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In future, Germany will be taking a whole new approach to promoting bioenergy. As with photovoltaics, from 1st January 2017 newly built biogas plants will no longer receive a fixed feed-in tariff. Instead, compensation for electricity fed into the grid is supposed to be determined by a tendering process, which is subject to mandatory maximum limits. This is governed by the amendment to the German Renewable Energies Act (EEG 2017), which was adopted last summer. The positive thing about it is that existing plants, whose initial compensation period ends after 20 years, now have future prospects. This development is new. Existing plants will therefore be able to continue to operate on the basis of fixed tender specifications.

Stakeholders from throughout the sector agree that determination of compensation by a tendering process entails many risk factors and problems, but there is a minimum consensus within the current political debate in Germany. In particular, the Federal Ministry of Economic Affairs and Energy committed itself to the tender scheme on the grounds of continued affordability of electricity. New plants will receive a maximum of 16.9 cents per kilowatt hour in future, existing plants a maximum of 14.88 cents. Based on this consensus, the German biogas industry will continue to work on suitable framework conditions, so that biogas can take up its special cross-sectoral role in the Energiewende (energy transition process), agriculture and climate protection. The further impact and potential of biogas plants, such as the production of biofuels, heat generation, climate protection, nitrogen and carbon fixation, production of organic fertilizers, etc. must be increased and priced, in addition to making electricity production more flexible.

A different view has been taken of biogas plants in many other countries, such as emerging and developing countries. A large number of plants, many of them domestic biogas plants, have been existing there for decades. What these plants have in common is that they use household and agricultural organic residues (manure, fodder residues, kitchen waste) that accumulate directly on the farm and then use the biogas produced for cooking and heating purposes. Recovery of the fermentation products for use as organic fertilizer in the garden or on agricultural land, or in the vicinity of the plant, is of particular importance in the case of these plants. These plants superbly complete agricultural cycles and ensure a sustainable energy supply in rural regions.

Interestingly, a large number of these plants are no longer in operation or are malfunctioning. Take India, for instance: experts estimate that about 80% of the some five million domestic biogas plants are not in operation. Although reasons are most certainly complex, they are frequently connected with lack of functionality or technical problems. However, it is precisely this trend that has led to numerous reservations about biogas as a whole and about these domestic biogas plants. Functioning plants are of fundamental importance for further development of biogas technology, particularly in this plant category (see also reports covering Cuba, Kenya and Tanzania).

Further international professionalisation of domestic biogas plant technology is therefore urgently required and is now being drafted and initiated in corresponding working groups for the ISO standardisation process (ISO/TC 255 Biogas). The German Biogas Association is also actively taking part in these discussions in the ISO standardisation process, various projects (e.g. India) and numerous consultations and training programmes.

Due to the great market potential and its particular importance in development of the biogas industry as a whole, it is worth focussing discussions more on this plant segment. Maybe this trend from “small to big” could perhaps increase acceptance and strengthen the necessity for biogas technology to become a key international technology for climate protection, agriculture and energy supply.

Sincerely,

Manuel Maciejczyk,
CEO, German Biogas Association
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Cogeneration: Many factors affect the operation

Looking at the flexibilisation and the further restriction of the emission limits expected in the revised Clean Air Act (TA Luft) the requirements on the operation of a cogeneration unit will become even more stringent. In this context, there is an increasing need to provide clean fuel and perform professional maintenance of the cogeneration units to ensure a long term economic operation.

By Dipl.-Ing. (FH) Volker Aschmann, M.Sc. Simon Tappen and Dr. Mathias Effenberger

In the past, the development of biogas fueled cogeneration units focused primarily on the electrical efficiency because that was the decisive criterion whenever the financial aspect of the conversion of biogas to electricity was considered. And until recently, operating the cogeneration unit at maximum output around the clock was the only aspect that counted. This is changing rapidly now because the biogas sector must change its mind set to bring the strength of biogas as storable fuel into play: the possibility of generating electricity when it is needed the most. It goes without saying that these new challenges do not fail to leave their mark on the cogeneration equipment. In comparison with the requirements of continuous operation so far, now the start-stop mode and the part-load mode of the engines are the focus.

Practical tests with different cogeneration units have been undertaken at the Institut für Landtechnik und Tierhaltung since 2004. These tests have shown few fundamental factors which can have a positive effect on the cost effective operation of existing and new cogeneration units.

Gas cleaning

One of the main preconditions of the long-term efficient operation of a cogeneration unit is the efficient cleaning of the gas. This includes, at first, sufficient cooling and thereby dehumidification of the gas, which as a rule can only be achieved with an active system. Particularly in view of the flexibilisation of the system, a cooling facility in the ground is no longer sufficient because the high gas flow rate cannot be cooled sufficiently under full load conditions of the cogeneration unit.
The same also applies to the removal of the sulfur from the biogas. Desulfurisation by blowing air in the gas forming section of the system should merely be considered as rough cleaning. Fine cleaning of the gas by suitable filters (e.g., activated charcoal, cellulose, etc.) before it enters the cogeneration unit is an absolute ‘must’ particularly in the flexible mode of the unit because when the unit is switched off the exhaust section cools down and condensation occurs which in the presence of small amounts of sulfur can cause corrosion at the exhaust heat exchanger, the catalytic converter and the turbo charger.

**Lifetime**

Long-term investigations (from 2006 to 2012) have shown that a cogeneration unit loses efficiency due to age-related wear and tear. Figure 1 illustrates the comparison of the development of the electrical efficiency of three gas-fired cogeneration units with different electrical output ratings. The loss of electrical efficiency across the life of the units is different for each cogeneration unit. Whereas the 324-kW gas cogeneration unit recorded a high efficiency loss and needed replacement as early as after 48,000 hours of operation, the 526-kW gas fired cogeneration unit hardly suffered a loss of electrical efficiency across the lifetime of the unit and was replaced by a new unit after 60,000 hours as scheduled.

The 190-kW gas fired cogeneration unit reached 75,000 hours of operation, despite some loss across the lifetime of the unit (it continued operation after the last measurement). The reasons for the different loss behaviors are multifarious. One decisive factor, however, seems to be the right maintenance strategy.

**Maintenance**

The 526-kW gas fueled cogeneration unit was maintained by the manufacturer under a full-maintenance contract with output and runtime warranty and included general overhaul (replacement of all parts and overhaul of the generator) after about 30,000 operating hours. As can be seen in Figure 1, the electrical efficiency of the unit after the general repairs was as high as originally. So the general efficiency loss across the lifetime of the cogeneration unit was comparatively low. The cost of that full maintenance was fairly high with more than 5.50 EUR per operating hour but permitted the unit owner to calculate the cost in advance and to reduce his personal time input in the operation of the unit.

The 190-kW gas fired cogeneration unit had not been designed to deliver maximum efficiency but for a long lifetime. In that case the owner was able to obtain a very long lifetime of the unit with average efficiency under the conditions of high time input and efficient own maintenance, plus general overhaul.

After two years of maintenance by the manufacturer, the 324-kW gas cogeneration unit was maintained only by the owner and had to be replaced after merely 48,000 hours because it failed to deliver the required output. The loss of efficiency was already substantial at that time. An unfavorable maintenance strategy can be assumed in this case.

For comparison of the efficiency losses, a mean efficiency loss was calculated for every unit after 10,000 hours (see table). The extra substrate consumption for the output to be obtained can be calculated from these figures.

**Substrate saving**

When the electrical efficiency suffers but the same output is expected of the unit, this means that more substrate must be fed to produce more gas. For example, an efficiency loss of 1 percentage point of a 500-kW gas fired cogeneration unit means that the extra amount of substrate the unit needs is equal to the yield of 6 hectares of maize silage.

Figure 2 illustrates different developments of the required gas volume of the gas fired cogeneration units discussed here for the life of 60,000 hours. Whereas the 526-kW gas fired unit required only 3 per cent more gas across its full lifetime, the 324-kW gas fired unit consumed totally 13 per cent more gas in order to maintain the output on a constant level. An arithmetic comparison of two cogeneration units with an...
assumed output of 500 kW each shows that the unit poorly maintained consumes substrate equivalent to 108 hectares of maize silage. Assuming substrate cost of 1,800 Euro a hectare corn free digester the extra costs result in a total of 193,500 Euro or 3.22 Euro per hour of operation.

Added to this must be the observation that the availability (shorter downtime due to maintenance or technical failure) of the cogeneration unit with an efficient maintenance strategy was higher by 5 per cent, on average. For a 500-kW gas fired cogeneration unit, this means estimated extra revenue of 42,500 Euro a year at 20 ct/kWh compensation rate.

**Part-load mode**

The electrical efficiency of all ten units monitored dropped by several percentage points when they operated in part-load mode. Compared with full load, the electrical efficiency measured at 80 percent part load was between 1 and 3 percentage points lower and between 2 and 6 percentage points lower at 60 percent part load. No correlation with the absolute rated electrical output of the engines was established.

