Together for a clean future

"Biogas balances the energy mix"

Georg Hackl, three-time Olympic luge champion

Biogas knowledge COMPACT

Fachverband BIOGAS

Credits

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Content

Biogas

Regional. Reliable. Climate-friendly.

The regenerative energy turnaround will succeed, if all renewable energy sources bring in their advantages in an optimal way. Wind turbines and solar plants can supply a lot of power, when strong winds blow and the sun shines intensely. Biogas can always step in flexibly, whenever it is dark and windless. And it is climate-friendly in two ways: Not only under the aspect of generating power, the fermentation of liquid manure in the agricultural sector also helps avoiding considerable quantities of methane emissions, which would otherwise be discharged into the atmosphere.

Nor must we forget in the current discussions about the energy turnaround that energy is more than just (electric) power. More than half of our annual energy consumption is used for the generation of heat. In biogas plants, though, heat is virtually generated as a by-product of the power – and can be used, wherever heat energy is required: in residential buildings, in animal sheds, in outdoor and indoor swimming pools as well as in greenhouses.

Biogas processed into biomethane provides already a climate-friendly and practicable solution for the third column of our energy demand, i.e. mobility. Every conventional vehicle fuelled with compressed natural gas (CNG), or natural gas, can be operated with biomethane – and thus reduce the CO_2 emissions by up to 90 per cent as compared with a petrol-fuelled vehicle. If this biomethane is processed into liquefied natural gas (LNG), it can – due to its high energy density – also be used for trucks and ships. The first ships with LNG engines are currently put into operation.

Power, heat and fuel; regional, reliable and climate-friendly – Yes, biogas can!

Yours sincerely,

Horst Seide
President of the Fachverband Biogas e.V.

1_Biogas – the energy-rich gas mixture

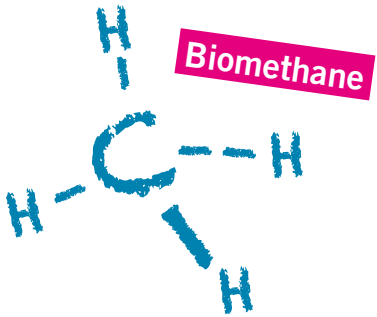
Biogas is generated as a result of the natural degradation of organic matter under the exclusion of air, e.g. in moors and swamps, but also in the digestive tract of animals, especially in the cow's rumen.

This natural process is used technically in biogas plants to generate biogas from biologically degradable substrates, such as liquid manure, bio-waste or energy crops (maize, grass, sugar beet etc.). These substrates are fermented in hermetically sealed fermentation tanks, so-called digesters, where they are converted into biogas in a four-stage process. This requires the work of many different micro-organisms. First of all, the long-chain components, such as carbohydrates, proteins and fats, are fractionated into short-chain organic compounds, such as amino-acids, sugar and fatty acids. Following that, these intermediate products disintegrate into fatty acids (acetic, propanoic and butyric acids) as well as carbon dioxide and hydrogen. During the last stage, the so-called archaea generate methane, carbon dioxide and water. Archaea belong to the oldest living beings on Earth and developed some 3-4 billion years ago, i.e. long before the atmosphere as we know it today.

Composition of biogas

The most important component of biogas is combustible methane (CH_4), which is also a major component of natural gas. Depending on the substrates used, the methane content in biogas varies between 50 and 65 per cent. The second major component of biogas is carbon dioxide (CO_2) with a content of 35-50 per cent. Apart from that, other substances, such as nitrogen, water, oxygen and hydrogen sulphide, may also be found in the biogas in low concentrations.

Biogas can be converted into energy in the form of electricity, heat or fuel, which leaves a fermentation product that is ideal for being utilized as fertilizer.

