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State of the Art of Biogas Technology in Austria

Improved general legal framework has resulted in a steep rise in the number of biogas plants in Austria. Simultaneously, energy crops are increasingly being used for anaerobic fermentation. Through modifying technology for the new materials being digested, a "new generation" of biogas plants is arising, which place special requirements on substrate feeding and fermenter mixing. 40 Austrian farm-based biogas plants were investigated regarding technology, process parameters, factors for economic efficiency, as well as possibilities for system optimisation.

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Keywords

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Literature

Literature references can be called up under LT 06116 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

The Austrian Government transposed the EU directive into national law through the Green Electricity Act 2002. The Act regulates guaranteed prices for electricity generated from biomass until 2015 for all plants licensed by the end of 2004 and operational by mid 2006. The supply compensation determined in accordance with the Eco-Power Act now offers an economic calculability of eco-power generation. The price guarantee is an important basis for the economic calculability of investments into biogas production The number of farm based biogas plants has increased rapidly since 2002. In April 2005, 294 biogas plants with a net total of 27 MW_{el} were operated in Austria [1].

In the last few years, an increasing trend towards anaerobic digestion of energy crops has been observed [2]. The "first generation" of biogas plants mainly relied on animal manures. It was shown, however, that higher methane yields and a better economic efficiency can be achieved through the additional use of energy crops in anaerobic digestion. The "new generation" of biogas plants mainly or only digest energy crops. The new plants comprise a big variety of fermentation technologies and technical equipments. The aim of this study is to monitor and benchmark technologies installed in the new biogas plants. Recommendations on optimum technologies and on possibilities for optimising biogas production along the whole process chain shall be worked out.

Material and methods

An nation-wide monitoring was carried out of 40 new biogas plants in Austria, which went into operation between 2003 and 2005. The monitoring included technical, economic and management parameters. Data on biogas technology, substance and energy flows, economic efficiency, work requirement and management were collected. From these data, a clear picture on the current state of the art and of the performance of biogas plants can be drawn. Possibilities for the optimisation of biogas production can be concluded. In addition to the nation-wide monitoring, a very detailed monitoring was carried out on two biogas plants for eight months.

The results given in this paper include data from 32 biogas plants too, which were included in the nation-wide monitoring. The data were gathered through on-farm visits between February and July 2005. The on-farm visits guarantee a good data quality. Samples of the input substrates and of the digestate were taken during the on-farm visits.

Results

Electric capacity installed

During the last two years, more than one hundred new biogas plants were built in Austria. The capacity of 72 % of these new biogas plants ranges between 100 and 500 kW electricity installed. 15.5 % of the new biogas plants have less than 100 kW electricity installed, and 12.5 % have more than 500 kW electricity installed. About 50 additional biogas plants will go into operation this year. Their average size is 500 kW_{el}.

Substrates

Three types of biogas plants can be differentiated: I. Digestion of energy crops II. Digestion of energy crops and animal manures, and III. Digestion of energy crops, animal manures and organic wastes. About 10 % of the new biogas plants only digest energy crops. About 65 % digest energy crops and animal manures,

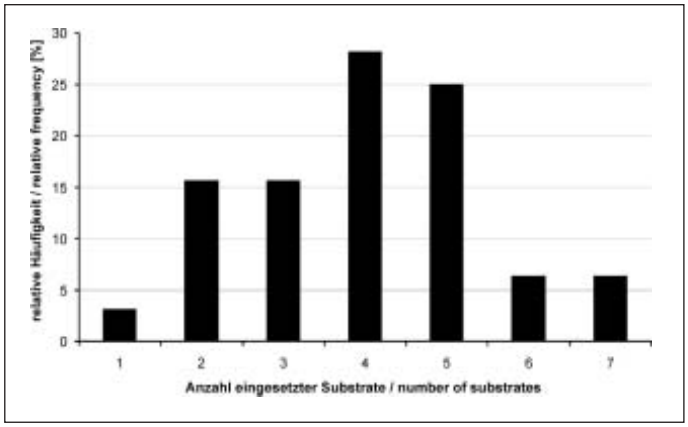

Fig. 1: Frequency of substrates used

with 61 % of these being fed with pig slurry, and 39 % with cattle slurry. The Green Electricity Act 2002 encourages the digestion of energy crops and/or animal manures, because when organic wastes are codigested in so called "co-fermentation plants", biogas plant operators in Austria receive a 25 % lower guaranteed price for the electricity produced. About 25 % of the monitored biogas plants digest animal manures and organic wastes.

Most biogas plants digest a multitude of contrasting substrates as *Figure 1* shows. Only 3.1 % digest only one substrate. Most of the monitored biogas plants use two to five different substrates as input material. About 13 % even digest six or seven different substrates. Many different types of energy crops are suitable for anaerobic digestion. Still, forage maize silage is the most widely used energy crop. However, additional energy crops become more and more important: grass silage, corn maize silage, alfalfa, clover, sunflowers, sugar millet and Sudan grass [3].

Direct feeding systems

The digestion of energy crops and the increase in the capacity of biogas plants require the application of technologies that can feed solid substrates directly into the digester. A stabile fermentation process and a high methane yield can only be achieved if the input substrates are well mixed, chopped and fed at a as much as possible constant rate. With animal manures and other liquid substrates, a preparation pit had been used from which the viscous substrates were pumped into the digester. This technology is not very suitable for the digestion of considerable amounts of energy crops. Thus, a range of technologies for feeding solid substrates directly into the digester was installed in the new biogas plants. *Figure 2* shows the distribution of direct feeding systems on the monitored plants.