Looking at exhaust gas emissions, the concentration of nitrogen oxides (NOx) in the exhaust was lower in part load mode in most cases whereas the hydrocarbon concentration (CnHm) increased. The approximated methane slip calculated on the basis of the CnHm load in the exhaust gas also rose in part-load mode. The concentration of carbon monoxide (CO) in the exhaust gas also increased in engines without exhaust gas treatment. The cogeneration unit with exhaust gas treatment measured, was a spark-ignited Otto engine with oxidation catalytic converter (oxy cat) and a rated electrical output of 250 kW. This unit of the new generation is equipped with BlueRail® injection which uses part of the biogas separately for spark ignition in the pre-chambers. Another component is the turbo compound technology, a turbine that uses the energy in the exhaust gas for increasing the flywheel moment via a crankshaft and thereby reduces the consumption. That engine obtained an electrical efficiency of over 42 per cent in full load mode in our measurements. The downstream oxidation catalytic converter kept the CO concentrations in the exhaust gas at a very low level, which were even lower under part load conditions (see Figure 3). Thermal afterburning is another version of exhaust gas treatment. With this method, reaction chambers are heated to a combustion temperature of over 620 degrees Celsius and alternately flushed with air. The afterburning becomes an automatic process with a
Figure 4: Measuring results of a 549-kW spark ignition gas engine before and after thermal afterburning in full load and part load modes

<table>
<thead>
<tr>
<th>Cogeneration unit</th>
<th>el. efficiency 1st measurem. [%]</th>
<th>el. efficiency last measurem. [%]</th>
<th>Monitoring period [hrs.]</th>
<th>Reduction of the el. efficiency [% points]</th>
<th>Average reduction of the el. efficiency [%/10,000hrs.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>190 kW GO</td>
<td>36.7</td>
<td>33.4</td>
<td>59,520</td>
<td>3.3</td>
<td>0.4</td>
</tr>
<tr>
<td>324 kW GO</td>
<td>35.6</td>
<td>31.9</td>
<td>42,840</td>
<td>3.7</td>
<td>0.7</td>
</tr>
<tr>
<td>526 kW GO</td>
<td>38.4</td>
<td>37.6</td>
<td>55,515</td>
<td>0.8</td>
<td>0.2</td>
</tr>
</tbody>
</table>

methane slip of about 2 per cent. When the methane slip is lower, additional fuel gas must be supplied to maintain the process. The burning causes a reduction of CO and the effective elimination of most hydrocarbons and of formaldehyde. These reactions were noted in a powerful 549 kW engine with thermal afterburning (see Figure 4).

**Start-stop behavior**

Cogeneration units can operate in intervals to generate electricity on an as-needed basis. The effects of more frequent starts/stops on the rate of wear of the equipment cannot be assessed in quantitative terms at this time because the application is too recent. Besides, the life of the cogeneration units becomes longer because it operates only for a few hours every day. Important in this regard is that the engine block and the engine oil are preheated before the start to avoid increased wear on start-up of operation. More recent cogeneration units have this functionality as standard.

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Individually straw and poultry manure are regarded as difficult to ferment. But in the fermenter they complement each other and facilitate an even nitrogen balance, as the results of the EFFIGEST research project show.

By Wolfgang Rudolph

For some years the biogas sector has been looking closely at agricultural waste in the form of straw and poultry manure. The volumes alone make them an interesting alternative to nachwachsende Rohstoffe (short for “nachwachsende Rohstoffe”, German for renewable raw materials) substrates. The rising demand for poultry meat means the amount of poultry manure is also growing, creating regional disposal problems. Current studies put the potentially available straw at a minimum of eight to nine million tonnes per year.

Unlike burning, straw can be used as energy in the biogas plant, but by applying the fermentation fertilizer it can act to create humus, as difficult to degrade carbon compounds are retained. Also, compared to straw rotting in the field, it reduces the removal of nitrogen from the soil.

There are several disadvantages though. The sand contained in poultry manure makes the biogas process more difficult and leads to greater wear on the dosing and stirring equipment. Plenty of water has to be added to ensure pumpability due to the high dry matter content. Straw tends to form floating layers. Also the volume-to-mass ratio is unsuitable for transport. In the case of a maximum straw bale density of 200 kilograms per cubic meter that’s a lot of air to drive about.

Contrary nitrogen balances

The main reason why both groups of raw materials are regarded as difficult to ferment is the undesirable nitrogen balances during biogas production. These display the opposite signs, though: the formation of ammoniacal nitrogen (NH₃) is a characteristic of poultry manure fermentation and therefore accom-
panied by poisonous ammonia, which harms the microbes in the fermenter. The complete opposite is true of straw, with its low raw protein content. There is a lack of nitrogen here, which sooner or later disrupts the fermenter biology.

When two factors disrupt the fermentation process in contradictory ways, so to speak, when combined these substances ought to cancel out the negative effect and thus achieve a nitrogen balance. This was the initial hypothesis adopted by the EFFIGEST research project supported by the German Federal Ministry for Economic Affairs and Energy at the Fraunhofer Institut für Keramische Technologien und Systeme (IKTS) in Dresden. “The project was furthermore concerned with providing process water by removing impurities from the liquid fraction of the fermentation products and by improving straw’s transportability and degree of degradation,” explained project manager Björn Schwarz. Mixing as used for poultry manure fermentation – especially in the horizontal square containers with large paddle stirrers – and subsequent use of dried fermentation products was also investigated. The project was partnered by Rückert Naturgas, which has already constructed plants with a poultry manure ratio of up to 70% and pellet equipment manufacturer PCM Green Energy.

Search for the optimum mix
The scientists at Fraunhofer IKTS first looked closely at the biochemical behaviour of both substances to determine the optimum ratio of poultry manure and straw in the mix. Schwarz describes the approach to the batch tests in the laboratory fermenters as “We wanted to know exactly what was going in in terms of nitrogen and how much ammonium was being created by molecular breakdown of the organic acids and proteins”. This revealed, for example, that the release of nitrogen from poultry manure depends on the way the poultry is kept and the age of the litter. The proportion of ammoniacal nitrogen is between 20 milligrams per gram (mg/g) of dry matter (DM) when using poultry manure from breeding and keeping adult animals and 50 mg/g DM for poultry manure from laying hens after they have been removed from the pens. “Overall, we were able to assume that during fermentation of poultry manure, around 40% of the NH₄ released is already carried in the substrate and 60% is created in the fermenter,” states the scientist as a rule of thumb.

As expected the nitrogen balance was negative for mono-fermentation of wheat straw. The values established were 4.7 mg of NH₄ lost per gram of organic substance for straw comminuted in the hammer mill and 3.8 mg
in process tomography
the mixing of substrate components in the fermenter vessel can be examined using conductivity detectors.

for straw pellets. The scientists established the mix ratio for an even nitrogen balance from these results. Accordingly the proportion of straw is very high. 88% straw is required based on organic dry matter (ODM) to soak up the excess nitrogen from the remaining 12% poultry manure. “By implication this results in a guideline value for mono-fermentation of straw,” points out the scientist. Accordingly at least 12% ODM in poultry manure or another suitable source of nitrogen, such as pig slurry, is required to maintain the process.

Combi process for water reclamation
If there is insufficient clean water available for the essential dilution of poultry manure during fermentation, or if such use is omitted out of environmental considerations, it is necessary to reclaim water from the fermentation products. Schwarz describes the technical processing challenge as follows: “It is primarily a question of eliminating the nitrogen which is almost completely dissolved as ammonia in the liquid fraction and removing fine particles, which otherwise accumulate in the water cycle and would overall make handling more difficult”.

In the test of various preparation processes, a combination of mechanical separation using cold pressing, or a centrifuge and thermal drying (evaporation) proved practicable. In practice drying was sometimes preceded by fine filtering or the use of flocculants. Whether the use of these additional process stages is worth it for preparation of fermentation products depends on the specific conditions. In the case of flocculation polymers remain in the liquid phase.

To counteract the formation of volatile gaseous ammonia the manure for fermentation was acidified before drying. As the pH value falls, the ammonium-NH₃ ratio shifts towards ammonium. The Frauenhofer IKTS scientists tested two acidification methods: Firstly they added the acidifying agent (sulphuric acid) to the fermentation product, which as a trial had not been separated, secondly they added it to the solid fraction which had been separated out using moderate pressing force. The condensate obtained from subsequent drying was directly fed back into the water cycle or, in the second case, added to the press water before being reused in the biogas process to reduce the proportion of nitrogen. In these tests too, separation before drying proved to be the better option because, unlike direct addition of acid to the fermentation product, there was no excessive foam formation. In addition less acid was used and, last but not least, energy for drying saved.

“In principle fermentation with high proportions of poultry manure is possible with appropriate water management,” is Schwarz’s summation. “But”, he adds, “the batch tests also showed that the addition of 40, or better 50% straw, leads to a clear reduction in the nitrogen pressure, the proportion of gas in the overall more stable process increases and there are fewer problems with hydrogen sulphide”.

