FUEL FROM AGRICULTURAL BIOGAS PLANTS – AN ECONOMIC ALTERNATIVE TO POWER GENERATION ?

STROM ODER KRAFTSTOFF AUS BIOGAS – EIN ÖKONOMISCHER VERGLEICH

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Abstract:
This research addresses the topic of agricultural biogas plants, specifically the economics of producing fuel-quality upgraded biogas (green gas). The costs of this production in relation to annual gas output and feed stock prices are evaluated using model calculations. The competitiveness of fuel production compared to that of electricity production from the same source is also examined.

Key words:
biogas, green electricity, green gas, cost

Zusammenfassung:
Die vorliegende Arbeit beschäftigt sich mit landwirtschaftlichen Biogasanlagen. In einer Modellrechnung werden die Kosten für in Kraftstoffqualität aufbereitetes Biogas (Green Gas) in Abhängigkeit von der jährlichen Gaserzeugung und den Substratkosten ermittelt. Weiters wird die Wettbewerbsfähigkeit mit der Erzeugung von Ökostrom untersucht.

Schlagwörter:
Biogas, Ökostrom, Biokraftstoff, Kosten

1. The problem

Biogas in Austria is almost always used in combined heat and power (CHP) plants to produce electricity. According to information from the manufacturers themselves, facilities with a capacity of 500 kW_{el} can achieve an electrical efficiency of 39.2% and a thermal efficiency of 45% (GE Jenbacher 2004, 5). However, given the lack of appropriate uses, the thermal energy released is mostly used only in further processing stages in the plant itself or for heating local buildings. More often than not, most of the heat is released unused into the surrounding environment (WALLA and SCHNEEBERGER 2003b, 114).

An alternative to electricity production would be to upgrade biogas to the quality of natural gas and then feed it into the gas grid for use as fuel. The available pipeline and gas station distribution networks could be used, and the appropriate gas-driven vehicles are already available on the mass market. Exploiting biogas in this way would have the advantage of using up to around 87% of its energy content; heating the fermenter would require about 8% of the total energy (calculated for ECO Gas Vers. 02-A3) and the upgrading process itself would include a methane loss of about 5% (PÖLZ and SALCHENEGGER 2005, 54).

Biogas can be produced from any biomass material, with the exception of plants with high levels of lignin or cellulose. There is, therefore, considerable potential for biogas production. Given the use of the entire plant, considerably more fuel energy can be produced per hectare of cultivated area than with fuel production from seeds (ethanol from wheat, rape oil and rape oil methyl ester). Ethanol production from sugar beet yields about the same amount of energy per hectare as methane production from maize silage (see Table 1).

Table 1
Energy production per hectare from selected biofuel crops, based on average yields in Austria in 2004

Crop	dt/ha	Biofuel	Quantity/ha	kWh/ha
Wheat	60.4	Ethanol	2,170 l	12,760
Sugar beet	648.7	Ethanol	6,500 l	38,170
Rape	34.3	Rape oil	1,400 kg	13,740
Rape	34.3	Rape oil methyl ester	1,340 kg	13,770
Maize	446.2	Methane	4,030 m^3	38,340

Source: BMLFUW 2005, 175; KNOFLACHER et al. 1991, 88, 92, 105, 107; KTBL 2005, 11; BGBl. II Nr. 417/2004, 5 f.

The aim of the research presented here is to use model calculations to determine the price at which feeding biogas into the natural gas grid can compete economically with electricity production from the same raw material. This competitiveness is examined under changing levels of annual gas production and feed stock prices.

2. Method

The model calculations are based on a facility with an average hourly output of 132 Nm^3 methane (= ca. 220 m^3 raw gas). Such a plant is the equivalent of a 500 kW_{el} CHP facility operating at 7,000 full load hours. The capital investment costs were estimated using WALLA and SCHNEEBERGER's (2003a, 529) regression function. In the model where biogas is fed into the natural gas grid, the costs of the CHP facility were replaced with those of a gas-fired boiler used to heat the fermenter.

The operating costs of the biogas plant were mainly taken from relevant literature (WALLA and SCHNEEBERGER 2003a, 532; WALLA and SCHNEEBERGER 2003b, 115; HARTMANN 2002, 524). The costs of upgrading the gas prior to feeding it into the natural gas grid were also taken from published sources (PERSSON 2003, 65; HORNBACHNER et al. 2005, 259, 246).

The methane yield per tonne silage maize and per m^3 of slurry were kept constant in all models. As such, the amount of feed stock used changed in proportion to the annual gas output.

