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Biogas



BIOGAS Digest

- **Basics**
- **Framework Conditions**
- **Application and Product Development**
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Biogas plants constitute a widely disseminated branch of technology that came into use more than 30 years ago in developing countries. There are hundreds of thousands of simple biogas plants now in operation, and each one of them helps to improve the living conditions of people in rural areas. Biogas systems are an efficient way of dealing with organic waste, dung and crop residues while making optimal use of their energetic as well as nutrient content.

In addition to generating renewable energy, biogas systems help to stimulate ecologically beneficial closed-loop systems in the agricultural sector while improving soil quality and promoting progress in animal husbandry and farming.

While the main focus is on biogas systems of simple design, the technology is nonetheless complex enough to warrant close attention to its proper application, planning and construction. Only a well-planned, carefully constructed and properly functioning biogas system will fulfill its purpose of improving living conditions in rural areas.

You will find useful and detailed information about all aspects of biogas plant design and maintenance, biogas appliances, social, political, economic and ecological framework conditions, planning and dissemination of biogas systems and last but not least country- and project-specific information.

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Biogas Application

Maintenance, Monitoring and Repair

The maintenance of a biogas plant comprises all work which is necessary to guarantee trouble-free operation and a long working life of the plant. Repair reacts to breakdowns of the biogas system. Maintenance services should be carried out by the manager or main operator of the biogas plant or a well-trained biogas technician. One has to bear in mind that measurements indicating problems may be wrong. All doubtful measurements have to be verified. Often, one symptom has a variety of possible reasons.

Daily maintenance work

Control	Mistakes	Removal
gas pressure	gas pressure too high; (gas pressure rises, if gas consumption is lower than the production and if the gas storage is full)	The pressure relief valve malfunctions - it should be cleaned or renewed;

	gas pressure too low; (gas pressure falls, if the consumption (including leakage!) is higher than the production and if the gas storage is empty);	leakage in gas conducting parts: find out the leakage and seal; gas production has fallen: check the sludge's quality;
substrate temperature (heated plants) (bacteria are very sensitive to temperature extremes and fluctuations);	temperature too high;	defective heating control system. Check control system and repair or exchange part(s) concerned;
	temperature too low;	defective heating control system. Check control system and other concerned part(s), repair or exchange; sediment layer on the heating surface: remove layer;
gas production	gas production clearly under normal levels;	biological reasons: temperature, substrate, antibiotics, change of pH-value; leakage in digester or piping system; blocked gas pipes due to water or alien elements;

		identify problem and act accordingly;
strong sludge odor	plant is overloaded or fermenting conditions are sub-optimal;	reduce substrate intake; correct pH-value with adequate means;

Weekly/monthly (prophylactic) maintenance work

- clean gas appliances;
- lubricate movable parts (slides, guiding frame of floating drum plants, taps etc.);
- servicing of biogas-driven engines within the prescribed time intervals;
- maintenance of pressure relief valves and under pressure valves;
- maintenance of slurry agitator / mixer;
- control gas appliances and fittings on tightness and function

Control of functions

Control	Mistakes	Removal
water separator	non-automatic water separator is full;	empty the water separator;
piping system	no water is collected in the water separator; gradient of the pipes is wrong;	Reinstall pipes in a way that condensation flow leads to the water separator;

pressure relief and under pressure valves	non-functioning	clean valves or renew them
---	-----------------	----------------------------

Annual maintenance work

- Check the plant in respect of corrosion and, if necessary, renew protective coating material;
- Check the gas pipes for gas tightness (pressure check). If necessary, search the leakage and repair the parts concerned. Note: minor gas leakage is usually undetected during normal operation as it is 'compensated' by gas production

Monitoring

Monitoring subsumes all activities of data collection regarding an individual biogas unit or biogas programs. Collecting data on the performance of biogas units is necessary to

- detect problems in the unit's performance;
- to have a base for economic evaluation;
- to have a base for comparing different models and different modes of operation

Measurements and other data which become necessary for the optimization of the existing biogas unit should be recorded by the owner or by a person appointed by him/her. The records should include the following data:

- The amount and type of substrate, incl. the amounts of mixing water.