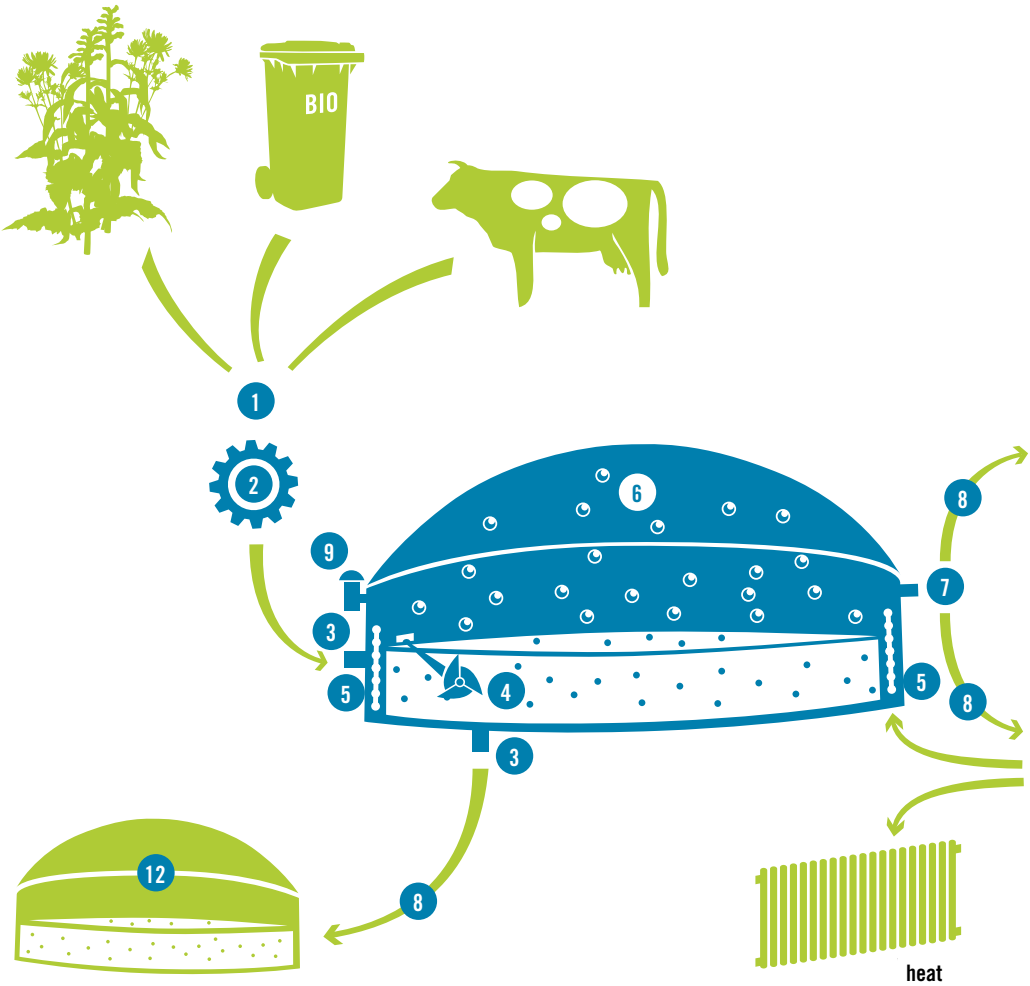


What are fermentation products?

