SURVEY OF FARM BIOGAS PLANTS WITH COMBINED HEAT AND POWER PRODUCTION IN AUSTRIA

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ABSTRACT: The number of farm-based biogas plants in Austria increased rapidly in the recent past, a continuing interest in this technology is expected. A survey was carried out in 2002 to provide information for farmers and the decision makers involved. In most plants slurry and manure is co-digestion with energy crops and/or organic waste. Wet fermentation in mesophilic digesters with post-digesters combined with separate storage tanks is the main technology used. The trapped biogas is utilized in CHP-units and the electricity is sold to the grid. The waste heat is supplied to the farm and farm house, only a few sell it for district heating. The labour requirement depends on the fermented feedstock. Slurry and manure cause the lowest and the co-digestion of organic waste the highest labour requirement. The survey results indicate a distinct decrease in investment costs per unit. On average 75 % of the capacity of the farm-based biogas plants are used. Most farmers intend to increase production at higher electricity prices. Further reasons to produce more biogas would be the abandonment of livestock husbandry or direct payments for energy crops.
Keywords: Biogas, investment costs, labour requirement

1. INTRODUCTION

The increase of renewable energy production is of great interest today. In order to accelerate the market penetration, the European Union (2001/77/EC) and Austria (BGBl. I Nr. 149/2002) issued different supporting measures and created financial incentives for the production of green electricity.

By the end of 2001 86 farm-based biogas plants and by the end of 2002 110 were in operation with a capacity of 7,446 kW_{el} [8]. The number of biogas plants is expected to increase further. Austria´s potential for biogas production is about 180 MW_{el} [10]. Prices for electricity generated form biomass are regulated by the Green Electricity Act 2002 (BGBl. I Nr. 149/2002) for 13 years. This causes certainty for long-term strategies on investments in biogas plants. Biogas plants which use organic waste have a 25 % lower electricity tariff compared to those which ferment only agricultural feedstock. Investment grants for farm biogas plants up to 40 % are possible within the scope of the rural development program which is co-financed by the EU [3] or within the national technology promotion program (BGBl. I Nr. 149/2002).

Most of the Austrian biogas plants are farm-based as shown in Figure 1. Before 2001 the farm-based biogas plants were not registered separately, so only the total number of biogas plants is known. The total capacity of the biogas plants increased fast, especially the capacity of farm-based plants nearly doubled between 2001 and 2002.

2. OBJECTIVES

Farmers interested in building a biogas plant require data and know-how concerning the efficient organisation of biogas plants and the costs. Only a few studies address the technical equipment, feedstock efficiency and investment costs of small scale farm-based biogas plants relevant for Austrian conditions. Therefore a survey was carried out to assess the significance of feedstock, chosen technology, investment costs and labour requirement connected with different plant concepts. The results of the survey will provide information for farmers and decision makers involved.

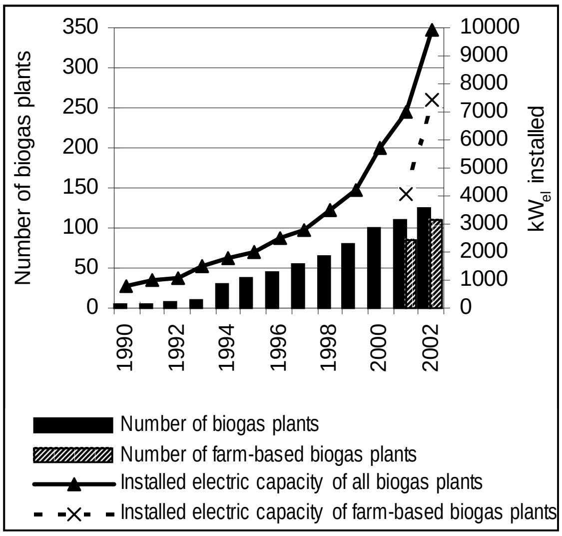

Figure 1: Number and capacity of biogas plants in Austria [2, 6 and 8]

3. METHOD

A standardised questionnaire was sent in November 2002 to 86 farm-based biogas plants in Austria. 44 questionnaires were available for an analysis. The questions cover the characteristics of the farms and the biogas plants, the feedstock and the techniques used, labour requirement and the investment costs. The biogas plants are grouped according to the operation starting date: the ones implemented before 2000 and those operating since 2000. This cut off date was chosen due to the Austrian Electricity Act of 1998 which liberalised the Austrian electricity market. In 2000 the first plants could benefit from the regulations of this law. 20 out of the 44 biogas plant owners in the survey started the biogas production before 2000 (here named old plants) and 24 plants operate since 2000 (named new plants).