- The substrate temperature, if necessary at various stages of the substrate flow (heated plants). By measuring the substrate temperature, faults in the heating system can be detected.
- Gas production: measurements are carried out with a gas meter between the digester and the gas-holder (gas production) or between the gas-holder and the points of consumption (gas consumption). In simple plants, the gas production can be estimated during times of no consumption. Changes in gas production and the speed by which these changes occur give valuable hints on the nature of the problem.
- Electricity and heat production from co-generation units;
- pH-value (monthly); recorded substrate intake;
- content of hydrogen sulfide in the gas (monthly);
- analysis of the fertilizing value of biogas slurry (annually or seasonally) to determine the optimal amount of slurry to be spread on the fields.
- Records on breakdowns and their causes. By means of previously recorded breakdowns it is easier to compare the breakdowns and detect the reasons for failure.

Beyond this, there are various institutions, associations and companies which carry out series of measurements for different kinds of biogas plants. These series of measurements, records and evaluations analyze errors with the objective to disseminate and optimize biogas technology as well as to avoid mistakes of the past.

Repair

Breakdowns which might appear when operating biogas plants are described in the following. The most frequently occurring disturbance is insufficient gas production which can have a variety of different reasons. Sometimes observations and experiments might take weeks until a perfect solution is found.

Disturbances	Possible reasons	Measures to be taken
blocked inlet/outlet pipe	fibrous material inside the pipe or sinking layer blocking the lower end of the pipe	cleaning up the pipe with a pole; removing sinking layer by frequent 'poking' through inlet and outlet pipe.
floating drum is stuck	swimming layer	turn the dome more frequently; if turning not possible, take off the dome and remove the swimming layer
	broken guiding frame	weld, repair and grease guiding frame
sinking sludge level	digester not water-tight	if cracks in the digester do not self-seal within weeks, empty digester and seal cracks;
insufficient gas storage	gas store not gas-tight due to cracks or corrosion	seal cracks, replace corroded parts;
blocked taps	corrosion	open and close several times, grease or replace taps;
gas pipe is not tight	corrosion or porosity; insufficient sealing of connections;	identify leaking parts; replace corroded or porous parts; re-seal connections
	1. crack in the gas pipe	1. repair or replace 2. add/refill water, detect reason for over-

sudden gas loss	<ol style="list-style-type: none"> 2. automatic water trap blown empty 3. open gas tap 	<p>pressure; check dimensioning of the water-trap</p> <ol style="list-style-type: none"> 3. close tap
throbbing gas pressure	<ol style="list-style-type: none"> 1. water in the gas pipe 2. blocked gas pipe 	<ol style="list-style-type: none"> 1. check functioning of water trap; install water traps in depressions of piping system or eliminate these depressions; 2. identify the blocked parts (start with gas outlet, connections to appliances and bends); clean the respective parts;

Repair measures are being taken in case of acute disturbances or during routine maintenance work. Repair measures which go beyond routine maintenance work have to be carried out by specialists, since the biogas plant owner in most cases does not have the required tools and the necessary technical know-how. In any case, annual maintenance service should be carried out by a skilled biogas technician.

In industrialized countries with large plants and good infrastructure, a professional biogas service can cover a large area. In developing countries with scattered small scale biogas units, logistical problems can severely hamper the evolution of a professional and commercial biogas service. To ensure that built biogas units are maintained and, if necessary, repaired, the following approaches are conceivable:

- **The farmer technician approach:** out of a group of biogas farmers, an outstanding individual is encouraged to undergo maintenance and repair training to take this up as a side job. Emphasis has to be placed on management training. To make his enterprise sustainable, the farmer

technician should gain a reasonable income.

- **The cluster approach:** if the demand for biogas plants is high, the biogas project or the biogas company can attempt to install biogas units in a regional clustering to minimize distances for the maintenance service.
- **The subsidized transport approach:** a professional biogas technician is supported with transport by the biogas project or government departments (e.g. agricultural extension, veterinary service). The technician can also receive a bicycle or small motorbike as an initial input, running costs can either initially be shared by the biogas project or directly be charged to the farmers.

However the logistical problems may be solved, the critical ingredient for the evolution of a professional and commercial biogas service is the training of the technicians-to-be both in technical and managerial terms. Experience shows, that this can take several years. Biogas projects should, therefore, plan with a not too narrow time horizon.

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Biogas Application

Operation and Use

The day-to day operation of a biogas unit requires a high level of discipline and routine to maintain a high gas production and to ensure a long life-span of the biogas unit. Many problems in the performance of biogas plants occur due to user mistakes or operational neglect. Often, these problems can be reduced,

- by less complicated designs that are adapted to the substrate, the climatic conditions and the technical competence of the user,
- by high-quality and user-friendly appliances,
- by design and lay-out of the biogas for convenient work routine,
- by proper training and easy access to advice on operation problems.

