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When will Small Farm Manure Biogas Plants be Profitable?

Planning examples are used here to check if the EEG 2009 (Renewable Energy Sources Act) offers sufficient incentives for the construction of small biogas plants up to 150 kW, and to see which substrate combinations and organizational forms come into question. It is evident that small one-farm and multi-farm biogas facilities with capacities of 30 kW (200 cattle animal units), which are operated only with slurry, although it is a free substrate, and with additional proceeds from selling heat, can hardly be operated economically. The economic break-even for farm manure plants (without adding biomass) is barely attained by 75 kW facilities (equal to 500 cattle animal units) with a return on investment of about 4%.

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On 1st January 2009, the revised Renewable Energy Source Act (EEG) will enter into force. When the EEG takes effect, it will provide higher basic compensation for plants having an electric output of up to 150 kW than the EEG 2004. In addition, the renewable resource bonus and the power-heat cogeneration bonus will each be increased by € 0.01 per kWh of electricity fed into the public mains network for plants producing up to 500 kW. In addition, an emission reduction bonus (€ 0.01/kWh) for the observation of the limits of the Clean Air Directive (TA Luft) and a landscape care bonus (€ 0.02 per kWh) are granted for the predominant use of landscape care material in plants having a capacity of up to 500 kW. Moreover, this is the first regulation that provides additional subsidies for the use of manure. This so-called slurry bonus in the amount of € 0.04 per kWh is granted for plants with an output of 150 kW if more than 30% of the substrate consists of manure of animal origin. This bonus is also provided for plants producing up to 500 kW, though only for the electricity equivalent of 150 kW plants. Beyond this limit, the bonus amounts to € 0.01 per kWh.

This slurry bonus is intended to give biogas plant operators incentives for the increased use of manure. *Table 1* shows an overview of the old and new payment rates provided by the EEG.

Below, planning examples are used to check whether the EEG 2009 gives enough incentives for the construction of small biogas plants up to 150 kW in output and what substrate combinations and forms of organization are possible for such biogas plants.

Planning Examples

Cogeneration units for small biogas plants are offered for electric outputs of approximately 30 to 40 kW or more. Therefore, plant sizes and concepts in the 30 to 150 kW range are considered. The most important assumptions for the planning examples are shown in *Table 2*. The examples are based on cattle herds of 200 to 500 cattle animal units, whose manure is fermented in the model biogas plants with and without biomass. Three plant concepts are distinguished:

1) One-farm plant (30 kW) with slurry from 200 cattle animal units (plant 1). The plant has a storage container.
2) Cooperative plant (30 kW) of immediately neighbouring farms with a total of 200 cattle animal units. The slurry is pumped to the plant on the neighbouring farm, which is equipped with a collecting pit and a storage container. The fermentation residues are pumped back to the cooperating farm. The distance between the two farms is 250 m.
3) Like 2), though with an additional 870 t/a of maize as substrate. A fermentation silo and additional storage capacity are required (75 kW).
4) Like 2). However, the slurry is transported to the cooperating farm by a slurry tanker over a distance of 3 km (30 kW).
5) Like 3). However, the slurry is transported to the cooperating farm by a slurry tanker over a distance of 3 km (75 kW).
6) Cooperative plant with slurry from 500 cattle animal units (75 kW) consisting of three farms situated 3 km apart. Slurry is transported to the cooperating farm by a slurry tanker. The cooperating farm is equipped with a collecting pit and a storage container. The fermentation residues are brought back to the cooperating farm.
7) Like 6), though with an additional 1,330 t/a of maize as substrate. A fermentation silo and additional storage capacity are required.

Plant Technology and Investments

Table 2 shows some assumptions for the planning examples. Since remaining fermentation storage capacities from livestock farming are intended to be taken into consideration (180 days), the plant equipment is composed differently depending on substrate input.

Thus, the following equipment was purchased for plants 1, 2, 4, and 6 in *Table 2*:

- Fermenter with leak detection, air-supported roof, desulphurisation, heating, and two submerged motor agitators

- Control, measuring, and regulating units
- Pilot-injection cogeneration plant
- Gas cover for the fermentation residue storage container

Due to the use of maize silage, plants number 3, 5, and 7 require the following additional plant parts:

- Silage areas for maize storage
- Mobile equipment for the unloading of solid substrate from the silo which is then added to the solid matter input
- Solid matter input system
- Fermentation residue capacities (adapted to the maize quantity used)

The amounts of total investments and specific investments are shown in *Table 3*. The necessary investment varies between € 200,000 and € 580,000 depending on the plant and the slurry transport system. The pump systems for slurry transport require large investments. For transport by slurry tankers, no additional investments are assumed because they are borne by a contractor. For ecological reasons and for additional cost reduction, there are no empty rides. The tanker transports slurry on the way to the plant and fermentation residues on the way back. Thus, the storage capacities of the farmers involved are fully exploited, and additional investments are avoided.

