Germany's Renewable Energy Policy as a Response to Energy Crisis - the Example of Biogas Production

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1) Renewable energies in Germany

The world's energy demand is growing from day to day! Economic growth linked with social prosperity and expanding populations have a share in this global deployment tendency. According to the "Official Energy Statistics 2008" from the US Energy Information Administration, the world energy consumption is projected to expand by 50 percent from 2005 to 2030 *(Figure 1)*.

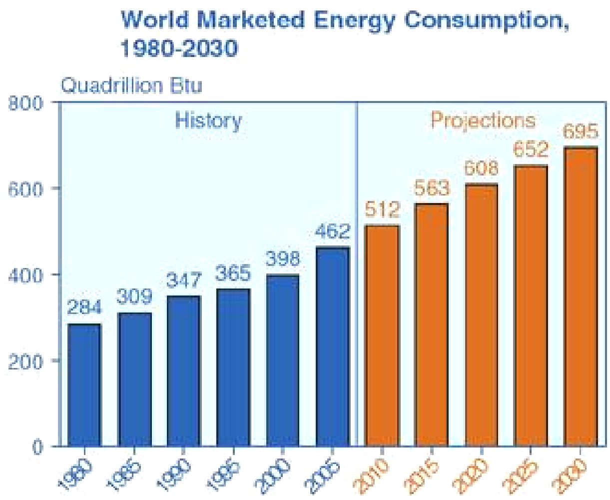


***Figure 1:* World Marketed Energy Consumption, 1980-2030**
Source: Energy Information Administration, USA

But the fossil energy carriers are middle-term limited! Against the background of sustainability and with responsibility to the future generations, the German Government searches for practical approaches. Referring to this the renewable energies will play a key role in national energy politics: biomass, photovoltaics, wind energy and hydropower have replaced nearly 7 percent of the primary energy consumption in 2007 *(Figure 2)*. In contrast to energy sources such as oil, coal, uranium and natural gas, the use of renewable energies protects the climate and environment, is safe, resource-efficient and environmentally friendly. In 2008 the use of renewable energies in Germany prevented the release of about 112 million tons of climate-damaging CO_2. Furthermore it ensures greater independence from energy imports, greater security of supply and strengthens the domestic economy. Consequently the renewables are increasingly becoming an important economic factor. Linked to this, there is also significant growth in employment. According to an ongoing research project of the Federal Ministry of the Environment, the whole branche provided approximately 117,000 new jobs during the last four years.