During design selection, planning, construction, handing over and follow-up, the biogas extension program should emphasize further on a reduction of the users' workload for operating the biogas unit and using the gas and the slurry. In particular during work peaks for farm work, it is important that the biogas unit relieves the user from work rather than adding to the workload. As a general rule, the farming family should have *less work with a biogas unit than without it*, while enjoying the additional benefits in terms of a clean fuel and high quality fertilizer.

Daily operation

Feeding of the digester

In larger biogas units, the dung, urine and other substrate usually enter the plant by pipes, channels, belts or pumps. The available substrate has to enter the digester as soon as it is available to avoid pre-digestion outside the digester. The functioning of the feeding mechanisms has to be checked

daily. Separators for unsuitable material have to be checked and emptied. The amounts of substrate fed into the digester may be recorded to monitor the performance of the biogas plant.

Smaller plants in developing countries are fed by hand. The substrates, often dung and urine, should be thoroughly mixed, plant residues should be chopped, if necessary. Obstructive materials like stones and sand should be removed from the mixing chamber. Simple tools like a rubber squeegee, a dipper, forks to fish out fibrous material, proper buckets and shovels greatly facilitate this work. Filling work is further made easier by smooth concrete stable-floors and a minimized distance between the stable and the plant.

Agitation

In industrialized countries and for large plants in developing countries, engine driven stirring devices are the norm. Usually, but not always, they are operated automatically. The user, however, should check the operation of the stirring device daily.

Small size biogas plants have manual stirring devices that have to be turned by hand as recommended. If there is no stirring device, poking with sticks through the inlet and outlet is recommended. The stick should be strong, long enough but not too heavy. It should have a plate fixed at the end (small enough to fit in the inlet-/outlet pipes) to produce a movement of the slurry. Regular poking also ensures that the inlet/outlet pipes do not clog up. The drums of floating drum plants should be turned several times a day.

Experience shows that stirring and poking is hardly ever done as frequently as it should be. Farmers should be encouraged to run a trial on gas production with and without stirring. The higher gas production will convince the user more than any advice.

Controlling the overflow

A special problem of small scale fixed dome plants is the clogging up of the overflow point. This can lead to over-pressure (the hydraulic pressure increases with the slurry level in the expansion chamber) and to clogging of the gas outlet if too much slurry flows back into the digester. The overflow point should, therefore, be checked and cleaned daily.

Slurry distribution

If the slurry distribution is done directly by gravity, the slurry furrows need to be checked and slurry diverted accordingly. Slurry may be applied from the furrows directly to the plant with the help of dippers or shovels.

Weekly / monthly operation

- Controlling of the water separator
- Renewing the agents of the gas purification system (if existing)
- Mixing the swimming and sinking layers of in the expansion chamber of fixed dome plants
- The water sealing of the lid in the man hole of a fixed dome plant should be checked and filled up
- Gentle cleaning of the drum of a floating drum plant
- Checking and filling up the water jacket of water jacket plants
- Flexible pipes above ground should be checked for porosity
- Slurry storage tanks should be checked and emptied, if required and slurry flows diverted accordingly

Annual operation

- Swimming layers should be removed from the digester
- The whole plant and digester should be exposed to a pressure test once a year to detect lesser leakages

Security

When operating a biogas plant special attention has to be paid to the following dangers:

- Breathing in biogas in a high concentration and over longer periods of time can cause poisoning and death from suffocation. The hydrogen sulfide contents of biogas is highly poisonous. Unpurified biogas has the typical smell of rotten eggs. Purified biogas is odorless and neutral. Therefore, all areas with biogas operating appliances should be well ventilated. Gas pipes and fittings should be checked regularly for their gas-tightness and be protected from damage. Gas appliances should always be under supervision during operation. Everybody dealing with biogas, in particular children, should be instructed well and made aware of the potential dangers of biogas.
- After emptying biogas plants for repair, they have to be sufficiently ventilated before being entered. Here the danger of fire and explosion is very big (gas/air mixture!). The so-called chicken test (a chicken in a basket enters the plant before the person) guarantees sufficient ventilation.
- Biogas in form of a gas-air mixture with a share of 5 to 12 % biogas and a source of ignition of 600C or more can easily explode. Danger of fire is given if the gas-air mixture contains more than 12 % of biogas. Smoking and open fire must therefore be prohibited in and around the biogas plant.
- The initial filling of a biogas plant poses a particular danger, when biogas mixes with large empty air-spaces. A farmer may want to check with an open flame how full the plant is already and cause an explosion.
- The digester of a biogas plant and the slurry storage facilities should be built in such a way that

neither persons nor animals are in danger of falling into them.

