OPTIMIZATION OF THE DEPLOYMENT OF BIOENERGY BY INCREASING THE EFFICIENCY OF BIOGAS PRODUCTION

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Abstract The share of renewable energy, which is used for power supply, increases worldwide steadily to avoid the threat of climate change. In the renewable energy production from renewable resources biogas plays an important role. Biogas can be provided continuously by the permanent availability of biomass and it is also easily to store. In the context of competition for land between food and feed production as well as the cultivation of renewables an efficient biogas production is extremely important. Strategies for this aim are installing biogas plants in order to increase the biogas output and take measures to increase the efficiency of existing biogas plants or of concepts of biogas digesters for the new installation.

Paper type: Research Paper

Published online: 29 January 2016
Vol. 6, No. 1, pp. 5-14

ISSN 2083-4942 (Print)
ISSN 2083-4950 (Online)

Keywords: *Bioenergy, Biogas, Biogasdigester, Efficiency, Methaneproduction*

1. INTRODUCTION

The deployment of energy is currently undergoing a radical change. Fossil and nuclear fuels will be replaced by renewable energy sources worldwide, to counter the threat of climate change. Different energy sources can be used as renewable energy sources. Hydroelectric power, wind power and the use of biomass include globally the most important renewable raw materials for the generation of energy (REN21, 2015). The proportions of the respective renewable raw materials on the world's electricity production are listed in Fig. 1.

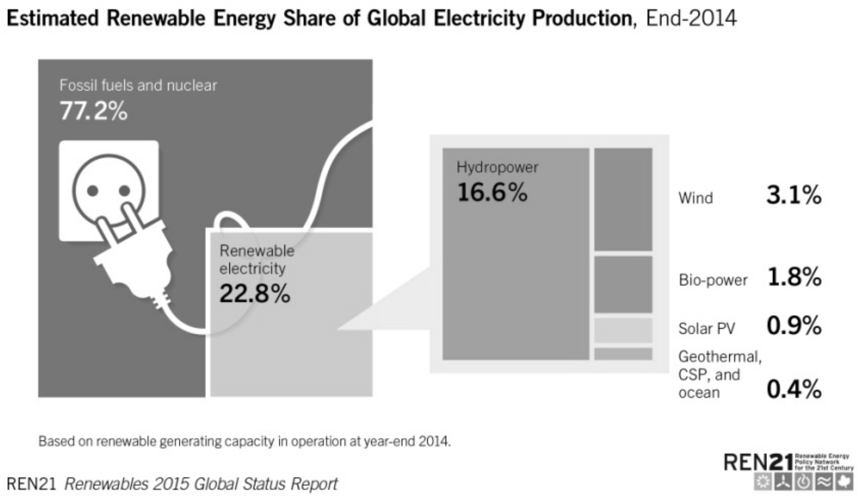

Fig. 1 Estimated Renewable Energy Share of Global Electricity Production 2014 (Quelle: REN21, 2015)

The Polish government has established the National Renewable Energy Action Plan (NREAP) in 2010 with the target, that in 2020 15 % of energy consumption in Poland provided by renewable energy (Ministerstwo Gospodarki, 2010). The production of renewable energy from biogas has great potential. Poland is among the countries of the EU with the largest agricultural area. The biogas potential for Poland is estimated at more than 5 billion cubic meters (Krzysztofik, 2014). Therefore, should the use of biomass for biogas production expanded. The aim is to increase the number of agricultural biogas plants until 2020 to 2500 digesters. This means about 1 plant per municipality (Chodkowska-Miszczuk & Szymańska, 2013); (Katin, 2014).

The proportion of energy from biogas in the total energy supply from renewable materials is in Poland with currently 1.7 % very low. Ninety percent of renewable energy in Poland is provided through the use of biomass but mainly by production of biofuel and biomass cumbustion (Budzianowski, 2012); (Iglinski et al., 2012). Biogas is produced in Poland mainly from the methanation of municipal solid waste or as part of the treatment of waste water. 2011 only about 8% of the biogas plants were operated with biomass from agricultural production (Iglinski et al., 2011); (Iglinski et al., 2015).

Biogas as an energy source can help to achieve the objectives of the NREAP. For providing biogas efficiently, from both terms the environmentally and the economicallym, optimization measures in biogas plants and biogas procedures should be carried out (Dettmann et al., 2014). This article shows possible improvements to the biogas process, being currently researched or always in application.