3. The legal environment

The European Parliament's Directive 2001/77/EC on the "Promotion of Electricity Produced from Renewable Energy Sources" was implemented in Austria through the following pieces of legislation: the Ökostromgesetz (BGBl. I Nr. 149/2002) and the Ökostromverordnung (BGBl. II Nr. 508/2002) which complements EIWOG (BGBl. I Nr. 143/1998). Purchase and tariff guarantees are given for the first 13 years of operation of a facility producing "green" electricity. This guarantee applies to all those biogas plants which received the necessary planning permission after 31.12.2002 and before 31.12.2004. In addition, agricultural biogas plants with an output not exceeding 250 kW_{el} can apply for investment subsidies from rural development funds (BMLFUW 2003, 48).

Directive 2003/55/EC (concerning common rules for the internal market in natural gas) establishes the right to feed biogas into the natural gas grid. This directive was incorporated into Austrian law through an amendment to the existing Gaswirtschaftsgesetz (BGBl. I Nr. 148/2002). Access to the natural gas grid is only allowed if the biogas meets quality criteria set down within the "Erdgas in Österreich" ("Natural Gas in Austria") guideline from May, 2001 published by the Österreichische Vereinigung für das Gas- und Wasserfach (Austrian Gas and Water Association). In the section on general requirements for the gas distribution grid, grid users are obligated to demonstrate the quality of the natural or biogenic gas at the point of transfer to the grid system. To meet these quality requirements, biogas has to be cleaned, enriched with methane and gas odour, dried, filtered and compressed to the required pressure (see HORNBACHNER et al. 2005, 3).

The quality requirements for biogas destined for the gas grid are considerably stricter in Austria than in Germany, where there is no upper threshold limit for carbon dioxide, no indications regarding methane content and a set minimum calorific value of 8.4 kWh. In Sweden and Denmark, it's the quality of the resultant mixed gas in the gas grid that's relevant, and not the quality at the entry point to the grid. In Switzerland, partly upgraded biogas can enter the grid up to an amount equivalent to 5% of the total gas volume (HORNBACHNER et al. 2005, 23 ff.).

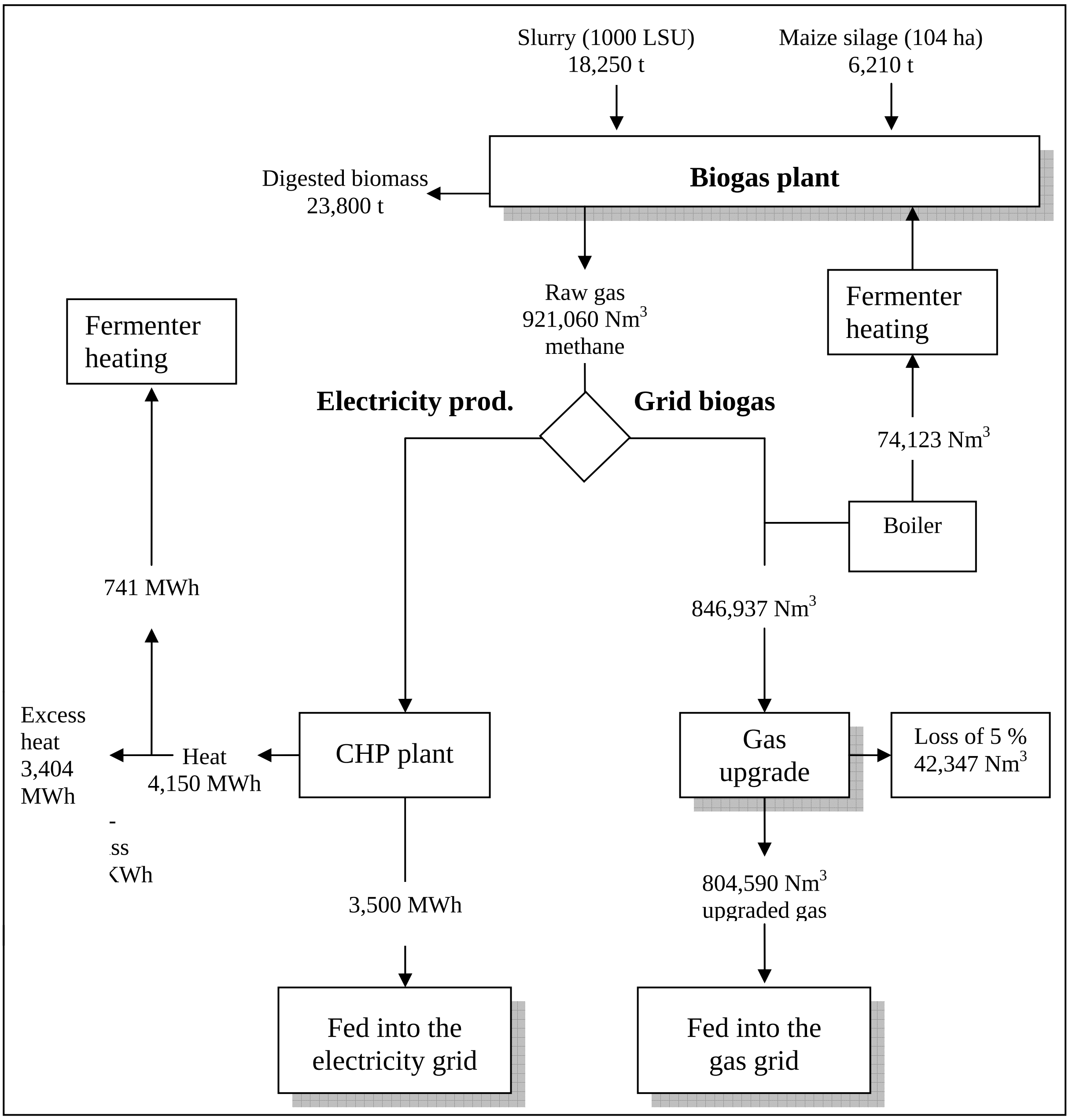
The price for electricity produced from biogas is regulated by law. However, there is no binding tariff for biogas fed into the natural gas grid.