- Moved and movable parts should have a protective casing to avoid catching persons or animals.
- Appliances operating on biogas normally have high surface temperatures. The danger of burning is high, in particular for children and strangers. A casing of non-heat-conducting material is advisable.
- The mantle of the gas lamp is radioactive. The mantle has to be changed with utmost caution. Especially the inhalation of crumbling particles must be avoided. Hands should be washed immediately afterwards.
- The piping system can form traps on the farm compound. As much as possible, pipes should be laid some 30 cm underground. Pits for water traps, gas meters, main valves or test-units should be cased by a concrete frame and covered with a heavy concrete lid.

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Biogas Application

Biogas - Sludge Management

Sludge storage

To retain the maximum fertilizing quality of digested slurry, i.e. its nitrogen content, it should be stored only briefly in liquid form in a closed pit or tank and then applied on the fields. Preferably, it should be dug into the soil to prevent losses on the field.

Sludge storage is normally effected according to one or the other of the following three techniques

- **Liquid storage**
- **Drying**
- **Composting**

Liquid storage

The effluent outlet of the biogas system leads directly to a collecting tank. Loss of liquid due to evaporation or seepage must be avoided. Just before the sludge is needed, the contents of the tank is thoroughly agitated and then filled into a liquid manure spreader or, if it is liquid and homogenous enough, spread by irrigation sprinklers. The main advantage of liquid storage is that little nitrogen is lost. On the other hand, liquid storage requires a large, waterproof storage facility entailing a high initial capital investment.

The practice of spreading liquid slurry also presents problems in that not only storage tanks are needed, but transport vessels as well. The amount of work involved depends also on the distance over which the slurry has to be transported. For example, loading and transporting one ton of slurry over a distance of 500 m in an oxcart (200 kg per trip) takes about five hours. Distributing one ton of slurry on the fields requires another three hours.

Drying

It is only possible to dry digested sludge as long as the rate of evaporation is substantially higher than the rate of precipitation. The main advantage of drying is the resultant reduction in volume and weight. Drying can also make the manual spreading easier. The cost of constructing shallow earthen drying basins is modest. On the other hand, drying results in a near-total loss of inorganic nitrogen (up to 90%) and heavy losses of the total nitrogen content (approx. 50%).

Composting

Nitrogen losses can be reduced by mixing the digested sludge with organic material. As an additive to crop residues for composting, biogas sludge provides a good source of nitrogen for speeding up the process. At the same time it enriches the compost in nitrogen, phosphorus and other plant nutrients. Furthermore, the aerobic composting process, by its temperature, effectively destroys pathogens and parasites that have survived the anaerobic digestion treatment. The ready-made compost is moist, compact and can be spread out by simple tools. With most available transport facilities in developing countries, it is easier to transport than liquid manure.

Composition of sludge

Process of biomethanation

Anaerobic digestion draws carbon, hydrogen and oxygen from the substrate. The essential plant nutrients (N,P,K) remain largely in the slurry. The composition of fertilizing agents in digested slurry depends on the



Drying of digested sludge and sludge disposal in Thailand

Photo: Kossmann (gtz/GATE)

fermented substrate and can, therefore, vary within certain limits.

For an average daily substrate feed rate of 50 kg per livestock unit (LSU = 500 kg live weight) and a daily gas yield of 1 m³ biogas/LSU, the mass of the influent substrate will be reduced by some 2% through the process of bio-methanation (volumetric weight of biogas: 1.2 kg/m³).

Viscosity

The viscosity of the slurry decreases significantly, because the amount of volatile solids is reduced by about 50% in the course of a stable process of fermentation. In addition, the long carbon chains (cellulose, alcohol and organic acids) are converted into short carbon chains (see also under **Microbiology**).

Odor

The effluent sludge is much less odorous than the influent substrate (dung, urine). Given sufficient retention time, nearly all odorous substances are completely digested.

Nutrients

The fertilizing properties of digested slurry are determined by how much mineral substances and trace elements it contains. In tropical soil, the nitrogen content is not necessarily of prime importance - lateritic soils, for example, are more likely to suffer from a lack of phosphorus. All plant nutrients such as nitrogen, phosphorous, potassium and magnesium, as well as the trace elements essential to plant growth, are preserved in the substrate. The **C/N ratio** is reduced by the simultaneous loss of carbon, thus generally improving the fertilizing effect of the digested sludge, since a lower C/N ratio (ca. 1:15) has a favorable phytophysiological effect. **Table B4** lists the approximate nutrient contents of various substrates, whereby it should be remembered that the actual values may vary

considerably, depending on fodder eaten by the animals.