4. FARM CHARACTERISTICS

The biogas plants are operated by farmers, who manage on average 70 ha agricultural land, which is much above the Austrian average of 16.8 ha [4]. Farmers who started before the year 2000 cultivate 52 ha and those producing since 2000 manage 85 ha. Most farms are provided with grassland and arable land, but 16 % have only grassland and 16 % only arable land. More than 90 % of the farmers keep animals. About two thirds of the livestock owners keep dairy cows, every second fattens cattle or pigs and every fourth keeps poultry. On average a livestock owner keeps 64 livestock units.

23 % of the biogas plants are operated by organic farmers although only 9 % of the Austrian farmers are organic [4]. This may indicate that degassed manure is of high quality and of high value for organic farms. The organic farms mostly manage grassland and cattle. On average they are smaller than the conventional farms. Approximately 15 % of the biogas plants are organised as cooperatives; all of them are in the group of the new biogas plants.

5. MOTIVES FOR INVESTMENT

In the questionnaire several motives for building a biogas plant were mentioned: On the average more than three motives out of the possibilities were selected by the respondents. The majority declared the “improvement of manure” as one motive (Figure 2). All organic farmers indicated the improved quality of the degassed manure as one of the motives to construct a biogas plant. Other motives were the possibility to produce the own energy demand and to “diversify” the farm income. The motives “diversification” and “odour reduction” were more often named by the operators of new biogas plants. The motive “changes of the farm organisation” was mainly named by organic farmers. Some of the farmers built the biogas plant in combination with shed investments.

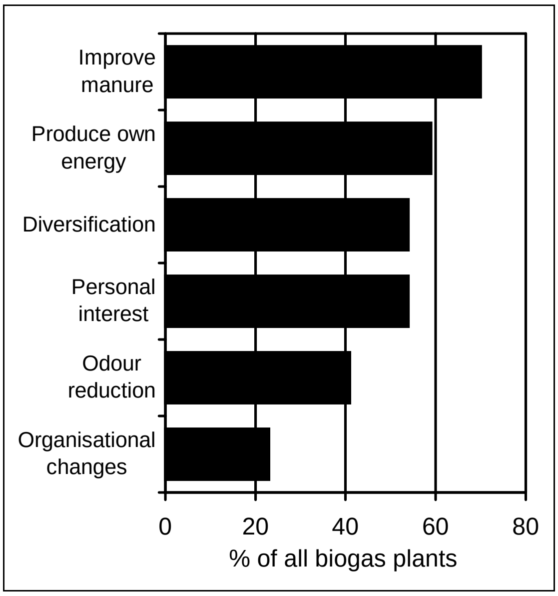

Figure 2: Motives for investment

6. PLANNING AND CONSTRUCTING PERIOD

The planning period lasted between 9 months (old plants) and 14 months (new plants), on average one year. The construction period lasted 10 months on average, no difference within the two groups was found. The shortest planning and construction period was half a year, the longest more than three years. Most biogas plants were planned by specialized planners in co-operation with the farmers. Only a few plants were planned by experts or local civil engineers. The construction was mainly done by local enterprises, supported by craftsmen and the owners. Two biogas plants were handed over as turn key facilities and seven smaller plants were constructed by the farmers themselves.

7. FEEDSTOCK

Nearly all farm-based biogas plants operate as co-digestion plants with slurry as basic feedstock (Table 1). Most plants ferment slurry from cattle or pigs, some use a mixture of several animal species. Pig slurry as basic feedstock increased recently. 32% of the plants use manure, most of them ferments the manure from cattle or poultry, others from horses or sheep.

About two thirds of the biogas plants ferment energy crops. The most used crop is maize, it is part of the feedstock in every second plant. Other materials for biogas production are grass silage, green rye, alfalfa, clover, sunflowers, sudan grass and sugar millet. The energy crops are mainly grown on the farm, only a few operators of new biogas plants buy maize or grass silage. The agricultural conditions allow producing energy crops on set aside land (2461/1999/EC). 23 % of the farmers make use of this possibility by growing more than three hectares energy crops for biogas production. Some farmers use waste from grain and/or oil-seed cleaning in their biogas plant.