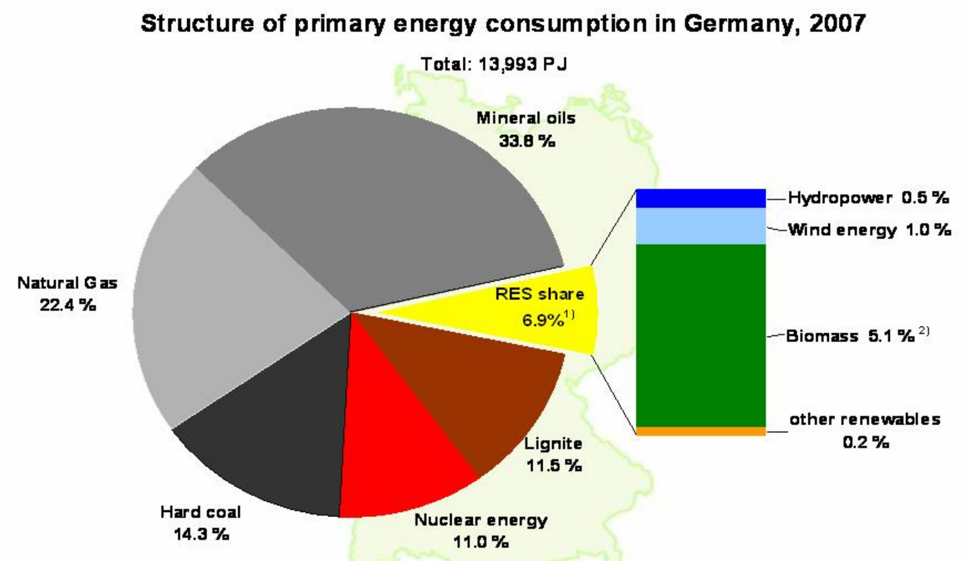


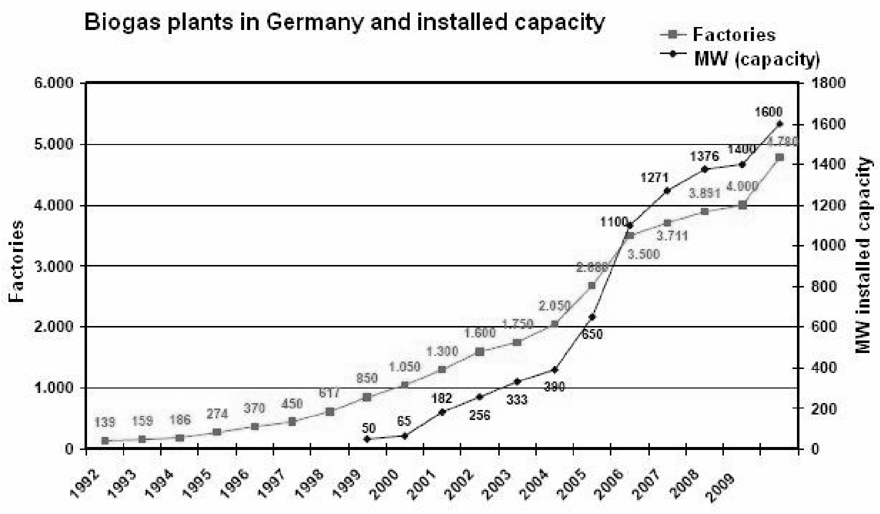
***Figure 2:* Structure of primary energy consumption in Germany, 2007**
Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany

2) The "Renewable Energy Sources Act" and its secure frame conditions

Such a positive growth of course requires general conditions concerning the subsidy of this advanced and innovative sector. With the “New EEG” (“Renewable Energy Sources Act”), which was amended for the second time in January 2009, investors and contractors are able to calculate with sure and attractive feed-in payments for their energetic products and receive planning security for 20 years: operators of power grids are obliged by law to give priority to purchasing electricity from renewable energie producers. Therefore the "New EEG" is an important driving force in the expansion of renewable energies in Germany.

In line with this national law, different biogas processes are subsidized with bonuses, to use prospective potentials and generate energy efficiently. Beside the basic feed-in payments for electricity (11,67 cent / kWh), there also exist additional possibilities of subsidization: by way of example there is a bonus formulated for the insertion of renewable primary products (6 cent / kWh) and a special premium for farm fertilizers with a mass fraction of 30 percent (4 cent / kWh), to use these by-products energetically and make it more ecologically compatible. Moreover the "New EEG" includes a bonus for landscape conservation materials (2 cent / kWh) as well as a bonus for co-generation of heat and power (3 cent / kWh thermally usable heat) and a technology bonus for innovative factories (2 cent / kWh). In the focus of subsidization there are middle-sized biogas plants up to a capacity of 500 kW_{el}.

All in all biogas plant technology is sophisticated in Germany and will reach according to forecasts an installed capacity of electricity generation of 1600 MW, by means of 4780 separate factories *(Figure 3)*. The entry into force of the original "Renewable Energy Sources Act" in 2000 led to a similar boom in biomass and reached its temporary peak with the first amendment in 2004. Since renewables were not competitive on the market up to the year 2004, the government subsidized these ecological energy carriers more intensively. Therefore the renewable energy concept is already now a great success for German energy supply and policy with an actual annual turnover of 1,5 billion Euro exclusively on the biomass sector.