The phosphate content (" P_2O_5 " is the form of phosphorous available for plants) is not affected by fermentation. Some 50% of the total phosphorous content is available for plants in the form of phosphate. Similarly, anaerobic fermentation does not alter the rate of plant-available potassium (75 to 100% of the total potassium).

Nitrogen compounds

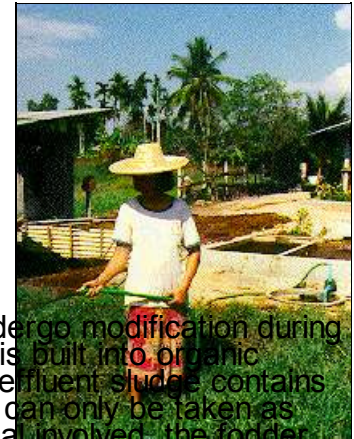
In contrast to the above nutrients, however, some nitrogen compounds undergo modification during anaerobic digestion. About 75% of the nitrogen contained in fresh manure is built into organic macromolecules, and 25% is available in mineral form as ammonium. The effluent sludge contains roughly 50% organic nitrogen and 50% mineral nitrogen. The stated levels can only be taken as approximate values, since they vary widely, depending on the type of animal involved, the fodder composition, the retention time, etc. Mineral nitrogen can be directly assimilated by plants, while organic nitrogen compounds must first be mineralized by microorganisms in the soil.

Fertilizing effect of effluent sludge

Digested slurry is most effective when it is spread on the fields shortly before (or at the beginning of) the vegetation period. Additional doses can be given periodically during the growth phase, with the amounts and timing depending on the crop in question. For reasons of hygiene, however, leafy vegetables should not be top-dressed.

Assuming that the soil should receive enough fertilizer to replace the nutrients that were extracted at harvesting time, each hectare will require an average dose of about 33 kg N, 11 kg P_2O_5 and 48 kg K_2O to compensate for an annual yield of 1-1.2 tons of, for example, sorghum or peanuts.

Depending on the nutritive content of the digested slurry, 3-6 t of solid substance per hectare will be required to cover the deficit. For supply with a moisture content of 90%, the required quantity comes to 30-60 t per hectare and year. That roughly corresponds to the annual capacity of a 6-8 m³ biogas



Sludge disposal in Thailand (oder zu soileffekt)

Photo: Kossmann

(GATE)

plant.



Field experiments with sludge in Thailand

Photo: Kossmann (gtz/GATE)

Caustic effect on grassland

Digested sludge has much less caustic effect on grassland than does fresh liquid manure. Effluent sludge is also very suitable for use as a "top-dressing" whenever its application is deemed to have the best fertilizing effect.

Eutrophication

Serious ecological damage can be done by applying fertilizing sludge in excessive amounts or at the wrong time, namely when the assimilative capacity of the plants is low. Nitrogen "washout" can cause over-fertilization (eutrophication) of ground and surface water.

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Biogas Application

Annual Manure Yield and Nutrient Content of Animal Excrements

[preformatted text version of the table]

Total annual yield [kg/LSU/a] and percentage shares							
	Total Wt.	TS		VS		N	
	kg/a	kg/a	[%]	kg/a	[%]	kg/a	[%]
Cow	16,100	1850	11.6	1400	8.7	77	0.5
Pig	13,500	1130	8.4	900	6.7	102	0.8

Chicken (fresh droppings)	18,250	4020	22.0	3170	17.4	232	1.3
Chicken (dry droppings)	4,230	3390	80	2560	60	146	3.5

	Total annual yield [kg/LSU/a] and percentage shares				Nutritive ratio (P ₂ O ₅ = 1)		
	P ₂ O ₅		K ₂ O		N	P ₂ O ₅	K ₂ O
	kg/a	[%]	kg/a	[%]			
Cow	34	0.2	84	0.5	2.3	1	2.5
Pig	56	0.4	35	0.3	1.8	1	0.6
Chicken (fresh droppings)	194	1.0	108	0.6	1.2	1	0.6
Chicken (dry droppings)	193	4.6	106	2.5	0.8	1	0.6

Table B4: Annual manure yield and nutrient content of cow, pig and chicken excrements; compiled from various sources

