Thomas Hügle, Helga Andree and Malte Jacobsen, Kiel

Biogas plants

When does it pay to invest?

The Renewable Energy Law (EEG) and the permission to utilise regenerative raw material as fermenting material makes the building and operating of biogas plants interesting for farmers. Observations up until now on the economical viability, aimed at helping farmers as investment orienteering and decision aids, were based as a rule on calculations from model plants. The following results allow every farm the possibility of establishing the investment sum that offers an economically viable biogas plant.

Priv.-Doz. Dr. Thomas Hügle is senior assistant, Dipl.-Ing. agr. Helga Andree is member of the scientific staff and Herr cand. agr. Malte Jacobsen diploma student at the Institute for Agricultural Procedural Technology, Christian Albrechts University (director: Prof. Dr. Edmund Isensee), Olshausenstr. 40, 24098 Kiel, e-mail: *thuegle@ilv.uni-kiel.de*

Keywords

Biogas plants, energy output, investment

The picture of modern farming has been further enriched in recent years with an extra aspect: biogas plants. With these, including newest technology, farmers can produce environmentally-friendly energy from slurry, biomass and organic waste.“ The above can be read in a brochure produced by the Ministry of Agriculture. The ground for this almost euphoric announcement is the Renewable Energy Law (EEG) introduced April 1, 2000. This guarantees a minimum return of 0.20 DM/kWh (§ 5 Abs. 1 EEG) for electricity produced from biomass up to and including an installed output of 500 kW. The law also allows the use of harvested crops as energy carriers. The Federal Institute for Agriculture and Nutrition allows, under certain conditions, the use of regenerative raw material grown on set-aside land. It is obvious that the establishing of a biogas plant on cattle or pig farms is therefore now under discussion as possible extra income source. Requirement here, however, is regular daily production of high specification gas. The production of cattle and pig slurry and its dry matter content depends on the feeding, the hygiene steps taken or also the manure handling system and the marked variations in gas yield information reflect this [1, 2]. Additionally, the slurry going into the fermenter should be as fresh as possible. Biological degradation during storage reduce potential gas yield. For this reason, livestock production in buildings with underfloor slurry storage represents a system generally not suitable for linking to a biogas plant. The only systems that really come into consideration are dung scraper or dung flushing systems where manure is collected in a preliminary catchment area and then fed continually into the fermenter. The processed manure is then stored in the main container.

Co-ferment material safeguards and stabilises continuous gas yield

Slurry fermentation itself actually gives a low and strongly varying gas yield and this means the addition of co-ferment material is almost mandatory. Most suitable for this is regenerative raw material. Food or catering industry waste is hygienically extremely questionable as co-ferment material. Using forage maize as co-ferment is attractive for the farmer because the experience is already there for establishing the crop, looking after it and then harvesting. In many cases there’s also spare silo capacity on farms. Where harvesting has been done properly, the silage itself has a relatively homogenous consistency which carries with it the advantage of a dependable expected minimum daily gas yield where the material is fed consistently into the plant.

Requirement for a high biogas yield by appropriate operative reliability is a plant that functions well technically, the kind which is only offered by specialised firms. Self-built systems are out of the question for a committed full-time farmer in that he or she has neither time for the necessary construction nor for the multiple necessary tasks of intensive servicing and maintenance required for DIY plants. Therefore a farmer has no choice other than acquiring estimates for the required biogas plant from the different firms involved. Based on the estimates a decision can be made on whether investment in a biogas plant would pay.

Calculation bases for the farmer

Factors in own calculations include the type and number of livestock on the farm, land available for cropping co-ferment material and expected yield of such. In this context one can in general expect a daily slurry production of 50 l per large animal unit (LAU). On good land a forage maize yield of 50 t/ha can be expected, on not so good locations, 30 t/ha should be possible. Additionally, the biogas yield from the various materials is also important. Per cubic metre of cattle slurry this seldom is more than 25 m^3 biogas due to the intensive digestive system of cattle. But with pig slurry, yields of up to 40 m^3/m^3 substrate can certainly be expected. Possible yields from co-ferment material such as forage maize are completely different. As the easily-fermentable nutrients are still in their composite form they are completely available for biogas production. Thus, a tonne of maize silage, depending on its maturity, can produce between 170 and 220 m^3 biogas.

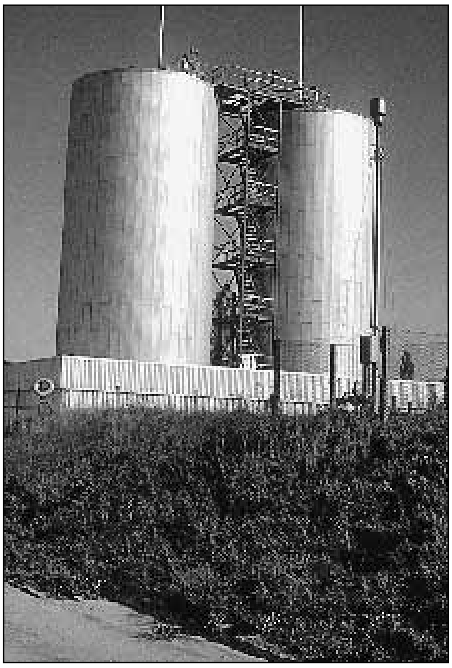

Fig. 1: Ambitious two step biogas plant

This means, e.g., that maize silage as co-ferment added at 20% in pig slurry would double gas yield per m^3 of fermentation area. With cattle slurry the increase could be even 150%.