***<u>Figure 3:</u>* Biogas plants in Germany and its installed capacity**
Source: German Biogas Association

3) The functional principle of biogas production

In particular the agriculture provides opportunities to use biomass in a closed material cycle. In this regard the operators generally use conventional farm fertilizers such as slurry and manure from cattle, hog, or poultry in combination with renewable commodities like crop, silo maize or meadow grass, to generate biogas. For this raw product there are principally a couple of applications: operating a combined heat and power station (CHP) to generate electricity and to use the rejected heat of the aggregate for heating housing developments or industrial buildings or cleaning and purifying the biogas to inject it into the central gas distribution system. Another innovative example for this purpose is the installation of a filling station for purified natural gas to fuel gas-powered vehicles, such as the biogas filling station in Jameln - Wendland, Germany.

Biogas plants - based on renewable primary products – are getting charged daily with ensilaged herbal and animalistic commodities by a biomass collection tank. From there the material enters the central fermenter *(Figure 4)*. Here the biomass is covered and compressed mechanically and by the weight of the material that is deposited from above. Biogas is produced when bacterial working stocks at the fermenter convert organic matter into methan gas. Instead four ingredients are needed to produce the raw gas: an adequate volume of organic material, bacteria, anaerobic conditions and the warmth of the heated fermenter (40-50°C). At this temperature anaerobic bacteria in the biomass-mixture are quite active converting the filled in organic matter into methane gas. Thus it is very important to feed the digester in a similar way to support the biological fermentation process. Principally the analogical process takes place in the ruman of a cow, so we often hear biogas plants referred to as anaerobic fermenters. The main constituants of biogas are methane (CH_4, 50-75 percent), carbon dioxide (CO_2, 25-50 percent) and nitrogen (N_2, 0-10 percent). This resulting biogas can be buffered in a voluminous gas storage as an elastic hood above the fermenter, to deliver the generated biogas to a CHP or to a gas treatment plant. The fully fermented residue gets stored temporarily in digestion residue storage and with the recovery it closes the material cycle in use as a nutrient-rich fertilizer, to feed the energy crops by replacing mineral fertilizer partially.