Accordingly, the specific investments (investment / installed electric power) vary significantly from one plant to the next. In plants 6 and 7 (*Table 3*), they are very low at approximately € 4,230 and € 3,870 per kW_{el}, respectively. The specific investments required for the other plants are significantly higher at € 5,300. Plant 2 has the largest investment requirements because expensive pump and pipe systems need significantly larger investments as compared with installed power.

Basic Assumptions for Cost Calculation, Work Time Requirements

For the calculation of the costs of the individual plants, the following assumptions were made:

- Manure is available free of charge.
- Costs of maize silage: € 35 per tonne, ensilaged and ready for unloading in the silo
- Ignition oil accounts for no more than 8.5% of total energy.
- Expenses for ignition oil: € 0.90 per litre of vegetable oil
- 30% EEG-conform heat utilization with heat sale at € 0.03 per kWh
- 8,000 full load hours of the plant
- Interest: 4%
- Gas yield of slurry: ~ 405 m^3 per tonne of organic dry matter and a dwell time of ~ 60 days
- Spreading of fermentation residues by a contractor: € 3.5 per tonne
- Slurry transport (tanker) by a contractor: € 2.88 per tonne

For slurry transport, € 300 per metre of pipe (e.g. along a field) are assumed here.

According to calculations based on the KTBL database, the expenses for slurry transport in a tanker amounted to € 2.88 per tonne. These costs include a twice 3 km ride with a full load as well as the time required for loading and unloading. These calculations are based on a 15 m^3 liquid manure tanker with an 87 kW tractor.

In all examples, the slurry is stored temporarily directly in a collecting pit, from where it is fed into the fermenter.

Since the planning examples include the quantity and the kind of the substrates used as well as the existing infrastructure of animal housing, the fermentation residue store, silage capacities, and solid matter inputs are adapted to the added quantity of maize. In plant 7, for example, fermentation residue stores holding an additional 945 t were built. In plants number 3 and 5, the capacity of the newly constructed stores was only 618 t (*Table 2*).

The work times listed in *Table 2* are composed of assumptions for different activities. Of this time, approximately 7 hours per week are assumed for the inspection and bookkeeping of the biogas plant. If substrates are pumped or transported, different time assumptions for substrate supply are added up. This includes the supervision of the pumping processes as well as the operation of mobile equipment for the unloading of solid substrate and the feeding of the substrate into the fermenter.

In the model plants shown here, the assumption is that 30% of the heat generated by the cogeneration plant is used according to the EEG so that the yields of the biogas plant can keep increasing. An additional assumption was that sales proceeds in the amount of € 0.03 per kWh of heat produced by this plant are reached.

Table 1: Compensation for electricity fed into the grid for 2009, compared to the effective EEG 2004 (Compensation for electricity fed into the grid; as of June 6 th 2008)

		installed electric plant power					
		Up to150 kW		Up to 500 kW		Up to 5 MW	
Unit for all figures: [ct/kWh		EEG 04	Draft EEG 09	EEG 04	Draft EEG 09	EEG 04	Draft EEG 09
basic compensation	Old plants bringing into service 1.1.2004 until 31.12.2008	2004: 11,50 2005: 11,33 2006: 11,16 2007: 10,99 2008: 10,83	from: 2009: 11,67	9,90 9,75 9,60 9,46 9,32	unchangeed	8,90 8,77 8,64 8,51 8,38	unchangeed
	New plants bringing into service 1.1.2009		from: 2009: 11,67 2010: 11,55		from: 2009: 9,18		from: 2009: 8,25
Degression 1		1,50%	1,00%	1,50%	1,00%	1,50%	1,00%
Boni							
1 Bonus for renewable resources		6	7	6	7	4	4
2 Slurry bonus 2		-	4	-	1 / proportionate	-	proportionate
3 Cogeneration bonus 3	Old plants	2	3	2	3	2	2
	New plants		3		3		3
4 Technology bonus 4		2	2	2	2	2	-
5 Immission-bonus 5		-	1	-	1	-	-
6 Landscape care bonus 6		-	2	-	2	-	-

1) Degression applies to all boni and not just to the basic compensation like in the past
2) For a slurry mass share of 30% 3) For plants with an existing heat concept acc. to EEG 2004
4) Without dry fermentation 5) If the formaldehyde limits of the Clean Air Directive are observed 6) If material from landscape care is used predominantly

Results

Table 3 shows the investment requirements, the yields, the costs, as well as the profit and the losses of the model plants. As another indicator of success, total return on investment is shown.