Source: Production and Utilization of Biogas in Rural Areas of Industrialized and Developing Countries, Schriftenreihe der gtz, No. 97, pp. 71-72; after: Rager, K. Th.: Abwassertechnische und wasserwirtschaftliche Probleme der Massentierhaltung; Darmstadt, FRG, 1971, p. 38

LSU = livestock unit (= 500 kg live weight)

TS = Total solids

VS = Volatile solids

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Biogas Application

Annual Manure Yield and Nutrient Content of Animal Excrements

Total annual yield [kg/LSU/a] and percentage shares

Total Wt.	TS	VS	N
kg/a	kg/a	[%]	kg/a
		[%]	[%]

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Cow	16,100	1850	11.6	1400	8.7	77	0.5
Pig	13,500	1130	8.4	900	6.7	102	0.8
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Total annual yield [kg/LSU/a] and percentage shares Nutritive ratio
(P205 = 1)

P205 K20

kg/a [%] kg/a [%]

N P205 K20

Cow	34	0.2	84	0.5	2.3	1	2.5
Pig	56	0.4	35	0.3	1.8	1	0.6
Chicken (fresh droppings)	194	1.0	108	0.6	1.2	1	0.6
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Biogas Application

Biogas Utilization

Gas production

If the daily amount of available dung (fresh weight) is known, gas production per day in warm tropical countries will approximately correspond to the following values:

- 1 kg cattle dung 40 liters biogas
- 1 kg buffalo dung 30 liter biogas
- 1 kg pig dung 60 liter biogas
- 1 kg chicken droppings 70 liter biogas

If the live weight of all animals whose dung is put into the biogas plant is known, the daily gas production will correspond approximately to the following values:

- cattle, buffalo and chicken: 1,5 liters biogas per day per 1 kg live weight
- pigs, humans: 30 liters biogas per day per 1 kg weight

See **table B1** for yield ranges and methane contents for 33 different substrates, including plant material and residues.

Conditioning of biogas

Sometimes the biogas must be treated/conditioned before utilization. The predominant forms of treatment aim at removing either **water**, **hydrogen sulfide** or **carbon dioxide** from the raw gas:

Reduction of the moisture content

The biogas is usually fully saturated with water vapor. This involves cooling the gas, e.g. by routing it through an underground pipe, so that the excess water vapor condenses at the lower temperature.

When the gas warms up again, its relative vapor content decreases. The "drying" of biogas is especially useful in connection with the use of dry gas meters, which otherwise would eventually fill up with condensed water.

Reduction of the hydrogen-sulfide content

The hydrogen sulfide in the biogas combines with condensing water and forms corrosive acids. Water-heating appliances, engines and refrigerators are particularly at risk. The reduction of the hydrogen sulfide content may be necessary if the biogas contains an excessive amount, i.e. more than 2% H_2S . Since most biogas contains less than 1% H_2S , de-sulfurization is normally not necessary.

For small- to mid-size systems, de-sulfurization can be effected by absorption onto ferric hydrate ($\text{Fe}(\text{OH})_3$), also referred to as bog iron, a porous form of limonite. The porous, granular purifying mass can be regenerated by exposure to air.

The absorptive capacity of the purifying mass depends on its iron-hydrate content: bog iron, containing 5-10% $\text{Fe}(\text{OH})_3$, can absorb about 15 g sulfur per kg without being regenerated and approximately 150 g/kg through repetitive regeneration. It is noteworthy that many types of tropical soils (laterite) are naturally ferriferous and suitable for use as purifying mass.

Another de-sulfurization process showing good results has been developed in Ivory Coast and is applied successfully since 1987. Air is pumped into the gas store at a ratio of 2% to 5 % of the biogas production. The minimum air intake for complete de-sulfurization has to be established by trials. Aquarium pumps are cheap and reliable implements for pumping air against the gas pressure into the gas holder. The oxygen of the air leads to a bio-catalytic, stabilized separation of the sulfur on the surface of the sludge. This simple method works best, where the gas holder is above the slurry, as the necessary bacteria require moisture, warmth (opt. 37C) and nutrients.

In industrialized countries and for large plants, this process has meanwhile reached satisfactory standard. For small scale plants in developing countries, however, using an electric pump becomes problematic due to missing or unreliable electricity supply. Pumping in air with a bicycle pump works

in principle, but is a cumbersome method that will be abandoned sooner or later.