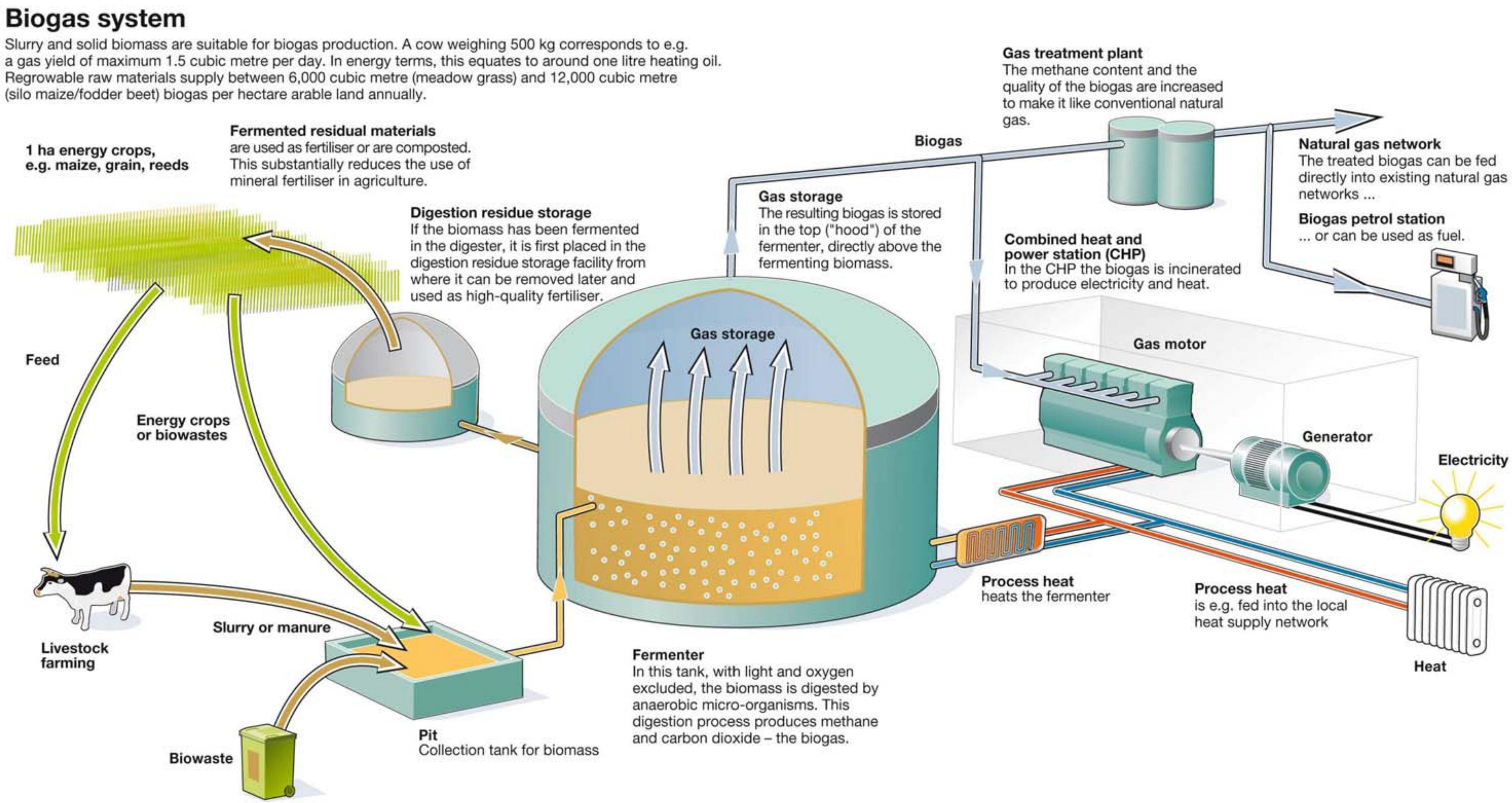


***Figure 4:* The general functioning principal of biogas production**
Source: Germany's Renewable Energy Agency

4) The example of a biogas plant from an energetic and ecological point of view

A paradigm for German biogas production is the "BG Naturacroft" biogas plant in Muinchberg, Bavaria - Germany. This plant, with an electrical capacity of 500 kWel, feeds in completely generated energy into the public electricity network. For generating 3,5 million kWh per year, it requires all in all an agricultural area of 300 hectares. Many farmers from the region are able to deliver their herbal commodities to the central silo platform at the factory, where the operator gauges the concrete dry mass content, which is the basis for payment. For illustration, one ton of dry mass gets discounted with 90 € (no costs considered), whereupon the result of one hectare of high-energy silo maize, with a fresh weight harvest of 50 tons per hectare and a dry mass rate of 34 percent, is a calculable dry mass weight of 17 tons per hectare. Approximately half of the whole energy requirement of the factory is covered by extern farmers within a radius of 20 kilometer around the biogas plant therefore strengthening the agricultural value added on location. In return the deliverymen retrieve their proportionate residue substrate as a fertilizer for liquid application, to balance the export of nutrients. Another fundamental component for primary product accommodation are annually 3,000 tons of slurry from a big dairy stable at a distance of 300 meter, which are pumped directly into the insulated general fermenter and get mixed with the balanced combination of maize, grain silage, meadow grass and manure. Hot water heating tubes are wrapped around the whole building, to keep the biomass content at about 45°C. This requires one fourth of the annual waste heat output of the 536 kWel MAN block-heating-station (CHP), whereas the largest part can be used to heat an industrial area within an efficient waste heat concept. To this end a 1,5 km long heat conduction leads to the industrial complex to assure the supply with local heat. Because of the heat loss on the way through the heat conduction to the consumers, it is important that the biogas factory with its CHP is not too decentral. In summary the following chart gives a survey of the input charge materials and the power data of "BG Naturacroft" as well as a practical illustration of the local conditions *(Figure 5 + Figure 6)*:

Composition of the Ration and power data		
Charge materials within a radius of 20 km	**fresh weight [to] / year [y]**	**biogas [m³] / fresh weight [to]**
Slurry (of cattle)	3,000 to / year	23 - 30 m³ / to
Manure (of cattle)	1,000 to / year	50 - 70 m³ / to
Maize (ensilaged)	3,500 to / year	190 - 240 m³ / to
Grain (rye, ensilaged)	2,500 to / year	180 - 250 m³ / to
Meadow gras (ensilaged)	2,500 to / year	150 - 220 m³ / to
Power data of "BG Naturacroft": Muinchberg, Germany		
Input charge materials	12,500 to / year	
Installed capacity	500 kWel	
Coefficient electrical	32 percent	
Operating hours	8000 / year	
Generation of electricity	3,5 Mio kWhel / year	
Self-power requirement	7 percent of annual output	
Use of waste heat	50 percent of annual output (industrial area)	
Energy efficiency	**3 kWh renewable energy / kWh fossil fuel**	

Figure 5: ***Composition of the ration and power data***
Source: Direct information of the biogas plant, own calculations

From an energetic point of view, this biogas plant has an averaged operational performance of 8,000 hours per year and as the result approximately 3,5 million kWh of electricity is produced. In addition an average German household of four persons consumes 3,500 kWh of electricity annually, which means that more than 900 households can be permanently supplied with electricity by the use of such a biogas plant. In the matter of heat production, the exemplary biogas plant in combination with the combined heat and power generation (CHP) supplies an industrial area with process heat. Whereas 25 percent of the annual output is needed for warming the fermenter, more than 50 percent of the waste heat can be efficiently used, which is comparable with the heat energy demand of 600 German households. In particular the power-heat coupling bonus of the “New EEG” advances such efficient developments, because it is a term used when referring to an energy production plant, which produces both electricity as well as heat. And the more the power-heat coupling technology of a plant is exploited, the higher the plant’s overall efficiency and economy. Considering the sum of all the facts of this “BG Naturacroft”, a very positive energy balance can be generated: by investing one kWh of fossil energy for fuel, fertilizers and other energy carriers during the biogas generation, three kWh of regenerative energy is produced. As a result an effective energy triplication of environmentally acceptable energy may be achieved. With bad thermal use, disproportionately high mineral fertilization or an increasing transportation distance of commodities, the energy efficiency decreases. For the purpose of energy efficiency it has to be a formulated main aim of biogas production, that it is linked with a sustainable and regional plant production as well as a sophisticated concept of waste heat usage of the CHP or an innovative biogas refining!

***Figure 6:* Pictures of “BG Naturacroft”: fermenter, industrial area, silo platform, charging station**
Source: Direct information of the biogas plant, own pictures

Interestingly the energy balance correlates positively with the CO_2 balance of the factory, so that an increase of energy efficiency implies an advancement concerning the CO_2 balance. For each kWh of electricity produced, approximately 600 g of CO_2 can be reduced. This is to say that the 500 kW factory of „ BG Naturacroft " is able to reduce a CO_2 equivalent of 2,000 tons of emission reductions each year. The outcome of the total account of the example plant is that we have a CO_2 avoiding of 7,0 tons per hectare in comparison to the indicated all-German energy mix including nuclear energy, coal, gas and oil *(Figure 7)*. This calculation also includes the aggregated emissions and energy inputs for the construction and of the whole working process to the point of far reaching environmental influences. From the point of view of the biogas plant in Muinchberg, there are a lot of potentials to upgrade the CO_2 balance for example by involving a larger share of farm fertilizers or by optimizing the energy-intensive application of the residue substrate. The fermentation of slurry and manure in biogas production greatly reduces the pathogen content and the odour of this material, as effectively all the volatile gases have been removed. Another advantage is, that the process also serves in homogenisation and sanitation of the residue substrate, so that it is easier to agitate, pump and spread. One concrete possibility to economize transportation could be to dehydrate the homogenous residue substrate using the remaining waste heat of the CHP, so that no water has to be transported and the fertilizer can be spread as a solid matter. For boosting the share of farm fertilizers and the total economy, it would be practicable to transport the pig slurry of a midsized hog house at a distance of 1,0 km to the biogas plant by tank car. For instance the mass fraction of farm fertilizers increases to more than 30 percent, which means in consequence that besides the positive energetic and environmental efficiency effect a higher feed-in payment of 2 cent per kWh_{el} could be realized.