Sodium hydroxide added to straw during pelleting
Straw conditioning during the research project aimed to improve transportability, improve degradation and
provide good handling in the biogas plant. This was achieved by pelleting the straw which has previously been comminuted in a hammer mill and simultaneously adding sodium hydroxide (NaOH). The straw pellets produced in the equipment of project partner PCM Green proved to be stable for transport and are around three times as dense as straw bales, with a bulk density of 500 to 700 kilograms per cubic metre. As the air is pressed out they do not form floating layers and dissolve completely within 60 minutes, according to the project manager.

"With the addition of NaOH we looked back to trials in the 1970s to improve the digestibility of straw-based animal feed," explains Schwarz. In fact this “digestion-aiding” effect also occurred in the biogas plant. Straw pellets with 5% sodium hydroxide have a lower raw fibre content and produce up to 15% more biogas. These would financially justify the extra work and expense. But “Under the present conditions the use of straw pellets as a biogas substrate is still too expensive overall, especially if the straw has to be bought in,” admits the scientist. Some technical process issues, such as the quantity of sodium hydroxide to add, also remain unresolved. This is why he hopes to continue the project, which came to an end in February this year. The follow-up “STEP” project is supposed to verify the research results in practice with 250 tonnes of straw pellets used in the biogas plant of GM Biogas GmbH, on the outskirts of Köthen (Saxony-Anhalt) and explore options for improving the cost effectiveness.

The Köthen biogas plant, which has an electrical output of 2.5 MW, uses a substrate which is 60% poultry manure. Rückert Naturgas, which is already indicating its willingness to participate in the follow-up project, designed and built the plant. “This gives us the opportunity to better understand the complex processes during fermentation of poultry manure,” is CEO Claus Rückert’s reason for his involvement. The aim is to manufacture fertilizers separated into nutrient fractions from dry input and dry output, as well as generating electricity and heat.

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A technical masterpiece: Ferry operates on biogas

The Konstanz municipal services are emphasising environmental compatibility and take diesel engines out of service. The boat that will be commissioned in 2018 will operate on biogas produced from residues.

By Dipl.-Ing. · Dipl.-Journ. Martina Bräsel

It is a lighthouse project: The new ferryboat of the Konstanz municipal utilities will be the first in Europe to be powered by a high-speed gas-fired engine. Such an engine offers distinct advantages: The boat produces less emissions, it will be more profitable in operation, performance and maneuverability will be the same as those of the prior boat. The engine, which is not yet available in the market, is developed by Rolls Royce Power Systems (RRPS) headquartered in Friedrichshafen. That company sells large marine engines and power systems for ships under the MTU brand. The new engine will either run on high-quality biogas or LNG. “In all of Europe”, municipal utilities managing director Norbert Reuter is sure, “there is no ship of that size either built or planned that is powered by this environmentally friendly fuel”. Actually there had been plans for a long time that the ferry should be powered electrically, but these plans failed. The project would have been too expensive. It would have cost an extra 6.2 million euro to build the boat, and the batteries would have had to be replaced every ten years. As the Konstanz municipal utilities wanted to operate the traffic link on an environmentally friendlier basis, they also looked for alternative drive systems and now decided for LNG (liquefied natural gas). The decisive reason for this step into a new world of drives, Reuter says, is “the particular environmental friendliness of the gas engines and the possibility of saving fuel cost”. As ferry operator on Lake Constance, Europe’s largest drinking water reservoir, the municipal utilities put a high stake on “safe and clean operation”.

Ferry link saves 80 million road kilometers

The ferry link between Konstanz and Meersburg, in existence since 1928, is important for the region. As part of the federal highway No. 33 it is used by commuters...
The ship which rejuvenates the fleet from 2018. It is as highly competitive as the other ships. But it is more ecologically friendly and more economically.

initially be equipped with a diesel engine, but it will also be prepared for installation of the gas engines,” Dr. Norbert Reuter explains. This means, the new ferryboat will be commissioned as early as by mid-2018. The gas engines will probably be installed one year later. The later replacement of the diesel engine by gas engines will be prepared by the builders of the boat. This includes the tank system because unlike diesel fuel, LNG is loaded into the ferryboat and connected as containers in pressure vessels.

The 8-cylinder gas engine which RRPS develops will have 750 kilowatt rated output. It builds on the proven MTU diesel engines of the 4000 series for working ships. The new 8V-4000-gas engine will have an additional cylinder-wise gas injection, dynamic engine control and a safety concept optimized for the operation of the engines on gas.

Unlike the diesel engine, the gas fired engine will not exhaust soot or sulfur oxides even without exhaust afterburning; it produces 90 per cent less nitrogen oxides and 10 per cent less greenhouse gas. According to information from RRPS, “the clean combustion concept will meet the IMO-III exhaust norms without additional afterburning of the exhaust”. The new series of gas engines is developed specifically to meet the special load profile of the ferryboat. The acceleration will be comparable with that of the MTU diesel engines. The development of the new gas engines profis from the company’s experience with stationary gas engines and the development work invested in a 16-cylinder marine gas engine at present running on the test stand.

Biogas from a nearby liquefaction plant

The Konstanz municipal utilities cooperate closely with Erdgas Südwest because the company is planning the construction of a biohybrid plant in the area. The core of the plant located in Mühlingen near...
Rolls Royce has developed a 8-cylinder gas engine for the ferry. She has a nominal capacity of 750 kW. He is based on the proven diesel engines of the type 4000 for working ships. The photo shows a 16V-4000-gas engine.

Stockach is the treatment and liquefaction of biogas. The biogas produced there from industrial and farm residues can be used as fuel for the ferryboat, which operates on LNG.

“Biogas is liquefied by excess green electricity in the biohybrid plant so that large amounts of it can be stored”, Susanne Freitag explains. By liquefying the biogas is reduced to 1/600 of its volume as gas. “This is the first plant on this type to be built in Germany”, the spokesperson for Erdgas Südwest emphasises. The liquefaction of biogas opens new sales markets and offers biogas plants an interesting future, she adds. The pilot plant has a gas capacity of 1,000 standard cubic meters of raw gas and a processing capacity of about one megawatt renewable electricity. When used at full capacity, it will produce up to 10 tons of BLG a day, which works out to roughly 3,650 tons of BLG a year. This corresponds to an annual energy content of 55,000 megawatt-hours. This is enough to supply over 6,000 homes with electricity and short of 2,000 homes with heat.

The biogas comes from a local company that operates a biogas plant on biogenic residue and waste in the area. For the owner, the biogas plant opens up an entirely new option which allows him to operate the plant also when EEG subsidies are no longer available. Should the biohybrid plant be denied permission, fossil natural gas would have to replace the biogas for the time being.

A strong signal
“We are convinced that gas engines as complements of the proven diesel engines will become ever more important for marine applications,” Marcus A. Wassenberg, chief financial officer of Rolls-Royce Power Systems AG, states. The development of the gas engine technology and of the fuel infrastructure requires state subsidies until it is economically viable in the market. Because the German government was expecting important know-how, the Ministry of Transport and Digital Infrastructure (BMVI) provides financial support of up to one million euros for the development of the environmen-
tally friendly drive solution. For state secretary Norbert Barthle, the project undertaken by the Konstanz municipal utilities is “future oriented and exemplary”. The operation of the ferryboat on LNG will fuel the regional demand for the product and sustainable business models for the development of a tank infrastructure may come up. “A promising practical application of LNG is the best argument for a wider dissemination of this technology,” Barthle says. The Ministry of Transport and Infrastructure of the state of Baden-Württemberg also promised support. The intention was to earmark an amount of up to 500,000 euro for the project, a letter from the ministry in Stuttgart states. Lord Mayor Uli Burchardt is glad: “With this support, we will be able to implement a pilot scale project”.

“With the newly developed engine and the fuel from Mühlingen we will have a boat that can operate profitably and reliably,” municipal utilities boss Reuter is convinced. Besides, it will be especially friendly environmentally on Lake Constance: “In comparison with the conventional drive by diesel engines, the new technology will emit – without afterburning the exhaust – no soot particles, no sulfur dioxide, 25 per cent less carbon dioxide (CO₂) and 90 per cent less nitrogen oxides (NOx)”. MTU is also extremely interested in the project: Not only is valuable new technical know-how expected for the growing market of gas fired engines, they also are confident that the new solution will act as a multiplier: “The development of the new gas engine and the test of that engine in the new ferryboat are challenges for the municipal utilities to work for further reduction of emissions and improvement of the efficiency of gas engines so that future emission requirements and customer needs can be met”, chief financial officer RRPS underlines.

And Norbert Reuter summarizes: “If the combined endeavor by the Konstanz municipal utilities, Rolls Royce Power Systems Friedrichshafen and Erdgas Südwest in the new plant in Mühlingen ends in a success, this will be a very strong signal.”

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Over 7,000 WANGEN pumps power the A.D. industry worldwide.
For all substrates choose the robust WANGEN BIO-MIX pumping system.
Thiobacteria for biological desulphurisation: Friend or foe of biogas plants?