Avoiding de-sulfurization altogether is possible, if only stainless steel appliances are used. But even if they are available, their costs are prohibitive for small scale users.

Reduction of the carbon-dioxide content

The reduction of the carbon-dioxide content is complicated and expensive. In principle, carbon-dioxide can be removed by absorption onto lime milk, but that practice produces "seas" of lime paste and must therefore be ruled out, particularly in connection with large-scale plants, for which only high-tech processes like micro-screening are worthy of consideration. CO₂ "scrubbing" is rarely advisable, except in order to increase the individual bottling capacity for high-pressure storage.

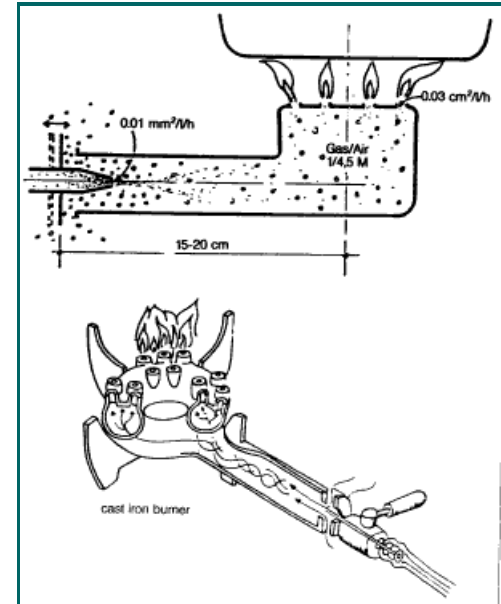
Biogas burners

In developing countries, the main prerequisite of biogas utilization is the availability of specially designed biogas burners or modified consumer **appliances**. The relatively large differences in gas quality from different plants, and even from one and the same plant (gas pressure, temperature, caloric value, etc.) must be given due consideration.

The heart of most gas appliances is a biogas burner. In most cases, atmospheric-type burners operating on premixed air/gas fuel are preferable. Due to complex conditions of flow and reaction kinetics, gas burners defy precise calculation, so that the final design and adjustments must be arrived at experimentally. Compared to other gases, biogas needs less air for combustion. Therefore, conventional gas appliances need larger gas jets when they are used for biogas combustion. About 5.7 liters of air are required for the complete combustion of one liter of biogas, while for butane

30.9 liters and for propane 23.8 liters are required.

The modification and adaptation of commercial-type burners is an experimental matter. With regard to butane and propane burners, i.e. the most readily available types, the following pointers are offered:



Schematic diagram of a gas burner

Source: Production and Utilization of Biogas in Rural Areas of Industrialized and Developing Countries, Schriftenreihe der gtz No. 97, pg.185

- Butane/propane gas has up to three times the caloric value of biogas and almost twice its

flame-propagation rate.

- Conversion to biogas always results in lower performance values.

Practical modification measures include:

- expanding the injector cross section by factor 2-4 in order to increase the flow of gas;
- modifying the combustion-air supply, particularly if a combustion-air controller is provided;
- increasing the size of the jet openings (avoid if possible).

The aim of all such measures is to obtain a stable, compact, slightly bluish flame.



**Different types of Biogas burners at
an agricultural exhibition in
Beijing/China**

Photo: Grosch (gtz/GATE)

Efficiency

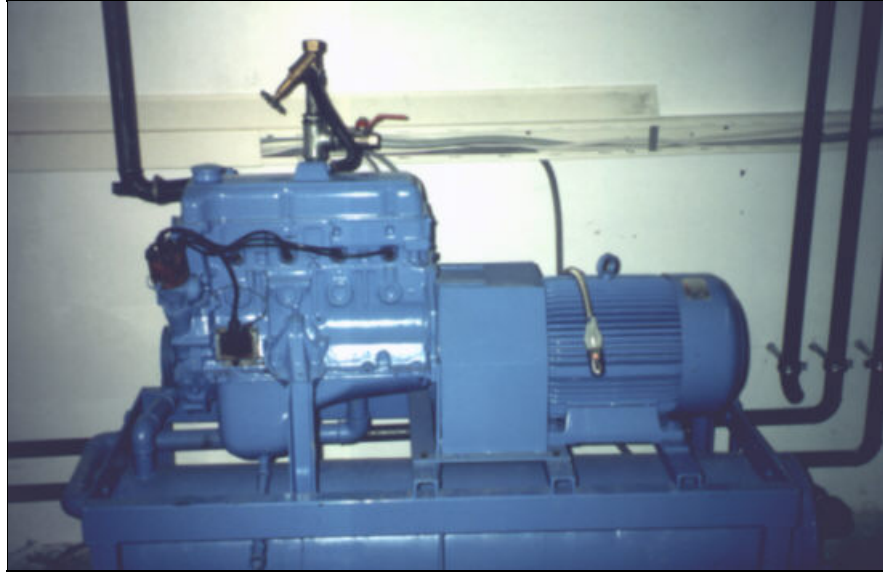
The calorific efficiency of using biogas is 55% in **stoves**, 24% in **engines**, but only 3% in **lamps**. A biogas lamp is only half as efficient as a kerosene lamp. The most efficient way of using biogas is in a heat-power combination where 88% efficiency can be reached. But this is only valid for larger installations and under the condition that the exhaust heat is used profitably. The use of biogas in stoves is the best way of exploiting biogas energy for farm households in developing countries.