Information on LAUs – stocking, specific slurry production plus cropping area with specific co-ferment material yield – is enough to roughly estimate the biogas yield to be expected. There results the simple functional association:

$$V_{GBa}=n_{GV}\bullet V_{BGGVd}\bullet 365+n_{AFCF}\bullet E_{CF}\bullet V_{BGCF}$$

V_{GBa}= annual produced amount of biogas
n_{GV} = LAUs
V_{BGGVd} = daily biogas output per LAU [m^3/d]
n_{AFCF} = available land for growing co-ferment [ha]
E_{CF} = co-ferment yield [t/ha]
V_{BGCF} = biogas from co-ferment [m^3/t]

Energy realisation

Energy density for produced biogas is 6.0 to 6.5 kW/m^3. Fed into a CHP, this is transformed into electrical energy and heat in a ration of 1:2. After subtraction of process losses, around 30% of the applied energy is available as electrical energy and around 50% in the form of heat.

The electrical energy can be fed directly into the national grid. The heat can really only be used on the farm because the possibility of delivering heat to houses, schools and other public facilities, or into a central heating pipeline system, is rare. This means that farms rearing piglets have a special advantage in this context because farrowing and rearing houses have to be heated for the greater part of the year. Thermal energy is seldom required by dairy farms because the required warm water is usually produced through heat exchange from the milk cooling system. The only customer for heat is then the dwelling house, as long as it is in the immediate vicinity of the biogas plant. For the energy realisation (E_{ver}) in this case there is the following association:

$$E_{ver} = E_{el} + E_{thermc}$$

E_{el} = electrical energy [kWh]
E_{thermc} = realisable thermal energy [kWh]

Because of the EEG there is full realisation for the electrical energy. Its annual energy contribution from biogas production is then:

$$E_{el} = V_{BGa} \bullet e_{BG} \bullet \eta_{el}$$

e_{BG} = biogas energy content [kWh/m^3]
η_{el} = electrical efficiency degree

A similar association applies to the thermally usable energy. The thermal efficiency degree η_{therm} in this case replaces the electrical degree of efficiency η_{el}

$$E_{therm} = V_{BGa} \bullet e_{BG} \bullet \eta_{therm}$$

If the thermal energy from biogas is actually used, then the following must be taken into account:

$$E_{thermc} \leq E_{therm}$$

Biogas production returns and costs

The following annual returns P_{BGa} from biogas production are given according to

$$P_{BGa} = p_{el} \bullet E_{el} + p_{therm} \bullet E_{thermc}$$

p_{el} = electricity tariff [0,20 DM/kWh]
p_{therm} = tariff for thermal energy, for instance 0.06 DM/kWh with a heating oil price of 0.60 DM/l

From the returns must be subtracted the costs for growing, harvesting and preparing the regenerative raw material as well as the additional costs for bringing out the ferment residues. Through long-term experience these are the only costs that can be judged accurately, or are available from tables. The remaining costs consist of depreciation and capital interest as well as maintenance, repairs and servicing costs, as a rule given as a part of the total investment. It is usual to put building working life as 16 years and the associated biogas production technology as 8 years. The costs for maintenance, servicing and repair are 1% and 4% respectively. As a rule interest paid on invested capital lies at 6% of half the investment sum. Insurance costs can almost be ignored at 0.2%. For the individual plant components (Ax) there is there is a theoretical cost proportion (k_{Ax}) on the total investment which can be estimated in the following way:

$$k_{Ax} = i_{Ax} \bullet (AfA_{Ax} + kWPR_{Ax})$$

i_{Ax} = absolute proportion of A_x of the total investment
AfA_{Ax} = depreciation for A_x [%]
$kWPR_{Ax}$ = cost proportion of A_x for maintenance, servicing, repairs [%]

The theoretical cost proportion of total investment (k_i) for the types of cost given above is then:

((Gleichung einsetzen))

ZS_i = interest charged on total investment [%]
kV_i = proportional costs for insurance of total investment [%]

Does the investment pay?

Through the established data it is therefore possible to establish the theoretically maximum permittable investment sum (I_{max}) with which a biogas plant can just break-even financially

$$I_{max} = 100 \bullet P_{BGa} / k_i \qquad [DM]$$

I_{max} and prices are to be compared. If the offer price lies lower than this then, as a rule, it pays to build the plant, especially as subsidies and premiums have purposely not been considered in all these calculations.

Literature

Books are denoted thus •

[1] *Kempkens, K.*: Wird Biogas jetzt für Landwirte interessant? Top agrar (2000), H.4, S. 26 – 31

[2] • *Oechsner, H. und M. Knebelspieß*: Investitionsbedarf landwirtschaftlicher Biogasanlagen und deren Wirtschaftlichkeit. Bau, Technik und Umwelt in der landwirtschaftlichen Nutztierhaltung (2001), Hohenheim