Empirical examinations of numerous events of damage in a number of different biogas plants have shown: In case of blowing too much compressed air into the gas space of the digesters, thiobacteria stop converting the hydrogen sulfide from the biogas to elemental sulfur and water but increasingly produce highly concentrated sulfuric acid ($H_2SO_4$).

By Dipl.-Ing. Manuel Stengert

The biological desulphurisation of biogas by blowing compressed air in the gas space of digesters has been state of the art in the biogas sector for a number of years. However, the number of events of occasional massive damage in the gas space of such digesters is growing due to extreme corrosion damage to components of high-grade stainless V4A steel (material number, e.g. 1.4401). The nature and causes of such damage will be described in the following. The hydrogen sulfide gas ($H_2S$) from the biogas in digesters of biogas plants feeding mainly on slurry and food waste involves a large damage potential both for the cogeneration unit (acidification of the lubricating oil with the related risk of rupture of the lubricating oil film and seizure) and also the exhaust system (corrosion of the exhaust heat exchangers).

For many years blowing compressed air in the gas space of the digesters has been an effective measure for distinctly reducing the sulfur content of the raw biogas in addition to adding iron salts and iron hydroxide. This is done in order to convert the $H_2S$ by using atmospheric oxygen into elemental sulfur and water, with the elemental sulfur depositing on surfaces (e.g. nets) installed above the substrate in the gas space. When a sufficient amount of sulfur has deposited it should drop into the substrate under its own weight. As the conversion of $H_2S$ to elemental sulfur and water is brought about by thiobacteria, this process is called biological desulphurisation. During the past few years, our expert office found increasingly larger damage of surfaces in the gas spaces of digesters which were desulphurised biologically by blowing in compressed air. Some of these cases involved warranty issues, others the poor application of coats on the inner walls of concrete structures or simply the analysis of the causes of damages (see typical photos 1.)

Initially, it was assumed that such damage had been caused by electric currents due to faults of installation at metal components because the associated damage patterns looked like galvanic removal of material such as, for example, sinking erosion (see typical photos 2). However, it was increasingly noted that material removals of this type also occurred on components through...
which no stray currents would be flowing in case of a disruption of operations. This included, for example, retaining brackets of stainless steel at the edge of the digester. At these non-conducting tension belts of plastic material were attached to which nets were secured that enlarged the surface on which elemental sulfur deposits (see typical photos 3).

For a conclusive answer as to the cause of the damage, our expert office sent several damage samples to an independent laboratory for metallurgical analysis. The report from the lab showed that the surfaces cleaned by steam jet still showed distinct amounts of sulfur components when viewed under the scanning electron microscope (SEM). The surface structures indicated the massive removal of materials by highly concentrated sulfuric acid (see photo 4.2).

At the same time, the concrete structures in the gas spaces of digesters in a number of different biogas plants had been attacked – in extreme cases – to such a degree that up to one third of the wall thickness of the inside wall could be scraped off by hand without applying much force. Detailed examinations showed that the exposure to the high-concentration sulfuric acid had caused the calcium components to dissociate from the concrete and transform to gypsum (CaSO₄) and water (see photos 5).

Similar massive damage was found on
stainless steel components in the gas space of digesters such as mixed holders of submersible motor stirrers or pipe leadthroughs in the vessel wall (see photos 6.). Furthermore, it was found that the formation of highly concentrated sulfuric acids was most distinct where there was a high moisture level in the digester gas space due to splash water or condensates. However, the question was why damage of this type was not found to the same extent in all plants with biological desulphurisation in the gas space.

Next to differing composition of substrate the added amount of oxygen and compressed-air in relation to the H₂S produced in the gas space of the digester seems to be of critical significance. Obviously, thiobacteria no longer convert the H₂S only to elemental sulfur and water in the presence of excess amounts of oxygen increasingly but more and more to highly concentrated sulfuric acid (\(2S + 2H_2O + O_2 \rightarrow 2H_2SO_4\) and \(H_2S + 2O_2 \rightarrow H_2SO_4\), resp.).

As a result of that, the pH value can drop from the actually required neutral range (pH 7) to the extreme acid end (pH 1 to 2), which is a plausible explanation for the massive removal of material at V4A stainless steel components demonstrated in the attached photos after only a few years of operation. The damage was also a problem for the owners in respect of insurance. The reason is that all common insurance terms for mechanical breakdown exclude damage caused gradually by corrosion.

For that reason, in the past, insurers paid damage only in cases in which components with corrosive damage became detached or dropped down thereby causing damage on other – previously undamaged – parts of digesters. The original damage as a consequence of the long-term depletion was and is not usually paid by mechanical failure insurers.

To conclude, what can the plant owner do to prevent this type of corrosion damage in the gas space of the digesters under conditions of biological desulphurisation? In the author’s opinion, the first and foremost measure is to limit the amount of air blown into the digester gas space and set it in relation to the H₂S volumes produced per unit of time; besides, the pH should be checked regularly on wet surfaces in the gas space of the digesters so that the above described undesirable developments (pH drop to pH 1) can be promptly reacted to.

In summary, it can be stated that thiobacteria, in the presence of excess quantities of oxygen in the gas space of digesters cause the formation of enough sulfuric acid that massive damage in the digester gas space seems unavoidable. Consequently, it lies in the hands of the plant owner whether the thiobacteria in the digester are his friend or his foe.

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The international activities of the German Biogas Association

Since the revision of the feed-in tariffs by the Renewable Energy Sources Act (EEG) 2012 and the EEG 2014 the German biogas market has undergone fundamental changes. No later than since these revisions came into effect has the German biogas sector, the global trailblazer of the use of biogas technology, been aware that it is necessary and expedient not to limit the extensive experience and competencies of the sector to Germany.

By Dipl.-Kulturwirt Sebastian Stolpp and Clemens Findeisen

Like others, the Fachverband Biogas e.V. (FvB), the German Biogas Association, has been hit hard by the fundamental changes in the German market. For that reason, the activities of the International Affairs Department have substantially been expanded in the last few years also because the FvB’s extensive know-how is in great demand outside Germany. So the performance of projects and the provision of services not only help improve the general conditions for biogas on a global scale but also generate additional revenue for the Association.

Since 1992, the Biogas Association has successfully represented manufacturers, plant makers as well as biogas plant operators in agriculture and industry. With a membership of over 4,900, the Association is the largest German and European group representing the interests of its members in the biogas sector. About 600 businesses are among the members of the Biogas Association; these have a particularly strong interest in the markets abroad. The export rate of these members already crossed the 65 per cent mark in 2015.

The International Affairs Department was set up in 2008, the period of growth of the German biogas sector and the restructuring of the Association. Whereas at the beginning the Department was staffed merely by one individual, it has expanded substantially since that time to meet the challenges posed by the changed general conditions and the higher importance of the foreign markets for the German biogas sector. At the beginning of 2016 the Department had a staff of seven (Sebastian Stolpp – Department head, Frank Hofmann – international affairs consultant, Julia Münch – international affairs consultant, Antje Kramer – project manager for India, Giannina Bontempo – junior project manager, Mareike Fischer – project assistant, Clemens Findeisen – consultant for development cooperation and Abhijeet Mukherjee, who manages the cooperation with the Indian Biogas Association in New Delhi). On the level of the Association management, Manuel Maciejczyk is responsible for the international agendas of the FvB. Partnerships with international organisations such as the United Nations Industrial Development Organization (UNIDO), the International Solid Waste Association (ISWA), Energy Solutions made in Germany (supported by the Federal Ministry for Economic Affairs and Energy) and, most of all, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, with which cooperation has been formalised since as early as 2011, are tools to
encourage the utilisation of biogas mainly in developing and emerging countries. The international activities of the FvB can be divided into the following areas:

1. European policies
2. Export promotion and information about biogas
3. International projects
4. Advisory services
5. Participation in international bodies

1. European policies
The formation of the European Biogas Association (EBA) in 2009 was decisively initiated and supported by the FvB because it was seen that it was becoming even more important to establish a joint representation of the interests of the biogas sector on the European level in Brussels without which it would be difficult to act successfully on the international scene. In the meantime, the EBA has a membership of about 80 in 28 countries (36 national biogas associations and 42 companies and universities). The International Affairs Department, together with the EBA, the EREF (European Renewable Energies Federation) and the BEE (Bundesverband Erneuerbare Energie e.V.), is pressing for the establishment of a supportive basis for the general legal conditions on the European level. For example, the FvB participates in the AG Europa and the Kompetenzzentrum Europa of the BEE and is represented at the board meetings of the EBA and the EREF. Topics discussed in 2016 include, among others the climate and energy policies of the European Union until 2030 (Governance Framework 2030), the revision of the Renewable Energy Directive, the European electricity market law and the environment and energy subsidy guidelines 2020.