Organic waste is mostly processed in older plants. 57 % of the biogas plants use fat and oil waste, 50 % catering waste, 27 % source-separated organic municipal solid waste and some other organic wastes. Half of the farmers collect the organic waste themselves. Most use tractors and trailers, farmers with small plants use a car with a trailer; farmer specialized in fermenting waste use garbage collecting lorries.

Table 1: Feedstock processed in the biogas plants

Feedstock	All plants	In operation before 2000	In operation since 2000
	%	%	%
Manure and slurry only	7	10	4
Co-digestion with			
Agricultural feedstock	28	5	50
Organic waste	30	50	17
Mixture	32	35	25
No data	2	0	4
Feedstock mix			
Year-round the same	73	80	66
Seasonal differences	27	20	34

Most operators use year-round the same feedstock mix. Seasonal differences in the feedstock mix may be caused by a varying waste supply in tourist regions or by grazing the cattle in summer. Only 7 % of the biogas plants operate without co-digestion. The number of co-digested materials differs according to the date of implementation. On average new plants co-digest three and old plants two different materials (Figure 3).

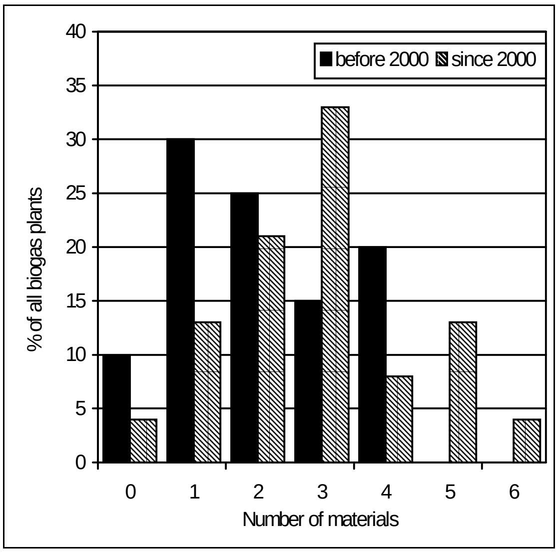

Figure 3: Number of co-digested materials

The average dry matter (DM) content of the feedstock is 18 %. Old plants work with a DM-content of 16 % and new plants with 19 %.

8. PLANT CONCEPTS

All farm-based biogas plants decided to use wet fermentation with continuously fed digesters. Plug-flow digesters are used up to a capacity of 150 m^3. The predominant system is a total-mixed digester. Usually a post-digester is attached and connected to the gas collecting system. The feedstock is pumped from the pre-storage tank into the digester and the degassed manure is stored in a storage tank until it is spread on the fields. The storage tank is covered, gastight and connected to the gas system to collect the trapped biogas (Table 2). In most cases the post-digester is operated as a continuous digester with a hydraulic retention time of 82 days. The operator usually empties the storage tank and the post-digester at the same time to use the available storage capacity best. All biogas plants are equipped with enough storage capacity for the degassed manure to fulfil the rules of the ÖPUL (Austrian program to promote an environmentally conscious, extensive and natural habitat protecting agriculture). The ÖPUL prohibits the fertilisation during four months in winter and on frozen soil. The average storage capacity of the biogas plants lasts for six months, which is enough capacity in case of bad weather conditions for spreading degassed manure.

Nearly all biogas plants are equipped with a mixing pit. Additional pumping and service pits partly exist. Biogas plants operated in cooperation are equipped with an additional pit to store the collected slurry. Old biogas plants use the mixing pit for several functions: collection of the feedstock, pre-storage and housing the central pump station. Most of the new plants are equipped with separate pits for each function. Table 2 shows details about the concepts of farm-based biogas plants in Austria.