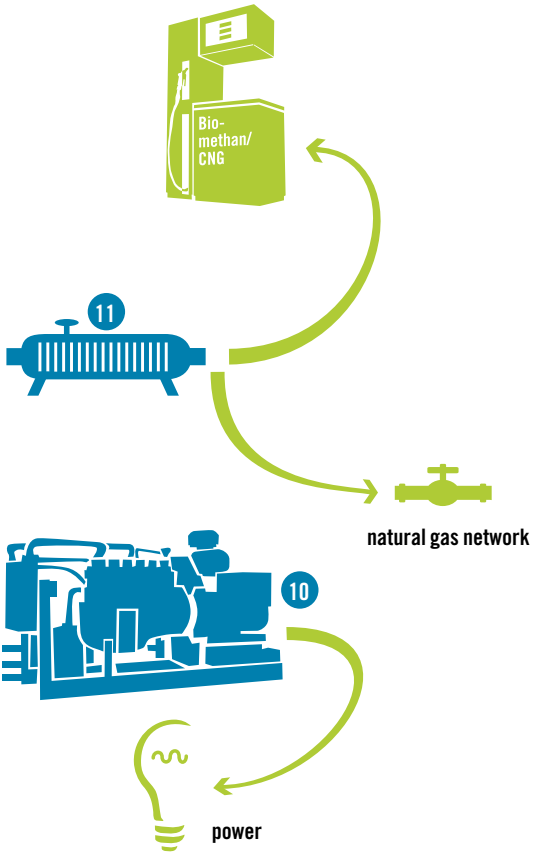
Fermentation products are high-quality fertilizers that are rich in humus-forming substances and nutrients. They are utilized in liquid or dry form, or are composted, as organic fertilizer or soil improver in the agricultural, landscaping and horticultural sectors as well as for private gardening. The fermentation product retains the nutrients contained in the source substrates, such as nitrogen, phosphorus, potassium and the organic carbon. The utilization of fermentation products thus closes the natural nutrient and humus cycle and replaces mineral fertilizer, which must otherwise be produced with a high input of energy or be extracted.

2_How a biogas plant works

The biogas generated in the digester is collected in the gas hood and transferred from there via gas pipelines to the combined heat and power unit (CHP) where power and heat is generated from the biogas.



The bacteria in the digester convert the biomass into biogas and the fermentation product. Numerous different systems, techniques and operating modes can be considered when designing a biogas plant. The usual configuration includes the following components:



1. Storage for the biomass to be fermented (silo, collection point, liquid manure container)
2. Processing, sorting or cleaning systems, wherever applicable, for the biomass to be fermented or for residues
3. Inlet/pumping equipment transfers the biomass into, or out of, the digester
4. Agitators mix the bacteria in the digester with the fresh biomass, thus reducing the layer floating on the digester content as well as distributing the thermal heat, and extract the biogas from the mass thus generated
5. Heating – the usual fermentation temperature levels at 40 °C
6. Gas storage for the short-term or intermediate (1 – 20 hrs.) storage of the biogas generated or for hermetically sealing the digester
7. Gas cleaning system for desulphurization and dewatering
8. Pump lines for fermentation substrates and biogas pipelines
9. Safety equipment: pressure relief devices, safety valves, gas flares as well as instrumentation and control equipment for the entire plant
10. Combined heat and power unit (CHP) for generating power and heat at the same time; gas flares, gas burners, micro-gas turbines
11. Processing equipment, if necessary, for converting biogas into bio-methane
12. Storage tank for the fully digested fermentation products (with equipment for further processing, where applicable, such as solid/liquid separation, drying, pelletizing etc.)

3_From apple cores and sugar beet

Originally, biogas plants were used for recycling biological waste and agricultural by-products. Farmers were looking for a way to utilize these materials in order to (re-) integrate them into the agricultural cycle.

Nowadays, most of our biological waste ends up in biogas plants. Apart from bio-waste generated in private households, the foodstuff, fodder, catering and luxury goods industries as well as the retail and agricultural sectors also generate residual waste. All this may be of vegetable origin, such as spent grain from the beer production or pomace (marc) from the juice production. Animal residues, such as fat and dairy waste, are excellent charge materials for biogas plants because of their high energy content. The most important agricultural residues are liquid manure, slurry and solid manure. At the moment, about a quarter of the entire livestock manure generated in Germany is fermented in biogas plants, where not only energy is produced. Also, climate-wrecking gases, generated when storing these residues in the open, will also be collected before they can escape into the atmosphere. Further agricultural by-products are crop residues, such as beet leaves, straw as well as vegetable, potato and grain waste. Apart from that, energy crops are also utilized in biogas plants.

When strictly using the brown waste bin, every citizen can make a personal contribution that energy is generated from foodstuff residues.