In the first run, mainly dropping shafts, flushing systems and systems with feeding augers were used to directly feed solid substrates into the digester. These did, however, not offer the possibility of continuous feeding of the digesters and of weighing the amount of input. Thus, nowadays mainly adapted feed mixers and adapted push-off trailers with weighting machines are applied. These systems ensure a constant and exact supply with organic matter, which is the basis for a stable digestion process with a good biogas quality.

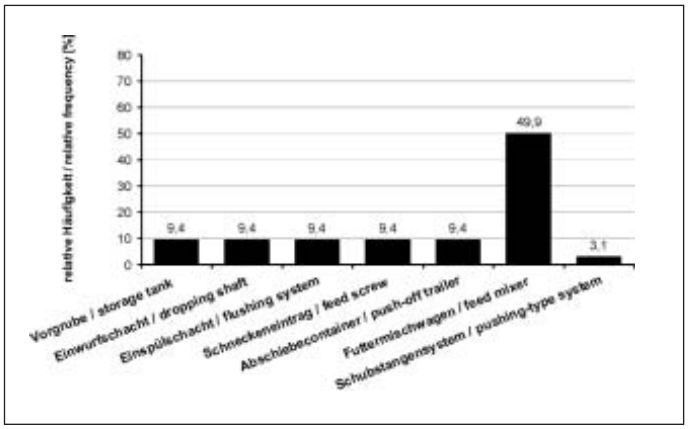

Fig. 2: Frequency distribution of system for direct feeding of solids

Digester systems

The digester is the core of a biogas plant. There are two principal types of digesters: vertical and horizontal digesters. The vertical digester is a completely mixed digester usually made of reinforced concrete. The substrate is continuously mixed during the digestion process in order to keep the solids in suspension. Biogas accumulates at the top of the digester. The standard size of vertical digesters is between 500 and 2,000 m^3. In horizontal or so called plug flow digesters the substrate flows semi-continuously through a horizontal tank. Plug-flow digesters are in most cases made of steel and have a volume between 50 and 150 m^3. In Austria more than 80 % of the new biogas plants have vertical digesters. Less than 20 % have a combination of horizontal and vertical digesters. In this case plug flow digesters are used for the first stage of fermentation and a complete mixed digester for the secondary stage. Horizontal digesters alone were not found in the investigated plants.

It must be assumed that vertical digesters will be most important in the future. Their volume can be up to 6,000 m^3, they are competitive to construct and more easily to operate than horizontal digesters. Horizontal digesters will only be installed on small biogas plants, because this digester type cannot be transported in large dimensions. But our monitoring also shows new developments. In some cases, horizontal digesters were made of reinforced concrete with on-site fabrication. Then they had a volume of 400 m^3.

Mixing technologies

The mixer is a very essential part of a biogas plants. Digestion of energy crops requires a sophisticated mixing technology. Only then the micro-organisms in the digester will have an uniform access to the whole digestate. A thorough mixing is a pre-requisite of a stabile digestion process, a good degradation of the organic substrates, a high biogas yield and a good biogas quality. A good mixing is especially important when digesting energy crops and/or animal manures as these substrates have a strong tendency to demix.

The changes in substrate inputs strongly influenced the mixing technologies. Earlier, rapid velocity submersible-motor propeller mixer were most commonly applied. The monitoring of the new biogas plants revealed a strong trend towards low velocity mixers, that keep energy consumption at a low level and can be operated continuously. More than 54 % of the new biogas plants have installed slowly moving paddle mixers in completely mixed digesters. About 9 % of all mixers are slowly moving long-shaft mixers and only 7 % are rapid velocity submersible-motor propeller mixer. In contrast to other mixing technologies, paddle and long-shaft mixers have no electrical parts inside the digester. This is an important factor for a trouble-free operation.

On more than 50 % of the new biogas plants only one mixer is installed (*Table 1*). However, the tendency is towards digesters with two or three mixers installed. The increasing volume of completely mixed digesters goes along with the installation of two or more mixers. As the mixer is a key factor for a smooth digestion process, the installation of several mixers increases the reliability of the process.

Digester with one mixer	Digester with two mixers installed
61,5 % paddle mixer	35,5 % paddle-/ submersible-motor propeller mixer
23,1 % submersible-motor propeller mixer	21,4 % long-shaft-/ submersible-motor propeller mixer
15,4 % long-shaft mixer	14,3 % 2 submersible-motor propeller mixer
	14,3 % submersible-motor propeller -/ rod-propeller mixer
	14,3 % paddle-/ rod-propeller mixer

Table 1: Frequency of number and type of mixers in vertical digesters

Outlook

The increased use of energy crops induced adaptations in digesters, feeding and mixer technologies as well as in process control. An optimisation of the efficiency along the whole process chain from the substrate input over technology, process control, digestate utilisation up to energy conversion is necessary to promote the very promising potentials of biogas technology and to establish viable biogas plants. Currently, only 3 - 5 % of the available organic substrates are used for biogas production in Austria.

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