) per m^3 biogas)? Nothing – except that this kind of isolated comparison will not tell the whole story. An efficient biogas plant is one that successfully balances a range of factors for maximum output with minimum input. Biogas in organic agriculture can rank very high in overall

[18] For details you will need to consult authorities in your region.

efficiency. However, an organic biogas plant will typically have benchmarks for factors influencing overall efficiency which differ somewhat from biogas plants in conventional agriculture:

Biological conversion efficiency: How much methane is produced from the biomass? This factor depends on the type of biomass and the technology used. There are great variations between plants. Substrate rich in starch and sugars like maize or beet will allow higher conversion rates than biomass with a high content of lignocelluloses (e.g. clover grass, landscaping material, straw), but longer retention time, high temperatures or biomass disintegration may greatly improve biogas yield from substrates rich in lignocellulose.

Figure 31: The biogas energy output from solid manure as substrate (in the foreground) may be lower than from silage (background), but the energy input for manure supply is negligible as it is a residue from animal husbandry. Photo: V. Jaensch, RENAC.

Since digestate is particularly relevant for organic farms, not only factors like the biological conversion efficiency but also the question of quality and quantity of fertiliser produced should be considered.

Technical conversion efficiency: How much electric power is produced from the biomass? Large units will generally have a better electric output than small-scale engines, but local use of the produced energy may be an advantage of small scale production. The degree and quality of heat utilisation is very specific to the situation of the individual project, but has great influence on overall efficiency. While the efficiency of biogas CHP units today range between about 35 and 45 % depending on size and technology used, heat use may account for another 0 to 45 %. The German organic farming association Bioland has fixed a conversion efficiency of 70 % as threshold for organic biogas production.

Auxiliary consumption: How much of the energy produced is needed for the plant's operation? We need to distinguish between the plant's requirements for electricity e.g. to operate pumping and stirring equipment on the one hand and its heat consumption to keep the fermenters at operating temperature.

Regarding the electricity produced, auxiliary consumption typically ranges between 5 and 15 % and will increase with the viscosity of the substrate. Plants constantly using their full capacities will have a better value than projects with many holdups in production or plants strategically storing gas for demand-oriented energy production. Comparison between farms is very difficult, but there is scope for improvement on plants.

Looking at thermal energy, about 5 to 20 % of the heat produced is needed – depending e.g. on insulation, fermenter size, temperatures and substrate input. There will be a high demand for heat when slurry or other substrate with high water content is used. In winter, when heat is most valuable, the fermenter will also need more thermal energy.

Even though hardly any biogas operation will excel in all aspects of efficiency, every project will be able to develop superior degrees of efficiency in some respects. Particularly biogas plants in organic agriculture can attain a very high degree of overall efficiency in the context of agricultural biogas when processing residues and efficiently using the digestate.

8 Further information

Biogas in general

- **Guide to biogas**
  Fachagentur nachwachsende Rohstoffe, 2012
- **Biogas – an introduction**
  Fachagentur nachwachsende Rohstoffe, 3rd edition, 2009
- **Biogas Handbook**
  BiG>East project, 2008
  http://kurzlink.de/BigEast-Handbook
- **European Agricultural AD Helpdesk**
  with information on economics, mixtures and contacts to biogas experts
  www.adhelpdesk.eu
- **European Biogas Association (EBA)**
  non-profit organisation aiming to promote the deployment of sustainable biogas production and use in Europe
  www.european-biogas.eu/
- **Anaerobic digestion portal**
  Information on anaerobic digestion, biogas and digestate
  www.biogas-info.co.uk
- **German Association for Technology and Structures in Agriculture**
  Reference figures for farming and more
  www.ktbl.de
- **German Society for sustainable Biogas and Bioenergy Utilization**
  Promotion and distribution of sustainable generation and use of energy made out of organic biomass
  www.fnbb.org/index.php?id=fnbb-aktuell&no_cache=1
- **International Biogas and Bioenergy Centre of Competence (IBBK)**
  network of experts and companies, as well as groups of interest and educational institutes in the field of biogas and bioenergy
  www.biogas-zentrum.de

Biogas in organic farming

- **SUSTAINGAS**
  Enhancing sustainable biogas production in organic farming
  www.sustaingas.eu

Organic agriculture

- **IFOAM**
  International Federation of Organic Agriculture Movements
  www.ifoam.org
- **IFOAM EU-Group**
  European umbrella organisation for organic food and farming
  www.ifoam-eu.org
- **Organic Europe**
  website with statistics, country reports and contact addresses
  www.organic-europe.net

Legal sources on biogas

- **RES LEGAL**
  European information on legislation concerning support schemes, grid issues and policies for energy from renewable sources covering electricity, heating/cooling and transport. Covers the EU 27 Member States, the EFTA Countries and some EU Accession Countries
  www.res-legal.eu/home/

EU-Projects with regard to biogas

- **AGRIFORENERGY 2**
  Promoting and securing the production of biomass from forestry and agriculture without harming the food production
  www.agriforenergy.com
- **BIOENERGY FARM**
  Implementation plan for BioEnergy Farm
  www.bioenergyfarm.eu
- **BIOGAS REGIONS**
  Promotion of biogas and its market development through local and regional partnerships
  www.biogasregions.org
- **BIOGASACCEPTED**
  Promoting Biogas in European Regions – Transfer of a Supporting Acceptance Tool for Stationary and Mobile Applications
  www.studia-austria.com/en/downloads.php
- **BIO-METHANE REGIONS**
  Promotion of Bio-Methane and its Market Development through Local and Regional Partnerships
  www.bio-methaneregions.eu
- **BIOPROFARM**
  Promotion of Biomethanisation in Agricultural Environment as a Decentralized Renewable Energy Resource for Europe
  www.terrenum.net/biogas/design.html
- **GasHighWay**
  Promoting the Uptake of Gaseous Vehicle Fuels, Biogas and Natural Gas in Europe
  www.gashighway.net
- **GERONIMO II-BIOGA**
  A Focussed Strategy for Enabling European Farmers to Tap into Biogas Opportunities
  www.energy4farms.eu
- **GR3**
  Grass as a Green Gas Resource: Energy from landscapes by promoting the use of grass residues
  www.dlv.be
- **GREENGASGRIDS**
  Boosting the European Market for Biogas Production, Upgrade and Feed-In into the Natural Gas Grid
  www.greengasgrids.eu
- **REDUBAR**
  Investigations targeted to the creation of legislative instruments and the reduction of administrative barriers for the use of biogas for heating, cooling and power generation
  www.redubar.eu

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Studienzentrum für internationale Analysen

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www.ecofys.com

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International Federation of Organic Agriculture

Movements European Union Regional Group

www.ifoam-eu.org

Økologisk Landsforening

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www.okologi.dk

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Spain

www.protecma.es

Renewables Academy AG

Germany

www.renac.de