Using energy crops

A large proportion of the energy crops is maize which has a high energy output and requires little treatment with pesticides. Farmers have been familiar with the maize cultivation practices for decades now. Other energy crops, apart from maize, are also utilized, such as silphium perfoliatum, tall wheat grass (agropyron elongatum) or wild plant mixtures.

Energy crops are cultivated on some 1.26 million ha of land for operating biogas plants.

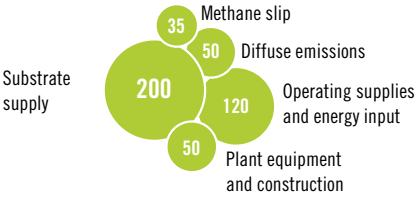
Colourful prospects from energy crops

It is an advantage of biogas that even crops can be utilized which are not required in the foodstuff or fodder production. These crops, such as wild plant mixtures, have a positive effect on insects, wild animals and on soil health. These new types of energy crops are therefore being tested in many projects and are cultivated already in practice. In addition to that, the production of energy crops offers a second pillar of revenue to many agricultural enterprises. In the past, the overproduction of foodstuff often resulted in heavily decreasing prices for agricultural raw materials. The cultivation of energy crops for biogas contributes to the stabilization of agricultural prices.

The Fachverband Biogas e.V. supports this with the project "Add colour to the fields": www.farbe-ins-feld.de

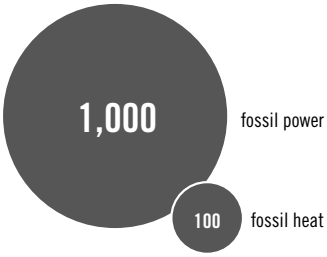
Greenhouse gas emissions of a 190-kW biogas plant as compared to a fossil power plant with the same capacity

Power and heat from biogas
(in t of CO_2)



Total emissions: 455 (t of CO_2)

Power and heat from fossil sources
(in t of CO_2)



Total emissions: 1,100 (t of CO_2)

Climate protection through biogas

The 190-kW biogas plant shown in the example above produces annually some 1.5 million kilowatt hours (kWh) of power and feeds 350,000 kWh of heat into the heat network. Hence, it supplies about 450 households with electricity and 30 households with heat.

The input is made up of almost 7,000 t of substrates, of which 2,500 t are liquid cattle manure. The greenhouse gas emissions generated in the process of providing the substrates (cultivation, fertilization and transport) add up to 200 t. Further emissions are generated during plant construction and while operating it, so that a total of 455 t of CO_2 are generated p.a.

If the same quantity of power and heat was provided by fossil energy carriers, 1,100 t of CO_2 would be generated.

The utilization of biogas thus results in net savings of 650 t of CO_2 p.a. Even higher savings can be achieved, when using more liquid manure, residues and waste as input materials. Extending the utilization of heat (up to 100 households would possible) improves the balance further, so that savings of almost 100 per cent are possible.

4_Advantageous. Exemplary. Biogas.

"Would you have known?"

The German biogas plants already generate
power for 8 million households

A car fuelled with biomethane
saves more than 90 % CO_2
as compared with a conventional petrol-fuelled vehicle

Biogas plants reduce the overall CO_2 emissions
by more than 17 million t p.a.

As a result of fermenting more
liquid manure in biogas plants than before,
another 7 million t of CO_2 can be saved

Power generated from biogas
will stabilize the power grid
and ensure an uninterrupted power supply at the same time

Liquid manure fermented in
biogas plants does not smell and
makes an excellent fertilizer

Biogas plants
create jobs and value added
in rural areas

Many biogas plants supply the neighbourhood
with favourable and climate-friendly heat

Biogas can generate power, whenever it is needed –
during day and night, in wind and weather

Biogas plants generate energy from residues
such as food residues, green waste and potato peelings

Biogas plants are a simple, safe and decentralized
energy source for developing and emerging countries

Biogas plants
secure the existence of farmers

Energy crops can increase
the bio-diversity in the fields and are
the habitat for bees

Biomethane processed from biogas can be
stored in the gas network for several months

5_Biogas is available, when wind and sun are asleep

The Federal Government intends to cover 80 % of the power supply in Germany from regenerative sources. Each renewable energy source has its own specific strengths and will have to assume different tasks. This is the only way to secure a stable and efficient power supply from renewable energy in the long run.