2. Export promotion and information about biogas
Germany is perceived as a pace setter in the biogas sector throughout the world. The International Affairs Department is receiving inquiries from parties interested in biogas on the Association’s website (www.biogas.org). These inquiries are answered by the Department staff professionally and without preference of any particular supplier. Besides, the International Affairs Department receives delegations from other countries who listen to introductory talks on biogas and visit biogas plants. Several publications and sources with information about biogas are available in English such as, for example: Biogas can do it (www.biogas-kanns.de), Biogas: an all-rounder (www.german-biogas-industry.com), English editions of the Biogas Journals (published twice a year) and “Biowaste to Biogas – production of energy and fertiliser from organic waste” (www.biowaste-to-biogas.com), a cooperation project with GIZ, EBA and ISWA.

In addition to that, FvB officials frequently deliver lectures on biogas in Germany and other countries, for example under Energy Solutions made in Germany initiative (e.g., in Italy, Poland, Latvia, Kenya, South Africa, Ghana, Brazil, Turkey, the Philippines, Indonesia, the U.S.A.) or at international conferences such as the German-Brazil Biogas Forum, the Bioexpo Colombia, Foro Enres 2015 Mexico, Biogas Asia Pacific Forum or the Biogas Africa Forum 2016 in Kenya. By cooperating in the Strategy Advisory Council, the German Biogas Association contributes to the organisation of activities and measures of the Energy Solutions made in Germany initiative. The world’s largest conference and trade fair for biogas, the Annual Biogas Convention, has
also become distinctly more international in recent years. There are quite a view of events and workshops in English at every Convention. The choice of topics also is increasingly guided by the growing interest in foreign markets. This international trend receives extra impetus from the cooperation with the DLG (Deutsche Landwirtschafts-Gesellschaft) and, from 2016, the new BIOGAS Convention as part of the EnergyDecentral.

3. International projects
The Biogas Association had already organised a number of projects in past years. For almost a decade of years, the activities focused on the German market. In contrast with that, the participation in projects, mainly within an international setting, has become distinctly more important. A case in point is the project BIOSURF, short for Biogas as SUStainable and Renewable Fuel – a European project financed by the European Commission under the Horizon 2020 program (eleven partners from eight European countries, among them EBA, DBFZ, FNR).

The purpose of the project is to increase the production and use of sustainable produced biomethane and to clear out technical obstacles in the way to establishing biomethane trading at an international scale. The topics include: International biomass trade, biomethane register, sustainable biomass, GHG calculation, and others. The FvB commitment to the project focuses, in particular, on the dissemination of knowledge and network building such as by organizing six workshops and a conference and the Association also acts as advisor to all work packages of the project.

The beginning of December 2015 also marked the beginning of the chamber and association partnership between the Fachverband Biogas e.V. and the Indian Biogas Association (IBA). This project, financed by the German Ministry of Economic Cooperation and Development (BMZ) and managed by the sequa gGmbH, is initially limited to three years with the option to extend it by another three years. The target of the partnership project is to encourage the use of biogas in India and to strengthen the Indian Biogas Association (IBA). As the association of the biogas sector, the IBA is to represent the interests of its members, communicate competently and actively with the Indian government and the respective stakeholders in that country and raise the awareness of biogas among the population. “The Fachverband Biogas was also very small when it started almost 25 years ago,” FvB CEO Dr. Claudius da Costa Gomez recalls. “We are glad to be able now to share our experience with the IBA and other biogas associations. We want that the IBA, like this Association, finances itself from member fees, in the long term – and biogas, the all-rounder, and makes its benefits for climate, energy, environment and development policy known throughout India”.

The above projects are funded and help not only to improve the general conditions for biogas in foreign markets but also create new jobs, new competence and earning opportunities for the FvB. At present, more international projects in the fields of vocational education and climate protection are in the pipeline.

4. Advisory services
The FvB can also draw on the vast expertise in the biogas field, which is very attractive and in demand internationally. In

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So... it does pay off after all!
2013, the FvB decided to offer advisory services on topics like feed-in tariffs, biogas plant safety, lobbying, biomethane, waste digestion, training concept and in other fields. Here are a few selected examples of services already given:

- 1st German Biogas Training Days: Workshop on safety in biogas plants (for: GIZ project development program, Thailand).
- Mapping of standards and norms in biogas (for: GIZ SAGEN project, South Africa).
- Revision of a study on the approval practice in the EU (for: GIZ Probiogas project, Brazil).
- Biogas safety training (GIZ German-Turkish biogas project).
- Providing advice on feed-in tariffs in Kenya (for: GIZ project development program).
- Consultation and paper on plant safety in Uruguay (for: UNIDO).
- Providing advice in feed-in tariffs, approvals and other provisions Japan (for: Japanese Biogas Association).
- 2-day biogas training of employees of the Serbian Ministry of Agriculture and Environment.

Often, the target of these events is that of improving the legal framework for biogas, providing advice on political matters or on the safety of biogas plants – core competencies of the FvB. Competition with member companies in providing these services is expressly avoided. The FvB and the Association’s employees will not plan, design or build biogas plants at any time in future. The purpose of the work done by the FvB is to support the emergence of biogas markets in other countries and to encourage their development.

The commitment of the German biogas sector in developing and emerging countries is eligible for funding from several different sources such as develoPPP.de, climate partnerships with the private sector, SES, etc. The Consultant for Development Cooperation at the of FvB will be glad to advise member companies for free.

5. Participation in international bodies

The number of countries in which biogas is a topic is growing. Consequently, there is a growing need for uniform international standards and norms, the importance of which for the future cannot be underrated. The FvB is a party to the drafting and definition of such norms and standards in bodies of the international standardisation organisations ISO (ISO/TC 255) and CEN (CEN/TC 408).

Two aspects are decisive for the cooperation: For one, on the background of its many years of experience and know-how the FvB can make a decisive contribution to the quality of the norms to be developed, for another the involvement of the FvB ensures that German standards and interests are not swept under the table.

The export business is growing and so the international agendas of the FvB too. Take advantage of the new competencies of the FvB – we look forward to your feedback and cooperating with you in order to create framework conditions for the new biogas markets and finally increase the number of efficient and safe biogas plants in many countries.

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Macro-economic impacts of biogas production in Austria

A continuous extrapolation of the production and investments made in past years can contribute to achieve annual macro-economic impacts of approximately 376.1 million euro in production, 117.6 million euro in added value and 3,430 of full-time-equivalent jobs.

By Dr. Wolfgang Koller

The about 300 Austrian biogas plants produce energy and services worth 125 million euro and provide about 580 jobs (full-time equivalents). In 2013, they fed 544 Terawatt-hours (TWh) green electricity into the grid, which accounts for 7.6 per cent (%) of the total amount of green electricity produced. Through both its production and investments, the biogas sector gives important impulses to the whole economy. Although the Austrian government renewed its commitment to the strengthening of renewable energy sources in connection with the climate conference in Paris in December 2015, the future of the biogas sector is not secure, since more and more plants reach the end of the period of 13 years of the feed-in tariff guaranteed in the Austrian Green Electricity Act. Many of them are hardly economically viable without a follow-up law. In this light, it is all the more important to determine the macro-economic effects of the biogas sector on the Austrian economy. Such an analysis was prepared as part of the research project “Biogas network Austria – F&I for SME for securing competitiveness” financed by the Austrian Research Promotion Agency (FFG) in which data from official statistics was juxtaposed with detailed data supplied by the Compost & Biogas Austria workgroup.

Why an input-output analysis?
The results presented below were calculated with the help of an input-output model which was developed by Nobel Prize Winner Wassily Leontief in the mid-20th century. It is suited particularly for determining the macro-economic significance of an industry such as the biogas sector because it considers all aspects of the interdependencies between different branches of the economy. The database of the analysis is the input-output table organized into 74 economic sectors and categories of final demand, which in addition to the effects of production contains detailed data on added value and employment.

The analysis provides results consistent with the national accounts. Therefore, the added value impacts calculated below represent the contribution of the biogas sector to the gross domestic product. Considering the set of assumptions of the input-output analysis – which, among other things, comprises that production technology is assumed to be fix and includes a chain of causes running from demand to production – the production, added value and employment can be determined which are
directly and indirectly linked to the biogas sector by means of the advance service interdependence, the generated income and the generated consumption. This approach focuses on the so called gross impacts of the sector. However, a calculation of the net impacts was not carried out as it would involve the difficult questions as to the alternative use of the fields now indirectly devoted to the production of biogas, and to the way of producing the lacking electricity, if there was no biogas sector.

Production
The production of the Austrian biogas sector, overall 125.1 million euro in 2013, comprises mainly but is not limited to energy and energy services (see Table 1). The largest share of 99.8 million euro goes to electricity production. For the purpose of the study, the value of the directly fed biomethane was estimated at 6.9 million euro, and that of local and district heating at 5.7 million euro. About one-fifth of the Austrian biogas plants use waste as substrate. Waste disposal services generate sales worth approximately 6.8 million euro. Finally, the estimation of production also included drying services which the biogas plants provide for the food and animal feed industry, the paper industry and the wood industry, totaling approximately 5.1 million euro. Concerning these estimations, it should be noted that monetary values from the whole biogas sector in official statistics is only available for the fed-in green electricity. For the other items, an estimation or respectively a projection were made on the basis of data provided by the Compost and Biogas Austria workgroup which represented 150 biogas plants, as well as through the energy balance and the statistics of Energie-Control; the prices were, in some cases, calculated from the input of goods statistics.