Table 2: Concepts of farm-based biogas plants

Component	All plants	In operation before 2000	In operation since 2000
	%	%	%
Plug-flow digester	32	40	25
Total-mixed digester	68	60	75
Post-digester	80	70	88
with heating	71	57	81
Separate storage tank	80	90	71
with biogas collection	40	28	53
not covered	40	50	29
no answer	20	22	18
Pre-storage pit	45	35	54
Mixing pit	89	95	83
Central pump station pit	43	35	50
Maintenance pit	32	40	20

All respondents use the biogas for electricity generation in combined heat and power (CHP) units. All plants have a low pressure gas system and for temporary storage a low pressure storage. Most farm-based biogas plants use a gas engine in the CHP-unit (Table 3). Modified petrol engines are used in small plants because of lower investment costs. In most plants two aggregates are installed to guarantee working reliability.

Table 3: Number and type of combined heat and power units

CHP-units and engines	All plants	In operation before 2000	In operation since 2000
	%	%	%
1 CHP-unit	39	30	46
2 CHP-units	57	60	54
3 CHP-units	2	5	0
No answer	2	5	0
Pilot injection gas engine*	7	5	8
Gas engine*	80	75	83
Modified petrol engine*	20	25	17

*Multiple answers

The new biogas plants require more hydraulic retention time (HRT) in the digester compared to the old ones, but a shorter HRT in the post-digester (Table 4). All farm-based biogas plants are operated in the mesospheric temperature range. The efficiency of the CHP-units reported by the operators increased slightly in the past. A progress in electricity generation efficiency is important for the cost efficiency of a biogas plant [9].

The generated electricity is sold to grid. 20 % of the biogas operators sell the heat year-round and 5 % during the winter months. 75 % of the operators use the produced heat on the farm to heat the living and stable buildings. The proportion of electricity and heat used by the biogas plants decreased in the recent past due to more efficient equipment for mixing, pumping and heating (Table 4).

Table 4: Some performance characteristics

Characteristics	All plants	In operation before 2000	In operation since 2000
HRT digester (days)	48	44	52
HRT post-digester (days)	82	92	76
Storage tank capacity (days)	104	108	100
Gas storage capacity (h)	13	15	11
Installed capacity (kW)	77	49	100
Average daily working hours (h)	18.6	18.7	18.6
Electric generation efficiency (%)	28.5	28.0	28.9
Electricity use in the biogas plants (%)	11	15	7
Heat use in the biogas plants (%)	27	34	21

9. LABOUR REQUIREMENT

The labour requirement does not differ according to the date of implementation. Differences were found regarding the feedstock. Biogas plants using exclusively slurry and manure require on average 1.1 hours per day, the data vary between 0.35 and 1.75 hours per day. The biogas plants fermenting energy crops needed on average 1.25 hours per day, varying between 0.5 and 2 hours per day. Biogas plants using organic waste reported the highest average labour requirement (1.7 hours per day), the dispersion is highest too (between 0.5 and 5.3 hours per day). The large dispersion results from the different degree of impurity of waste and the technical equipment for conditioning. Biogas plants with complex automatic control systems need less labour than those without.

10. INVESTMENT COSTS

The analysis of the investment costs was confined to plants built since 2000. The capacity of the plants measured in kW_{el} was the criteria to form five groups of plants for the analyses. Data of 34 plants between 10 and 330 kW_{el} were available. The class intervals differ. The intervals are adjusted to the number of plants in a certain capacity range and the price gradation in the Green Electricity Act (BGBl. I Nr. 149/2002). The grouping of the plant data were a prerequisite because the farmers were assured to publish no data of a single plant.

Table 5 contains the total average investment costs of the plants in the five capacity classes as well as the investment costs per kW_{el}. The survey results indicate a distinct decrease in costs per unit. The investment cost within the capacity classes differ to a great extent. The coefficients of variation illustrate this fact.

Various reasons are responsible for the deviation of the investment costs. The contribution of the owners, purchasing in cooperation, precise planning, site and construction of the plants, the distance between the biogas plant, the stable and the farm house, the availability of farm buildings and the technical equipment of the plant concerning stirrers, pumps, controlling devices are some of the examples mentioned in the survey. In Austria the plant operator is responsible for the establishment of a transformer station and the reinforcement of the grid (BGBl. I Nr. 149/2002).