Nobody needs to pay for wind and sun, and they are available virtually without any restrictions. Wind turbines and solar plants will therefore be the "beasts of burden" of the power system in the future. However, they also have a disadvantage: They are not available at any time – especially not always, when there is a demand for power. Any future power system must therefore be equipped with, and based on, technologies that "step into the breach", when the wind does not blow and the sun does not shine. This is, when biogas comes into the play. Biogas cannot only be generated reliably and all the time, it can also be stored. Biogas plants are therefore ideal to fill a gap in the regenerative energy turnaround.

At the moment, many biogas plants still generate their power around the clock. In order to fill this gap, they need to stand still, while the wind is blowing heavily and the sun is shining intensely. They need to start up, when the power generation from wind and sun goes down. The Fachverband Biogas e.V. assumes that the current inventory of biogas plants will have a capacity of approx. 5,300 MW to compensate power missing from wind and sun in the forthcoming years. This corresponds to about 18 modern power plants fuelled with natural gas (with a capacity of 300 MW each). Only the interaction between different renewable energy sources can ensure the power supply in the long run that combines climate protection, reliability and low costs.

"Biogas tops up our energy turnaround."

Georg Hackl

6_More than merely a by-product: Biogas heat

The energy turnaround is not merely concerned with converting our power supply to renewable energy; it is – to the same extent – also about regenerative heat production.

More than half of our annual energy consumption is used for heating. In biogas plants, heat is quasi generated as "by-product" of the power production.

In 2014, more than 25 billion kilowatt hours (kWh) of heat were generated in German biogas plants, with which it was possible to provide heat for 2 million households in a CO_2-neutral way. A fairly small biogas plant with a capacity of 190 kW can supply climate-friendly biogas heat to 100 households. Residents can benefit from the favourable, regional and climate-friendly heat energy via a local heat network, while the plant operator can use the heat generated during power

production in a useful and profitable way. The heat consumers often participate in the heat network via cooperatives, which creates a positive relationship with the biogas plant and promotes its acceptance. Bio-energy villages or energy communities even go one step further, when they supply themselves with renewable energy to the largest possible extent.

The Website www.kommunal-erneuerbar.de of the Agentur für Erneuerbare Energien (Renewable Energy Agency) provides an excellent overview over the energy communities and energy cooperatives in Germany. Apart from houses and residential blocks of flats, it is also possible to supply biogas heat to schools, gymnasiums, hospitals or kindergartens. A suitable heat customer during summer would be open-air swimming pools that could often open the season one month earlier with the biogas heat available.

If the biogas plant was not located in the immediate vicinity of a potential heat customer, so-called satellite BHKWs would offer themselves: in such cases, the gas generated at the biogas plant will be channelled through a specific biogas pipeline to the block-type power plant that is, ideally, located in the basement of a school or of a swimming pool a few kilometres away, where the gas can be converted into power and heat.

You can also find many good examples of successful biogas projects in the "Biogas Atlas" under www.biogas-kanns.de

7_Energy for the road: Biomethane

Apart from power and heat, biogas can also supply fuel. In order to so, the gas will not be converted into electricity in a local BHKW but processed and fed into the gas network.

Biogas consists of 50-60 per cent of methane, a combustible gas, with the remainder being largely CO_2. Natural gas or compressed natural gas (CNG) consists of 98 per cent of methane. In order to be able to feed biogas into the natural gas network, it must have the same methane content as natural gas.

To achieve that, the biogas will be scrubbed (= "washed"), so as to remove the CO_2, for which a number of techniques are now available.

When biogas has a methane content of 98 per cent, it is called "biomethane", which can be fed into the existing gas network and

tapped at any place, say at a gas pump at a natural gas fuelling station. Every vehicle operated with gas can be fuelled with biomethane without causing any problems.