Cost structure and employment
The cost structure of the Austrian biogas sector is extraordinary in several respects. The advance services in 2013 account for a total of 119.3 million euro, which is more than 95% of production. The largest share of 56.4% of the advance services goes to agricultural goods. Financial services follow with 15.8%. Other important advance services in the sector are the repair and installation of machinery and equipment (6.2%) as well as energy and energy services (3%). Overall 97% of the advance services are domestic in origin. The high share of advance services compares with low added value of only 4.6% of the production value, which is explained mainly by the negative operating surplus of -20.6 million euro (-16.5% of the production value). The remainder of the added value components (gross wages and salaries, employers’ social contributions and depreciations/write-offs) together account for 26.4 million euro (21.1% of the production value).

The estimation of this cost structure in the biogas sector is based on detailed data provided by the Compost...
and Biogas Austria workgroup (branch evaluation) and was extrapolated by the workgroup for the sector as a whole. About 580 persons (expressed in full-time equivalent) are employed in the biogas sector. No reliable information is available as to the number of self-employed or non-self-employed persons in the sector but about 100 self-employed full-time jobs can be assumed.

The macro-economic impact of production
Production in the biogas sector contributes a production worth totally 357.4 million euro on a national economic level (see Table 2). Thus, goods and services worth 232.3 million euro must be produced in other, upstream sectors to enable the biogas sector to contribute its production of 125.1 million euro. This discussion includes, in addition to the indirect impacts generated by the advance services chain, the so-called income-induced effects for the estimation for which it is assumed that a certain portion of the generated incomes of wages paid returns to consumption. The total added value generated in Austria’s economy adds up to a total of 109.5 million euro and the total number of jobs to 3,330 full-time equivalents.

Development and structure of investment
The significance of investment is considered separately from that of production and a separate input-output model is used for it. Total investments in the biogas sector amounted to 438.4 million euro in the period from 2002 to 2014. Investment was mainly done in the years from 2004 to 2007. After that, investment leveled out between about 7 and 14 million euro (see Figure 1). Most of the investment, 336.0 million euro (78%), was Austrian in origin. With 39.9%, construction work (mainly buildings and building construction) is the largest single item among capital goods and services. These are followed by electrical equipment (19.0%) and machinery (12.7%). Other important capital goods and services in the biogas sector include the installation of machinery and equipment, the wholesale trade and the services by architects and engineering firms (see Figure 2). Imported capital goods can mainly be found among electrical equipment, machinery and other assets.

Macro-economic impacts of investments
In a way similar to production, investment in the biogas sector generates production, added value and employment on the macro-economic level. In the whole period considered, 2002 to 2014, a production worth 684.2 million euro, added value of 297.8 million euro and employment of 3,669 annual full-time equivalents can be ascribed to the direct, indirect and income-induced impacts (see Table 3).

As mentioned earlier and shown in Figure 1, investment did not develop uniformly in the individual years. Therefore, the calculated total impacts also lack uniformity. In 2005, for example, about 710 full-time jobs in Austria were provided through investments of the biogas sector whereas that figure was between 50 and 110 full-time equivalents since 2008.

Summary: The macro-economic impacts of production and investments cannot simply be added together, since the former was determined for one year (2013), the latter for a longer period of time in which they fluctuated. A continuous extrapolation of the investment during the last few years yields macro-economic impacts of annually about 376.1 million euro production, 117.6 million euro added value and 3,430 full-time equivalent employment.

Outlook: Whether these macro-economic impacts can also be expected in future and whether more biogas plants will be built and investments into such plants go up in Austria depends on the decisions in the Austrian and European energy policies. If a follow-up regulation is installed, an expansion scenario of annually 32 million euro investment which increases the installed electrical capacity of the Austrian biogas sector from...
Table 2: Macroeconomic impact of the production of biogas plants in Austria, 2013

<table>
<thead>
<tr>
<th></th>
<th>Production in (\text{\textsterling}000) EUR</th>
<th>Value-added in (\text{\textsterling}000) EUR</th>
<th>Employment in full-time equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct impacts</td>
<td>125,117.3</td>
<td>5,804.3</td>
<td>583</td>
</tr>
<tr>
<td>Indirect impacts</td>
<td>204,419.7</td>
<td>89,056.3</td>
<td>2,555</td>
</tr>
<tr>
<td>Induced effects</td>
<td>27,871.7</td>
<td>14,669.1</td>
<td>193</td>
</tr>
<tr>
<td>Total effects</td>
<td>357,408.7</td>
<td>109,529.7</td>
<td>3,330</td>
</tr>
</tbody>
</table>

Table 3: Macroeconomic impacts of investments in biogas plants in Austria, 2002 – 2014

<table>
<thead>
<tr>
<th></th>
<th>Production in (\text{\textsterling}000) EUR</th>
<th>Value-added in (\text{\textsterling}000) EUR</th>
<th>Employment in annual full-time equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct impacts</td>
<td>336,027</td>
<td>140,062</td>
<td>1,579</td>
</tr>
<tr>
<td>Indirect impacts</td>
<td>258,310</td>
<td>110,446</td>
<td>1,468</td>
</tr>
<tr>
<td>Induced effects</td>
<td>88,869</td>
<td>47,282</td>
<td>621</td>
</tr>
<tr>
<td>Total effects</td>
<td>684,206</td>
<td>297,790</td>
<td>3,669</td>
</tr>
</tbody>
</table>

About 80 Megawatt (MW) at present up to 110 MW can be regarded as realistic. In that scenario, distinctly higher investment of up to 50 million euro could be expected for the first few years, as in addition to new and expansion projects replacement investments with held in the past would be made.

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The African neighbouring countries Tanzania and Kenya already have some experience with biogas. Even if still on a very small level, the number of politicians, energy experts, farmers and large agrarian enterprises are aware of the opportunities associated with the use of biogas. A round trip.

By Dierk Jensen

Peas, manioc, peanuts, maize, sweet potatoes, bananas: The fields of Fanice Khanalli in the little village of Eshibeye in West Kenya offer a wide variety. And on her farm, that farmer is very far ahead of her time. She was among the very first farmer in Kenya to build a small biogas plant in Kakamega County, north of Lake Victoria and east of the border to Uganda – with financial assistance of the German development aid. By European scales, the plant is not only small; it is very small: The volume of the digester is merely 24 cubic meters. In it, slurry and manure produced by four heads of cattle, calves and a bull – an above-average livestock population by West Kenyan standards – is digested in an anaerobic process. The size of the plant is too small to give the generation of electricity a real option.

Instead, the farmer, a biogas pioneer, uses the biogas for cooking meals and lighting gas lamps. Even if the 67 year old farmer experienced a number of setbacks in the first few years after her start into the production of biogas, she sees herself richly awarded. “The biogas which we take to the burners in two kitchens saves me a lot of wood,” she explains.

Unlike most of her neighbours she does not have to cut or gather firewood in the garden, the fields, on road verges, brooks or the surrounding woods for cooking her meals. Quite the contrary: Next to her farm, on which she employs six people, she has planted a little forest with different species of trees. She says the little forest is her “ecological bank”.

Biogas replaces charcoal – forests are saved

The uncontrolled use of wood for existential cooking is ultimately the decisive reason why forests in the dense-
ly populated and intensively farmed tropical regions of West Kenya are under pressure: It grows less wood than is consumed. This sober fact alone can make biogas an important contributor to the positive development of rural West Kenya – even without electricity production, stabilising grid supply or the production of motor fuel. “I still see many opportunities for this renewable energy source. I myself will start selling the gas which I do not need,” the committed woman is optimistic for the future.

How her plans might work can be seen today in the test site of the Bukura Agricultural Technology Center. The actors on that experimental farm, organised and financed by the local administration, deal with different ways of biogas that are based on the socio-economic structures of the agriculture in that region. The small Kenyan farmers would lack the capital required to invest into a biogas plant that produces electricity – quite apart from the fact that the current feed-in tariff is still far from a cost-effectiveness.

“Therefore,” the manager of the agrarian center, Martin Keya, underlines, “our first and foremost goal is to develop biogas applications which are simple, cheap and working to reflect the reality of living and working on our small farms”. Keya puts very high hopes in the “Rehau Home Gas” system, which has been tested at the experimental farm since the end of 2015. “This is a polymer gas bag that holds 2,000 litres of gas and lies on the ground. It is delivered by the German company Rehau Unlimited Polymer Solutions”.

The principle is simple: The bag is placed on a slight gradient, filled with manure and water at its lower end, the biogas ascends and is transferred into a second, smaller bag through a hose. When that bag is full, the hose is closed by a valve. “I take the full and yet very light-weight bag under my arm and carry it home, where my family uses the biogas for cooking,” says Keya with a broad grin across her face. “The gas is enough for cooking meals for several days”.