Table 5: Average investment costs of five capacity classes

Capacity classes in kW_{el}	Number=34	Average capacity in kW_{el}	Average investment costs in 1,000 €	Average investment costs in €/kW_{el}
<25	6	18,2	154 (37)*	8 436
25-50	9	37,0	206 (24)*	5 580
51-100	8	82,1	417 (52)*	5 083
101-200	7	155,7	642 (46)*	4 300
> 200	4	322,5	1,216 (11)*	3 770

*Coefficient of variation

The farmers were also asked to report the operating costs of the biogas plant: Maintenance and repair costs, insurance and administrative costs and feedstock costs. The data varied very much. In some farms no additional costs of insurance occur, because the biogas plant is covered by the overall insurance. As a result the survey data are not appropriate to derive the operating cost of biogas plants for calculations, they have to be taken from the available literature [7, 9 and 12].

11. CAPACITY USE

About one third of the farm-based biogas plants utilise the capacity fully. Table 6 presents the rates of capacity utilization. New plants have significant lower utilization rates, obviously the farmers did not adjust the biogas plants to the immediate supply of feedstock, supposably they expect an increase in feedstock supply in the future. The average rate of utilization of the plants with information to this topic is 75 %. The plants implemented before 2000 use the capacity to 80 %, these started since 2000 to 70 %.

Table 6: Capacity utilization rate

Capacity utilization rate in %	All plants	In operation before 2000	In operation since 2000
	%	%	%
< 25	0	0	0
25-50	23	20	25
51-75	27	20	34
76-100	7	10	4
100	36	50	25
No data	4	0	8

12. CONDITIONS STIMULATING THE CAPACITY UTILIZATION

Farmers who under-utilize the plant were asked for incentives to raise the utilization rate. Most farmers would intensify the energy production if the electricity price increases. Another reason for more biogas production stated by the respondents refers to the growth of the farms (livestock and/or land). More farmers tend to increase biogas production by using additional grassland than to use additional arable land.

About 50 % of the respondents consider no expansion of the capacity of the biogas plants. The rest would enlarge at an electricity price of 16.5 cent/kWh. Abandon livestock husbandry would be another reason for expanding the biogas plant capacity. Farmers would change their crop rotation, if they receive additional direct payments for energy crops. Figure 4 shows the prices at which farmers would expand their plant capacity compared with the recent prices. By the time the survey was conducted, nearly each Austrian province had different electricity prices which were generally below the recent prices [5].

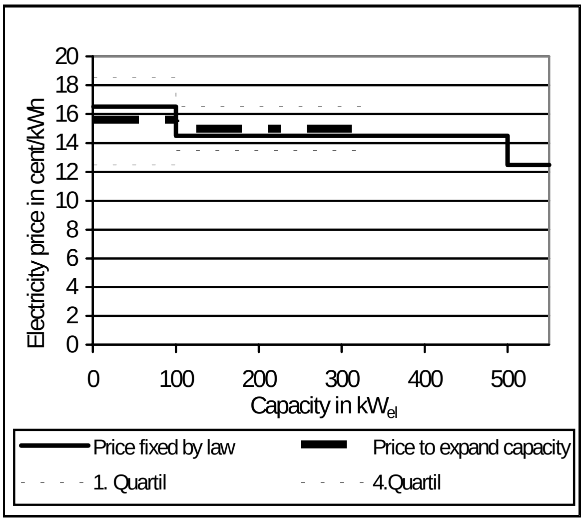

Figure 4: Recent electricity prices and capacity stimulating prices

13. CONCLUSIONS

In the recent past bigger biogas plants were built. Some co-operations were established. Old plants mainly use slurry and manure. Cattle are the main livestock on farms with biogas plants. For co-fermentation the operators use mainly maize, biomass from grassland and organic waste. The Green Electricity Act distinguishes between agricultural feedstock and organic waste. Energy crops become more important recently. New plants therefore are located in areas with high maize yields. The advantage to reduce the odour of slurry is mainly used by pig and poultry farmers.

Most biogas plants are located in rural areas, without district heating or business with high heat consumers nearby. Therefore the possibilities to use the heat efficient are limited. Nevertheless farm-based biogas plants are a possibility to increase the net income of the farm family, if the preconditions for a cost efficient enterprise are available. The size of the plants and the feedstock used determine the costs to a great extend. The plants should be planed carefully to avoid complications and to establish a viable enterprise.

14. ACKNOWLEDGMENTS

The Austrian National Bank supports the research project called “Electricity and heat from biogas, an economic and ecologic analysis”. The authors thank for financing the project, special thanks to the biogas plant operators who generously spent their time to complete the questionnaire and thus made this research possible.

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