Of the more than 900 CNG fuelling stations in Germany, more than a third offers biomethane – either partially or 100 per cent. As an example, the Stadtwerke München (Munich Municipal Utilities) exclusively sell pure biomethane at their altogether eight natural gas fuelling stations in the Bavarian capital. The entire municipal bus fleet of Augsburg is fuelled with biomethane. The gas quantity taken from the gas pumps corresponds exactly to the quantity of biomethane fed into the gas network elsewhere, which is referred to among experts as "accounting for reporting purposes". Apart from that, there are also biomethane filling stations that get their gas directly from an adjacent biogas plant – without the gas being fed into the network in the first place.

A vehicle operated with biomethane reduces the CO_2 emissions by up to 90 per cent as compared with a conventional petrol-fuelled vehicle, but it costs the vehicle owner only half of it per kilometre.

The processing of biogas into biomethane began in the Pliening biogas plant near Munich in late 2006. Today, more than 160 plants feed their gas directly into the gas network. The gas can be tapped from the network anywhere and be converted into power or heat; it can be used as fuel for vehicles or it can be stored for several months. If biomethane is liquefied into liquefied natural gas (LNG), it can – due to its high energy density – even be used as fuel for trucks and ships. The first ships with LNG engines are currently put into operation.

8_Biogas: Attractive jobs and driving force for the economy

The biogas industry is an important part of Germany's energy sector

By the end of 2015, about 8,100 biogas plants with an installed electrical output of more than 4,000 megawatts (MW) will be in operation. This is about the capacity of three or four nuclear power plants. Thanks to this successful development, the German biogas industry has gained a wealth of experience and the necessary investment power to establish the biogas technology at international level. "Biogas made in Germany" is not only internationally much in demand, it is also the driving force for the global biogas economy.

By now, the biogas sector has achieved an annual turnover of more than seven billion euros and, in doing so, secures approx. 40,000 jobs in small and medium-sized industrial and agricultural enterprises.

Numerous specialists are required from the first idea to the completed plant and its professional operation. More than 800 small and medium-sized companies plan and erect biogas plants, design components, offer maintenance services, provide the required substrates (such as energy crops) and take care of utilizing the output (i.e. power, heat, fuels and fermentation products).

More than 12,000 employees alone are involved in the operation of the 8,100 or so biogas plants. Mainly small and medium-sized businesses benefit from this and, in turn, contribute to the development of the rural area.

Biogas plants also make a contribution that young, well-qualified and skilled personnel find attractive, promising and future-oriented jobs also in structurally weak rural areas.

Moreover, the worldwide technology leadership of the German biogas enterprises opens up highly interesting export and development opportunities. Numerous other countries, such as Britain, France and Italy, have recognized the advantages of the biogas technology and offer support schemes that are shaped in line with the German model. The German biogas know-how is also very much in demand in North America as well as in many Asian countries.

9_Good to know

Don't be afraid of energy crops

Energy crops intended for being fermented in a biogas plant are grown on almost 1.3 million hectares of land in Germany. This is about seven per cent of the entire agricultural area. Even if this area was doubled, Germany could still supply herself with food without any problems. The cultivation of energy crops has contributed to a significant stabilization of income in the agricultural sector. On the one hand, farmers will benefit from the higher revenue when selling their crops but, on the other hand, biogas plants also offer farmers a safe and second pillar of revenue in times when milk and meat prices are low.

Maize = an undervalued yet powerful energy crop

Maize is cultivated for biogas plants on about 900,000 ha of land. This corresponds to approx. one third of the entire crop area for maize, which is today at about the same level as in the late 1980s. Nowadays, however, the perception is a different one. Maize is a very high-growing plant shortly before it is harvested. This has the disadvantage that it cannot be overlooked and is perceived as dominant. An advantage is, on the other hand, that maize yields so much biomass as hardly any other crop. In addition to that, it only needs little water, hardly any pesticides and produces a lot of biogas when being fermented. The ideal plant for biogas facilities and their operators. Nevertheless, the research focuses intensely on alternative crops.