„If I used portable bags, my neighbours could profit from my gas“

Fanice Khanalli
An employee of Simbi-Rosefarm bundles roses freshly picked in the greenhouse.

Residues of the rose production are chopped before being filled into the biogas plant.

When Khanalli saw this system at the Bukura Agricultural Technology Center for the first time, she glared for it instantly. "My biogas plant produces more gas than I can use. When I use these portable bags, my neighbours in the village could also use the gas," Khanalli, who now is an energy producer and farmer, says. She also notes that biogas is increasingly perceived by the Kenyan public.

Although in the same country, the use of biogas in the Rift Valley north of Nairobi is faced with totally different economic conditions. This is the region in which large agrarian businesses grow tea and coffee on large plantations or grow flowers and vegetables on a large scale. Everyone who travels by plane from Nairobi north, to Lake Turkana, the world's largest desert lake on the eastern bank of which the construction of Africa's largest wind farm with over 300 MW output has just begun, will see the gigantic greenhouses in which roses and green beans are grown for the international market.

These agrarian businesses produce large amounts of organic waste that provides excellent substrate for anaerobic digestion. Besides, the demand of these tropical farm-factories for energy is great; the locally produced electricity and heat can be used for internal production processes. Over half a dozen biogas plants in the megawatt-class have started operation in that region during the last few years. One of them was designed by the Bavarian planning firm Snow Leopard Projects for VegPro north-west of Naivasha Lake. The plant produces one mega-watt of electricity and operates on residues from the production of small maize cobs. But other actors such as, for example, Manfred Ebeling, biogas plant operator in Püggen in the Wendland region (Lower Saxony), were active as biogas advisors in Kenya in the past.

Electricity feed is not economical so far

"The site conditions are good, agriculture is holding out a huge potential," Frank Hofmann, specialist in the International Department of the German Biogas Association, confirms. He studied the situation in detail during two trips to that country in the past few months.

"Despite the possibilities, you have to remember that there are no fixed rates for the feed-in of electricity in Kenya's grid. Considering the current tariffs, no one can feed electricity in the public grid profitably," Hofmann puts the brakes on euphoria.

In fact, the biogas plant near Naivasha is operating only at 200 to 300 kW output, the level that meets the internal need of VegPro. More electricity is not produced because the feed-in of that electricity into the grid is not worth the effort. At the "Dialog Forum Biogas" initiated by the Gesellschaft für Internationale
A view on the channel where the liquid substrate feed-in system in the biogas plant of the sisal processor Kitani in Hale in the northeast of Tanzania.

Sisal production: a machine separates the fibres from the other parts of the plant.

Zusammenarbeit (GIZ) in Rift Valley in December 2015, actors of Kenya’s biogas scene met German experts for a discussion of current issues. The experts were agreed that a feed-in tariff of about 14 dollar-cent per kilowatt-hour would make production economical under present conditions. This sounds very moderate to European ears. But that is happening in a country in which the lobby of the conventional fuels has struck roots as far as deeply into the ministries and the present government is trying to reduce the energy prices for end consumers, an energy political target that will be difficult to put through. For that reason, biogas proponents in Kenya in the political debate never miss to stress the grid stabilising and regulating benefit of biogas. Whether these points will be heard in the energy ministry remains to be seen.
Tanzania: the first large plant is decaying

Hope always dies last. Also in Tanzania, where not far away from the port town of Tanga at the Indian Ocean, in the town of Hale, to be more exact, the first large biogas plant of that country was built with massive financial support from UNIDO about ten years ago. Although the plant, equipped with Chinese machines, among these two 150-kW engines of the manufacturer Jinan, was highlighted extensively in the media right from the beginning, the technology of the plant proved to be a flop. The plant has been out of service for quite some time. “The technical concept is in general all right and the plant was running successfully over years, but the operator has not followed consequently the advised maintenance from the manufacturer,” regret Alexander Boitin from BEB BioEnergy Berlin GmbH, which has planned the pioneer-project.

“We will soon start reconstructing the plant,” Gelead Kissaka assures the visitor with a sigh in his office. He is the general manager of Mkonge Energy Systems Company Ltd., a subsidiary of the sisal company Kitani Ltd. When Kissaka opens the container he looks at the two Jinan engines which have developed lots of rust, as well as the digesters digesters, which are glowing in the light of the tropical evening sun. The noise produced by the fiber breaking machine in the factory hall up on the hill. It crushes the thick agave leaves delivered fresh from the field and separates the valuable fiber from the plant.

Sisal fibres in the substrate create a problem

The juice produced when the plants are crushed flows down the hill in channels but not in the digester planned for this purpose, but on a dump, because the biogas plant is not working. “In the past, we have had lots of problems with the fibres in the sap,” Kissaka admits errors in the design of the plant, “the fibres got entangled in the stirrers that stopped running after enough fibres were collected”.

Despite these blatant mistakes in the concept of the plant, despite the money that was donated by the international community, the approach pursued by the owner is still promising for the future: Only a fraction of the agave biomass is used in the production of sisal, a natural fibre, the energy-rich liquid residue often evaporates or simply rots away. A squander of resources that the larger companies in the sisal industry seem to have realised meanwhile. For example, Tanzania’s sisal association expressly recommended that efforts should be undertaken to extend the value-added chain in the slowly recovering sisal sector by making use of the biogas. By the way, this is entirely also the aim of the sisal industry in Kenya where the crop is also grown on large plantations.

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The prospects for biogas on Cuba are good and they have been exploited in the difficult period following the fall of the Soviet Union. It is only very recently, though, that the number of plants has grown

By Klaus Sieg

All Pedro Espineira really wanted was for his grandson to thrive. “He was born in 1992, when the situation in the country was very difficult,” recalls the 71-year old. In Cuba this time is known as the “Periodo especial”. It was triggered by the collapse of the Soviet Union. The Caribbean island lost the consumer for the majority of the sugar grown on its farms, and the supplier of cheap industrial goods, petroleum and fertilizers. The American economic embargo was also tightened. There were great shortages on Cuba, especially power shortages. “There was neither kerosene nor gas, the women had to cook on wood fires,” the retired construction engineer continues. “That’s why I built the that plant”. He proudly points to the two-cubic-metre biogas plant which stands next to a mango tree behind his house on the outskirts of the town of Sancti Spiritus. His grandson has long since grown up. But Pedro Espineira continues to fill the plant with dung every day. He currently obtains it from a neighbour who keeps two cows. For almost a quarter of a century his wife has cooked every day for at least five people using the methane from this plant. She has only missed a few days, when after ten years of operation Pedro had to line the metal bell with a film, because the inside had been eaten away by sulphuric acid. “Otherwise I just have to clean the pipes every three months, because the moisture in biogas causes them to rust”.

**Biogas plant: drew up the plans himself**
Pedro Espineira pulls a hand-drawn construction drawing out of his shirt pocket, unfolds it and explains the plant’s principle. The two-metre-high, walled fermenter vessel measuring one metre across is sunk two-thirds deep into the ground. In it a kind of metal bell floats in the slurry of water and dung. The methane is forced into the pipes through the top of this eighty-centimetre-high bell. The bell rises or falls depending on the volume of methane. “It can rise by half a metre and then comes up to here on me”. Pedro Espineira holds his hand level with a point on his slender chest. The plant regulates the pressure through the rise and fall, so the supply of biogas to the little house’s kitchen is always sufficient to feed the four-ring cooker.

How did he come up with the idea? Pedro Espineira smiles mischievously. “Back in the 1970s there was once a campaign for small plants, but most didn’t work well”. Pedro Espineira waltzed into the library’s factual section and tinkered until he came up with an improved plant. Nothing gets the better of an engineer, especially
when he’s from Cuba. It’s a well-known fact that necessity is the mother of invention. The wiry man won awards for and had articles written about his homemade biogas plant, including in Granma, the Cuban Communist Party’s official magazine, and a prize of a week’s full board for him and his wife at the Varadero beach resort.

In the meantime petroleum supplies from Venezuela, production of Cuban oil and a national energy-saving programme have staved off the extreme shortages. Nine million energy-saving bulbs were distributed to Cuban households and low-interest loans made available for purchasing more efficient refrigerators, cookers and air conditioning. The government also decentralised the power supply, to relieve the big, old, ailing power stations. Although there are still switch-offs and blackouts, they are not to the same extent as in the 1990s, with power outages of up to 16 hours per day.

As the example of Pedro Espineira shows, micro biogas plants are still providing a valuable service today on the Caribbean island. Fuel is still expensive and methane a cheap alternative. The plants are also increasingly used as an environmentally friendly way to dispose of slurry and dung, and to obtain organic fertilizer. It is pig fattening farms in particular which are increasingly relying on biogas, so they no longer dispose of their slurry untreated in pits, as was previously frequently the case and still happens today.