CO_2 - Calculation for "BG Naturacroft", 500 kW biogas (with 300 ha agricaltural area)	
ENERGY YIELD	**kWh_{el} / ha**
GROSS ENERGY (output less energy for construction etc.)	15.000
ENERGY INPUT (fuel, fertilizers, aggregated emissions etc.)	-5.900
CREDIT FOR THERMAL USE (~ 50 percent exploitation)	4.000
ENERGY AFTER DEDUCTIONS	**13.100**
$CO_{2equivalent}$ - BALANCE	**kg $CO_{2equivalent}$ / kWhel**
CO2eq - EMISSIONS (including thermal and electrical use)	0,163
CO2eq - GERMAN ENERGY MIX (index for comparison)	0,627
CO_{2eq} - AVOIDING	**0,464**
CO_2equivalent - AVOIDING	**~ 7,0 to / ha**

Figure 7: ***CO2 - calculation for "BG Naturacroft" (Muinchberg), 500 kW biogas***
Source: German Biogas Association

5) German biogas production for the future

An expanding biogas production in the future could provide farmers with an additional source of income, while providing society with an alternative use for food co-products. Beside the numerous environmental benefits, there is also a tremendous potential for rural economic development. Consequently the potential exists for a typical “win-win-situation” for generator, consumer, association and country. In summary there are three main points which are responsible for the quick proliferation of biogas technology and sustainable energy production in Germany:

1) The government has made a commitment to have electricity prices that reflect the cost of producing renewable power;

2) The operators principally get guaranteed access to the electricity grid with fewer restrictions or fees;

3) The biogas branch is sophisticated and capable and know-how can be transferred very quickly on location;

Referring to this, the government formulates ambitious aims concerning the upgrading of regenerative energies for the future. The share of the primary energy consumption is to be increased from 7 to at least 18 percent by 2020, followed by a continuous increase. Furthermore, by 2020 the share of biogenic fuels and particularly the biogas fuel production is to be increased to a level of 12 percent (energy related). This is to achieve a 7 percent decrease of greenhouse gas emissions against the use of commercial fossil fuels and contributes all in all to global climate protection. On a global platform nearly ten percent of energy demand could be covered by biomass in the medium term. This is the conclusion drawn by the German Advisory Council on Global Change (WBGU) in its latest report. According to the authors of the study it is decisive for the long-term success of biomass that energy generation does not take place at the cost of food production or nature and climate protection. In order to achieve this binding sustainability standards should be introduced both at the national and international levels.

In 2008, as a year of extremely high commodity prices, a very controversial discussion about the competitive situation of food and energy production had started. Last year energy crops grew on 2 million hectare in Germany, which equates to 12 percent of the arable land. According to a study by the Federal Ministry for the Environment, by 2030 this area could be more than doubled without calling into question the food supply. The arable land can of course only be committed once - but biomass is also available in the form of residual materials from food and feedstuff production, farm fertilizers and landscape conservation materials. Agricultural food production and biogas-energy therefore do not have to compete against each other, but instead have to work hand in hand. For conclusion biogas production is of course not the patent medicine to solve all the energy problems of our world, but doubtlessly it is an integrative component of a balanced energy policy to use the total energetic potential of biomass much more efficiently!

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11. General information and mentoring *contact person: Prof. Dr. Ralf Schlauderer*