Colourful diversity through biogas

Almost every plant can be fermented in biogas plants. Hence, biogas can make a contribution that our fields become more colourful and rich in species. Above all wild animals, insects and especially bees benefit from colourful blooming plants. For the farmer, the cultivation of ecologically valuable energy crops usually means a lower revenue as compared with the cultivation of maize. Yet many biogas plant operators cultivate already alternative energy crops, such as silphium perfoliatum, tall wheat grass (agropyron elongatum) or sugar beets. Financial incentives granted by those responsible for the agricultural policy with a view to promoting ecologically valuable measures could make agriculture (even) more colourful and lively.

Energy from waste

Biogas plants convert that into energy and high-grade fertilizer what other people have thrown away: separately collected household waste, old fat from the restaurant kitchen or potato peelings from the French fries industry.

Not only does this help saving disposal charges, it also generates climate-friendly energy – with top-class fertilizer for the farmer and the hobby-gardener being gained at the end of the chain.

Good for the region

In 2014, the biogas sector generated a turnover of more than seven billion euros, with the money remaining where the biogas plants are situated: in the rural area. Biogas plants promote the regional value added and secure future-oriented employment.

“I smell with my little nose”

When spreading liquid manure over the fields and it stinks – there is certainly no biogas plant involved. Because liquid manure, once fermented, is almost odourless. Moreover, it is even better available for the crops, saves the farmer expensive and energy-intensive fertilizer thus making a contribution to environmental protection.

Good for the climate

When producing one kilowatt hour of electricity, the greenhouse gas generated in a biogas plant totals less than one third of the quantity generated in a coal-fuelled power plant for the same output of power. Moreover, biogas plants could save an additional 7 million tons of CO_2 equivalents by the strict fermentation of liquid manure which would otherwise be discharged into open cesspools. At the moment, only a fourth of all liquid manure generated in Germany is fermented in biogas plants before it is spread out in the fields.

Biogas does not make hungry

The fact that about one billion people in the world still suffer from hunger is the result of misguided agricultural policies over decades. The utilization of biogas has definitely no impact on people’s state of nutrition in the developing countries. Nor has it any global effect, whether in Germany one or three million hectares of land are used for the cultivation of energy crops. The hunger in the world is a politically created distribution problem.

10_Facts and figures

On average, 1 m³ of biogas yields 2.5 kWh of electricity, or fuel for 9 km, or the equivalent of heat requiring 0.6 l of heating oil.

What yields how much energy?*

Substrate basis	Biomass [t]	Power [kWh]	supplied households	Kilometres travelled	Heating oil substitute [l]
1 ha of maize	50	21,000	6	80,000	5,300
1 ha of blooming area	40	12,000	3.5	45,000	3,000
10 cattle	200	13,600	4	51,000	3,400
100 pigs	300	15,000	5	54,000	3,600
1 000 bio tons á 120 l	60	16,800	5	63,000	4,200

*The energy yield must be understood alternatively, i.e. either power, or fuel, or heat.

1 ha (hectare) = 10,000 m²
(about the equivalent of a football pitch)

8 CNG-fuelled vehicles can be operated for one year (with a mileage of 10,000 km) from the yield of 1 ha of maize.

The excrements of 3 cows are sufficient to supply an average household one year with power.

An average biogas plant with an electrical output of 190 kW can supply about 450 households with power and 100 households with heat. This helps avoiding the generation of 700 t of CO_2 a year on average and substitutes 20 t of mineral fertilizer. The plant costs less than one million Euro.