The single farm reaches an annual profit of about € 1,900, which corresponds to a return on investment of 0.9 %. Regardless of the transport variant for slurry (plants 2 and 4), however, the cooperative biogas plants for 200 cattle animal units are not profitable due to the additional expenses for slurry transport. The costs of the pump systems as well as the expenses for slurry transport by tankers cause losses of approximately € 6,500 and 7,200, respectively. If approximately 22 % of maize silage is added to slurry from 200 cattle animal units, the economic result improves considerably (plants 3 and 5). Despite increased

Table 2: Characteristics of planning examples

	Unit	On-farm biogas plant	Cooperative plant (two farmers)				Cooperative plant (three farmers)	
			Pumping of slurry		Slurry transport (tanker)			
Plant		1	2	3	4	5	6	7
plant power kWel		30	30	75	30	75	75	150
Slurry from cattle	animal units	200	200	200 (with Maize)	200	200 (with Maize)	500	500 (with Maize)
Substrates used								
Cattle slurry	t FM/a	3800	3800	3800	3800	3800	9.500	9.500
Maize silage	t FM/a	0		870		870		1.330
Specifications								
Electric efficiency	%	32	32	34	32	34	34	36
Thermal efficiency	%	48	48	46	48	46	46	46
Process-technological data								
Gross fermenter volume	m³	700	700	900	700	900	1700	2000
Mean hydraulic dwell time	d	58	58	60	58	60	58	60
Additional residual slurry store volume 1	t	0	0	618	0	618	0	945
Work time requirements of the plants	h	396	428	497	396	465	443	549
Slurry transport farm to farm	m	0	250 pump(300 C/m)		3000 farm to farm distance with 15m³ tank (2,88 C/t)			

Cattle slurry with feed residues, 8% DM
Maize, silage, wax-ripe, rich in grains, 35% DM
[1] Storage duration 6 months, storage capacity of animal housing considered

investment and time requirements, a return on investment of more than 2 % is reached. Nevertheless, the plants cannot be assumed to work profitably. Even if the investment sums were reduced by 10 %, this result would not change.

The two planning examples 2 and 4 show that under otherwise identical conditions the variant with the pump system reduces the costs by € 2,000. It must be taken into account, however, that the expenses for the pipe system were calculated for favourable conditions (installation in terrain which is easy to develop (arable land) without the need to break an asphalt layer). If the plant output is increased to 75 kW (plant 3) by additionally fermenting maize, the profit zone is reached, but the return on investment is not sufficient.

The cooperative plant with a slurry equivalent of 500 cattle animal units (plant 6; 75 kW) can provide economies of scale with regard to the investment and the operating expenses. The specific investments as well as the specific work time requirements per kWh of generated electricity sink significantly. As a result, this plant earns a profit of € 28,500 and a return on investment of ~ 9 %. If an additional ~ 14 % (1,330 t) of maize silage is used, which results in a power increase to 150 kW, profits of € 71,500 and returns on investment of 12.4% can be achieved. The expenses for slurry transport by mobile equipment do not reduce the profits significantly.

Conclusions

Even though the EEG 2009 provides the option to increase the output and the profits from the sale of electricity thanks to the slurry bonus, this is not sufficient for the profitable operation of small biogas plants on a slurry basis in the 30 kW power class. This core result does not change even if fossil heat energy carriers are replaced and used for other purposes on the farm or sold. Only when the 75 kW power class is reached by means of additional fermentation of biomass do economically successful plant concepts become possible. Returns on investment of 5 %, which must be striven for in order to make operation profitable, could only be reached if investments were significantly reduced. Plants having a size equal to 500 cattle animal units, however, are suitable for economically successful operation.

	Unit	On-farm biogas plant	Cooperative plant (two farmers)				Cooperative plant (three farmers)	
			Pumping of slurry		Slurry transport (tanker)			
Plant		1	2	3	4	5	6	7
Plant power kWel		30	30	75	30	75	75	150
Slurry from cattle animal unit	animal unit	200	200	200 (with Maize)	200	200 (with Maize)	500	500 (with Maize)
Power-class of the block heat and power plant		30	30	75	30	75	75	150
Investition		203.501	299.121	486.849	203.501	399.922	317.558	578.682
Specific investment	€/kWel Inst.	6.783	9.971	6.783	6.491	5.332	4.234	3.858
Yields	€	57.467	57.467	148.660	57.467	148.660	148.400	296.138
Costs	€	55.561	63.986	137.016	64.697	140.066	119.862	224.634
Profit/losses	€	1.905	-6.520	11.643	-7.231	8.594	28.538	71504
Return on investment	%	0,936	-2,180	2,392	-3,553	2,149	8,987	12,356
If investment is 10% lower								
Profit/losses	€	5.178	-2.452	18.153	-4.139	14.362	33.421	79.982
Return on investment	€	2,827	-0,911	4,143	-2,260	3,990	11,694	15,357

Table 3: Summary table