2. TECHNICAL OPTIMIZATION MEASURES IN THE BIOGAS PRODUCTION

In order to optimize the deployment of biogas, various approaches are possible. The construction of biogas plants for production of biomethane is an important step towards optimizing. In Table 1 the development of the number of plants in Poland is shown, provide the biogas using agricultural biomass. Here there is a great potential for optimization.

Table 1 Development of biogasdigesters in Poland using agricultural substrates from 2005 to 2014 (Quellen: Budzianowski, 2012; Iglinski et al, 2011; Krzysztofik, 2014)

Year	**2005**	**2008**	**2010**	**2012**	**2014**
Number of biogasplants	1	3	11	29	45

A further aspect to optimize the biogas yield is the technical nature of the fermenter (e.g. design or technology of the stirring units). The choice of the appropriate version for the respective fermenter depends on the available biomass, in this case particulary the dry matter. The design of bioreactors are very variously. Stirred tank, plug-flow, sludge-blanket, fixed bed or fluidized bed reactors can be used for the biogas process (Bischofberger, et al., 2005). The stirred tank digester is most commonly used digester.

For further optimization of the biogas process, especially with an adaptation to the substrate, technical additional components can be integrated into biogas plants. In digesters which use very fast fermentable substrates (e.g. sugarbeets, whey or food waste) can use an artificial settlement area for the microorganisms in a form of a fixed bed. The inflows and outflows in the biogas fermenter do not correspond to the formation of the methanogenic bacterias, which are very important to the production of biogas, especially when using these rapidly degradable substrates. The period until the methanogenic bacterias have built up a stable population is longer than 10 days (Bauer et al., 2009); (Dahlhoff, 2007). In fixed bed reactors the reactor volume consists mainly of support materials used as artificial growth surface for the microorganisms. So the growth of the microorganisms is facilitated by artificial structures and a washing out of valuable microbes from the system are counteracted (Bischofberger, et al., 2005). Applicable support materials for fixed bed registers are special plastics, spherical or in a defined structure as shown in Fig. 2. Fiber-rich biomasses such as straw or granules of clay minerals (e.g. Vermiculite) are used in addition. In the field of application substrates in the biogas process, there is still considerable need for research.

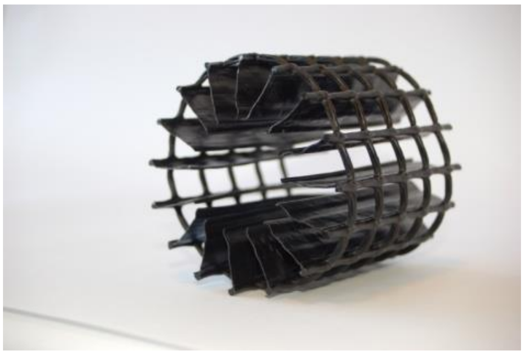

Fig. 2 Syntetic material from waste water treatment which can be used to increase the artificial surface in the biogas process (Pic: I. Helmer)

The production of biogas requires a thorough mixing of the substrate to provide the micro-organisms the digestion of the biomass. The use of artificial surface have a significantly influence to the mixing process in the fermenter. This process must take place slowly in order to avoid an excessive shear stress on the microorganisms of the respective carrier matrix for example (Grepmeier, 2002). It is possible to shear of the biofilm and wash out the microorganisms. With the choice of biogas concepts a significantly influence of the biogas yield can be taken. The procedures must be coordinated to the specific logistical arrangements. Principles that must be weighed in this case, are on the one hand decentralized or centralized procedures and on the other hand mobile or stationary systems (Schlegel et al., 2013); (Romanow et al., 2015). The output of biogas can be influences by the choice of the method and the equipment. Fig. 3 shows a large central biogas plant complex in Germany.

Fig. 3 Bioenergiepark Güstrow – 20 digesters with a capacity of 50 MWth (Quelle: NAWARO Bioenergie AG)

Fig. 3 also shows that the choice of the concept for the production of biogas from biomass depends on availability of biomass and the abilities to store the biomass and prepare for their use in the biogasdigester. In addition must be clarified, whether and how the removal from the power grid and supply of electricity is regulated. In this regard there are often problems locally (Katin, 2012).

3. OPTIMIZATION MEASURES FOR THE BIOGAS PROCESS

The potential hazards that can prevent a stable biogas process and thus a continuous methane production include:

- Foaming,
- Acidification,
- Low gas yield and quality,
- Poor mixing of the substrate.

These dangers can lead to process disturbances, which are always associated with additional costs and may even lead to the stoppage of the biogas process. Certain adjuvants can be added to the biogas process, acute or prophylactic, to prevent this dangers.