No. of biogas plants in Germany:	8,000
Installed electrical output:	4,000 MW
No. of households supplied:	8 million
CO_2 savings:	17.6 million t
2014 turnover:	Euro 7.4bn
Jobs in the biogas sector:	40,000

(status: end of 2014)

kWh = kilowatt hour m³ = cubic meter

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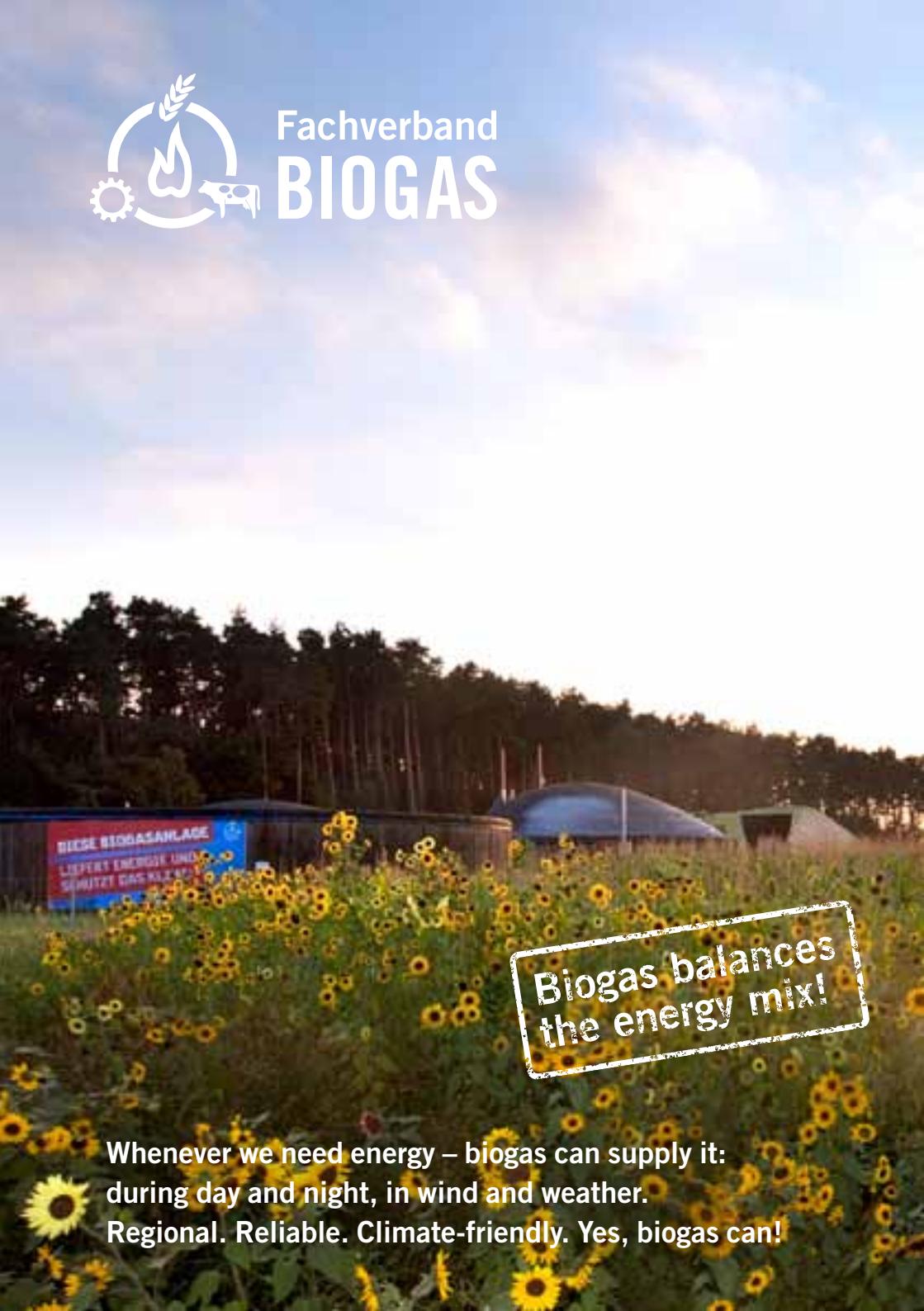

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during day and night, in wind and weather.
Regional. Reliable. Climate-friendly. Yes, biogas can!