appliances	gas lamps	engines	gas stoves	power-heat
efficiency [%]	3	24	55	88

For the utilization of biogas, the following consumption rates in liters per hour (l/h) can be assumed:

- household burners: 200-450 l/h
- industrial burners: 1000-3000 l/h
- refrigerator (100 l) depending on outside temperature: 30-75 l/h
- gas lamp, equiv. to 60 W bulb: 120-150 l/h
- biogas / diesel engine per bhp: 420 l/h
- generation of 1 kWh of electricity with biogas/diesel mixture: 700 l/h
- plastics molding press (15 g, 100 units) with biogas/diesel mixture: 140 l/h

Biogas can also be used for various other energy requirements in the project region. Refrigerators and chicken heaters are the most common applications. In some cases biogas is also used for roasting coffee, baking bread or sterilizing instruments.



Co-generation unit (electricity and heat utilisation)

Photo: Krmer (TBW)

Gas demand

In developing countries, the **household energy demand** is greatly influenced by eating and cooking habits. Gas demand for cooking is low in regions where the diet consists of vegetables, meat, milk products and small grain. The gas demand is higher in cultures with complicated cuisine and where whole grain maize or beans are part of the daily nourishment. As a rule of thumb, the cooking energy demand is higher for well-to-do families than for poor families. Energy demand is also a function of the energy price. Expensive or scarce energy is used more carefully than energy that is effluent and free of charge.

The gas consumption for cooking per person lies between 300 and 900 liter per day, the gas consumption per 5-member family for 2 cooked meals between 1500 and 2400 liter per day.

In industrialized countries, biogas almost always replaces existing energy sources like electricity, diesel or other gases. The objective of biogas production may be less to satisfy a certain demand, but to produce biogas as much and as cheap as possible. Whatever surplus is available can be fed as electricity into the grid. The gas demand is market-driven, while in developing countries, the gas demand is needs-driven.

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Biogas Application

Gas Yields and Methane Contents for Various Substrates

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Substrate	Gas yield	Methane content
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	(l/kg VS*)	(%)
Pig manure	340-550	65-70
Cow manure	90-310	65
Poultry droppings	310-620	60
Horse manure	200-300	
Sheep manure	90-310	
Barnyard dung	175-280	
Wheat straw	200-300	50-60
Rye straw	200-300	59
Barley straw	250-300	59
Oats straw	290-310	59
Corn straw	380-460	59
Rape straw	200	
Rice straw	170-280	

Rice seed coat	105	
Flax	360	59
Hemp	360	59
Grass	280-550	70
Elephant grass	430-560	60
Cane trash (bagasse)	165	
Broom	405	
Reed	170	
Clover	430-490	
Vegetables residue	330-360	
Potato tops/greens	280-490	
Field/sugar beet greens	400-500	
Sunflower leaves	300	59

Agricultural waste	310-430	60-70
Seeds	620	
Peanut shells	365	
Fallen leaves	210-290	58
Water hyacinth	375	
Algae	420-500	63
Sewage sludge	310-740	

Table B1: Gas yields and methane contents for various substrates at the end of a 10-20 day retention time at a process temperature of roughly 30C.

Source: Production and Utilization of Biogas in Rural Areas of Industrialized and Developing Countries, Schriftenreihe der gtz, No. 97, pg. 63, after: Felix Maramba, Biogas and Waste Recycling - The Phillipine Experience; Metro Manila, Phillipines, 1978

* VS = Total volatile solids, e.g. ca. 9% of total liquid manure mass for cows

Return to the [Biogas utilization](#) page.

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18/10/2011

Gate - AT Information: Biogas

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