In biogas plants often arises foam during the fermentation of biomass. Foaming is not principle problematically. The disturbances and damages to the biogas process and plants depending on gas formation, the presence of surface-active substances (e.g. proteins and polysaccharides), viscosity and density of the substrates in the reactors (Moeller et al., 2013).

Excessive foaming disrupts the biogas process seriously and the formation of biogas is no longer guaranteed. Heavy foaming causes significant damages at the biogas plants in addition. The consequences for the plant operator varies depending on the foam intensity. They range from extra spending on anti-foaming agents to expensive cleaning and repair costs with additional downtime of biogas plants (Moeller et al., 2013). The specific trigger for excessive foaming are not yet conclusively researched (Moeller et al., 2012). The measures for foam control can currently only carried out in response, if it has already occurred in the digester to foam. Effective measures are to minimize substrate feed, dilute the substrate mixture in the digester or add additives that destroy the foam. Since there are different types of foam, there are no universal effective foam control agents. Vegetable oil is considered to be the low-cost anti-foaming additive. (Moeller et al., 2012).

The pH sets in automatically by the constant assembly and disassembly of the metabolites in the various stages of the biogas process (Friehe et al., 2010). The varying amounts and types of substrates and a lack of trace elements, may lead to a process failure, the course is characterized by an accumulation of organic acids and a strong pH decrease (Schulz & Eder, 2006); (Edelmann, 2001). The biogas production can be seriously disrupted by such an acidification in the digester. By using a basic adjuvants like Sodium Bicarbonate ($NaCO_3$) the pH can be raised and an acidified digester content be buffered. This effected an improvement of the digester environment and a stabilization of the biogas process. The effect of $NaCO_3$ was detected in highly acidified fermenters in practice by the administration of a single acute application (Burgstaler et al., 2011). Furthermore $NaCO_3$ is suitable for preventive use in the biogas process and as a performance-enhancing additive with continuous application (Burgstaler et al., 2012); (Porath, 2012). Alternative pH-regulating adjuvants are e.g. Calciumoxide – CaO, Calciumhydroxide – $Ca(OH)_2$ or Calciumcarbonate – $CaCO_3$ (Hecht, 2008). An overview of potential process adjuvants and their respective modes of action shows Table 2.

Table 2 Adjuvants for the biogas process and their modes of action (changed by Koch et al. 2010)

Type of Adjuvants	Mode of action
Micronutrients	Micronutrients are needed for an optimal growths of the microorganisms
Ion exchangers	Inhibiting or reducing the concentration of toxic substances (e.g.. ammonia and sulfur) especially for the further biogas treatment
Microorganisms	Complement the existing biocenosis with specific microorganisms for optimization of the process (speed, stability) Rapid adaptation to new substrate compositions or changing boundary conditions
Enzymes	Cleavage of polymers to improve the suspension properties Increasing the rate of degradation of the substrates Support microbial activity
pH-stabilizers	Increase or stabilize the pH in acidified digesters

Investigations at the University of Rostock have shown that the modes of action of adjuvants may be combined. A treatment agent for slurry was used in the biogas process. By using this additive, the ammonia in the biogas load was reduced and in addition the viscosity of the substrate improved (Klatt, 2015). In this case, the formation of biogas could be optimized in both ways the economically and the ecologically.

4. CONCLUSION

To achieve the ambitious goals of the Polish government *a biogas plant for every community*, the production of biogas must be optimized. This can be implemented by a rapid increase in the number of biogas plants by new construction. In addition the biogas process has to be optimized, to ensure the best possible biogas yield of the used biomass. Various types of additives and technical utilities scientifically tested or already applied in practice. The auxiliaries include e.g. micronutrients, enzymes, minerals, micro-organisms, substances operating acidically or basically, other auxiliaries (e.g. seaweeds or vitamins), artificial surfaces for a rapid settlement of the microorganisms and new fermenter types. Basic objectives for the use of adjuvants are:

- Increase of biogas yield and quality,
- Acceleration of the Biogasprocess,
- Stabilization of the pH value,
- Prevent or reduce foaming,
- Increase stirrability by reducing the viscosity.

The efficiency of biogas plants can be realized by higher gas yields, and also by the reduction of costs for e.g. energy requirements for the stirrers or costs of maintenance of the equipment used by the auxiliaries (Koch et al., 2010).

The optimization of biogas production must be consider the environmental aspects (e.g. prevention of pollutant emissions or preservation of biodiversity in rural areas) and the economic point of view.

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