Joel Matienso’s biogas plant has been in operation since 2012. It too functions perfectly and processes the waste from 300 pigs. The slurry runs through concrete channels, straight from the sties to the 42-cubic-metre fermenter tank on the edge of his farm in the province of Sancti Spiritus. “I built the plant myself,” he shouts hoarsely above the noise from his pigs and the chipper which two of his employees are using to chop manioc. He had help from other farmers who already had experience. His biogas plant reliably produces methane every day. “We use it all ourselves,” says the stocky, short grey-haired farmer. Four families, a total of 16 people, live and cook on the farm. In addition to Joel Matienso, his wife and their two children, there is also one of his three brothers and family, who helps him run the business. “We also cook the feed for the piglets using methane from the broken rice”.

Matienso reckons he saves around 240 euros per year. In Cuba this corresponds to more than the annual salary for a university lecturer, a doctor, or a construction engineer – Joel Matienso’s real profession. He was able to give this up five years ago thanks to his pig breeding.
Since then the family have been doing well. There is a new air conditioning system in the house and a new television, a red 1989 MZ outside which, despite its advanced age, cost almost 8,000 euros.

1,700 euros to build

Private cars are a luxury in Cuba. The investment of around 1,700 euros for equipment and labour to build the biogas plant was comparatively modest. “I’ll soon get it back again,” says the 49-year old, who stomps off in his white wellies in the direction of the fields to show the effectiveness of the waste product from the biogas plant as a fertilizer. Sugar cane and manioc for the pigs grow on half a hectare and guavas, avocados, bananas, lemons, coconuts and much more for the family in another area.

This kind of smallholding is still very important in Cuba because of the continuing lack of supplies. Private farmers frequently have...
little access to expensive fertilizers or pesticides though. Both are sold almost exclusively through government businesses. This is why many farms are organic, without necessarily being certified as such. Many pig fatteners around Joel Matienzo’s farm rely on biogas plants. Even farms with less than 10 pigs use fermenters for their slurry. Four hundred of the 1,200 pig breeding farms in the province of Sancti Spíritus already use biogas. Most of the plants are relatively recent. Since the start of 2016 all pig farms which keep 20 or more pigs have to ferment their slurry in biogas plants. Many businesses work closely with the State Empresa porcina, from which they obtain piglets, milk feed and veterinary services and to which they sell their pigs. Since last year these businesses have to prove that they have a biogas plant when they conclude their contracts, which are always valid for six months. The boom in micro biogas plants also has something to do with the expertise at the University of Sancti Spíritus. In the small, central Cuban town which, as a Spanish colony, grew rich on sugar cane cultivation and the exploitation of black slaves, scientists have been researching biogas for many years. “There’s very great potential on Cuba,” says Osvaldo Romero Romero, from the University of Sancti Spíritus, currently visiting professor at the Technische Universität Berlin. According to official figures from the Cuban Energy Ministry, up to now there are 1,818 plants on the whole island. The volume varies between 10 and 200 cubic metres. There is also a not inconsiderable number of unknown plants. But Osvaldo Romero Romero knows that it could – and must – be many more. “Seven thousand alone could be fed on pig slurry and another 1,700 on cattle dung”. Five hundred plants could also ferment the waste from sugar and jam factories, distilleries, abattoirs or coffee processing. Just 4.3% of Cuba’s electricity is generated from renewable sources, the majority from biomass. ▶
Almost half of Cuban power stations burn crude oil, 60% of which has to be imported, as well as the other fossil fuels diesel and gas, which are used for electricity generation. According to the National Commission for the Development of Renewable Energies set up by Raoul Castro, this should change. The politician’s intention is that by 2020 the proportion of energy from biomass, solar, water and wind power should increase to 24%.

Financing for imported technology not possible

In this plan biogas does not appear for electricity generation, but as a source of fuel and organic fertilizer. On behalf of the Commission, though, the University of Sancti Spiritus is already working on a national program to develop biogas in Cuba and this programme also provides for electricity to be generated from methane. “Electricity from biogas could provide 7 to 10% of the electricity used on Cuba, even in excess of 20% in the province of Sancti Spiritus,” estimates Osvaldo Romero Romero. But the country is nowhere near this yet; there is neither a domestic technology nor the option of financing the import of foreign biogas technology.

The Archea Group of Companies from Oldendorf in Hesse, Germany, intends to change this in cooperation with the University of Sancti Spiritus. Keen interest was shown following preliminary talks with government representatives and an initial visit by a delegation to the Lower Saxony Minister of Agriculture in May 2012. “Cuba is very interested in green energy,” says Saskia Lowen, plant construction project engineer at Archea. She sees the potential electrical output from biogas plants as being at least 500 megawatts.

Archea wants to build a pilot plant with 250 kilowatts electrical output at a rice producer’s. The intention is to win support for this type of biogas use. At the same time the very well-educated scientists from the university will be able to gain practical experience. But what would be a suitable substrate? After harvesting fuel-containing paddy straw is left on the fields as fertilizer. There are no resources for cultivation of fuel plants. Moreover, there are more than six million hectares of agricultural land, of which almost one million is uncultivated. First and foremost, though, the Caribbean must increase production of food and animal feed in order to reduce imports.

Locally Archea developed the idea of using the left-overs from rice drying, and this ideas stemmed from the results of a doctoral thesis by Luz María Cotreras, from the University of Sancti Spiritus. The husks, broken rice and paddy straw could be mixed with the slurry from an adjacent pig fattening farm. The methane from the biogas plant could power a combined heat and power plant. The heat and electricity obtained could be used by the rice producers themselves for drying, amongst other things.
This is important. It is difficult to feed into Cuba's overburdened electricity network. But there are still numerous stumbling blocks: “Every bag of cement needed on Cuba must be planned a year in advance”, is how Saskia Louwen describes the defectiveness and difficulties of the centrally planned economic system. There is also the bureaucracy. And what is the right form of company? Very recently foreign firms have been able to set up their own subsidiaries, rather than a joint venture. These must not recruit employees direct, however, but must choose from the labour supply allocated by the state. “We still definitely want to get involved in biogas on Cuba”, says Saskia Louwen. This is what religious charitable organisation Centro Cristiano de Reflexión y Diálogo-Cuba (CCRD-C) has been doing for more than 20 years, in other words since the Periodo especial. “With biogas we are killing two birds with one stone”, says director Rita Morris. “We are improving the living conditions of the rural population and reducing environmental pollution from pig slurry.” The organisation is receiving assistance with this from the Berlin Missionswerk and the European Union, amongst others. CCRD-C’s social work in the provinces of Santiago de Cuba and Matanzas includes courses in the use of biogas plants and small loans for their construction, as well as care of the elderly, legal advice, help with domestic violence and courses in sustainable agriculture.

**Aid organisation assists with the construction of 300 plants**

Three hundred plants have been installed with the organisation’s help in the predominantly agricultural province of Matanzas alone. “Every plant is used by an average of three families”, explains Rita Morris. The province’s farmers are showing very great interest, because they can see the extent to which their lives would be improved by the methane they produce themselves. Many of the small farmers live very modestly. A biogas plant can help them to cut their energy costs in half. “We currently have around one hundred people on the list of those interested in a micro biogas plant.” But the organisation doesn’t have the money or the capacity to cope with all these enquiries. Evan Lafa from the village of Quatro Caminos has been lucky. He has been able to build a 10-cubic-metre plant with help from CCRD-C. In it ferments the slurry from around 30 pigs. The biogas plant and pig sty are in the garden behind his house, in the shade of tall banana trees. “Before it stank unbearably here, but that’s all over now and we have fertilizer and fuel.” Both the households on his farm exclusively use methane for cooking. This saves around five euros per month, which would otherwise have been spent on electricity for the hobs. A tour of the village makes clear what an important saving this is on Cuba: horse-drawn carts and teams of oxen traverse the deeply rutted main road. Yet the swing chairs that stand outside every little house make the visitor think of a relaxed, carefree Cuban lifestyle. Nothing could be further from the truth. Most people here have to work hard and skilfully improvise to make ends meet. Many people keep pigs as a side line or for self-sufficiency. Not everyone is in a position though, to run their biogas plants all the time. Many pig breeders get their feed from the government’s Empresa porcina. Because this has constant supply problems, some of the farmers sell their pigs without buying new piglets. These farmers then don’t have any slurry. CCRD-C itself operates two biogas plants of its own which save the organisation around 60 euros per month, which they previously had to spend on propane.

**Preserving with biogas**

Methane not only cooks the food for the 200 employees on the aid organisation’s 36-hectare fruit and vegetable farm near the little coastal town of Cárdenas. In a kitchen on the edge of the farm two women use biogas to cook cabbage, mangos, papaya, cucumbers and green tomatoes for sale. They thus keep the farm’s diverse produce, which supplies the local people with cheap and healthy food, going after the harvest season.

Used PET bottles are collected from hotels, restaurants or private households for this. The women cut these open and wash them in hot water to disinfect them. They then fill them with the cooked produce and vinegar, clamps the bottles in a device and weld them shut with an iron bar which they have previously heated on the stove. Heat is necessary for almost all these stages. Cuban improvisational skills and biogas seem like a marriage made in heaven.
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