4. Model assumptions

Figure 1 gives the quantities used in the model calculations when 921.060 Nm^3 methane per year is produced from slurry and maize silage (equivalent to 7,000 full load hours of a CHP plant). Slurry from around 1,000 livestock units and silage maize from around 100 ha of crop are required to produce this amount of gas (300,000 Nm^3 from slurry and 621,060 Nm^3 from silage maize). Methane yields are fixed at 300 Nm^3 per livestock unit and year for slurry (MØLLER et al. 2004, 492) and 300 Nm^3 per tonne dry matter for maize silage (KTBL 2005, 11). Slurry costs arise from its transport to the biogas plant and the return of the biogas slurry to the supplier. Slurry is transported an average of 3 km. When using a 15 m^3 slurry tank, 1,230 trips are necessary. The subsequent costs are derived from KTBL guideline values for machinery costs and amount to about € 37,600 per year (KTBL 2004). The price for maize silage is fixed at € 60 per tonne dry matter, and suppliers are obligated to take back their share of the biogas slurry at no cost.

The biogas so produced can be upgraded and fed into the gas grid or used to produce electricity in a CHP plant. Given 7,000 full load hours and an average electrical efficiency of 38%, then 3,500 MWh electricity would be produced. The fermenter is heated using thermal waste from the CHP plant and the remaining heat is not used. When upgrading the biogas for grid use, around 8% of the energy in the raw gas is needed for heating the fermenter and that leaves 805,000 Nm^3 methane for feeding into the grid (after accounting for some methane loss during the upgrade process).

Figure 1: Quantities used in the model calculations given 7,000 full load hours in a CHP plant or equivalent gas production for the gas grid



The investment costs, including a CHP plant, come to about € 2,000,000. A boiler for heating the fermenter is required in the gas production alternative in addition to the standard investment costs for technical equipment (see Table 2). The capital costs are calculated using an interest rate of 5 %. The buildings are allocated a useful life of 20 years and their repair and maintenance costs set at 1% of the investment cost. The annual costs for technical equipment are calculated assuming a useful life of 12 years, repair and maintenance costs are calculated as 3.5% of the investment costs, and insurance as 0.25% of the investment costs. The CHP plant has an assumed useful life of 20 years. A maintenance contract for the CHP is also needed, one which covers replacement parts. An appropriate bid document from the company GE Jenbacher (19. 7. 2005) puts these maintenance costs at € 7.70 per hour running time, equivalent to € 65,000 per year. The maintenance contract includes breakdown insurance.

Table 2
Investment and annual costs for the production of electricity and gas

Cost item	Electricity prod.	Gas production
	Net amount in €	Net amount in €
Investment: buildings	1.062.000	1.062.000
Investment: technical equipment	541.000	541.000
Investment: CHP plant / boiler	400.000	17.000
Annual capital costs	178.440	148.080
Feed stock	161.800	161.800
Insurance	5.010	4.050
Repair and maintenance	29.560	30.120
Repair and maintenance CHP plant (contract)	65.000	
Labour (1.75 hrs * 365 days * 15 €)	9.580	9.580
Electricity (€ 0.105 per kWh)	40.420	22.050
Other plant costs	5.000	5.000
Management	7.500	7.500
Total costs	**502.310**	**388.180**

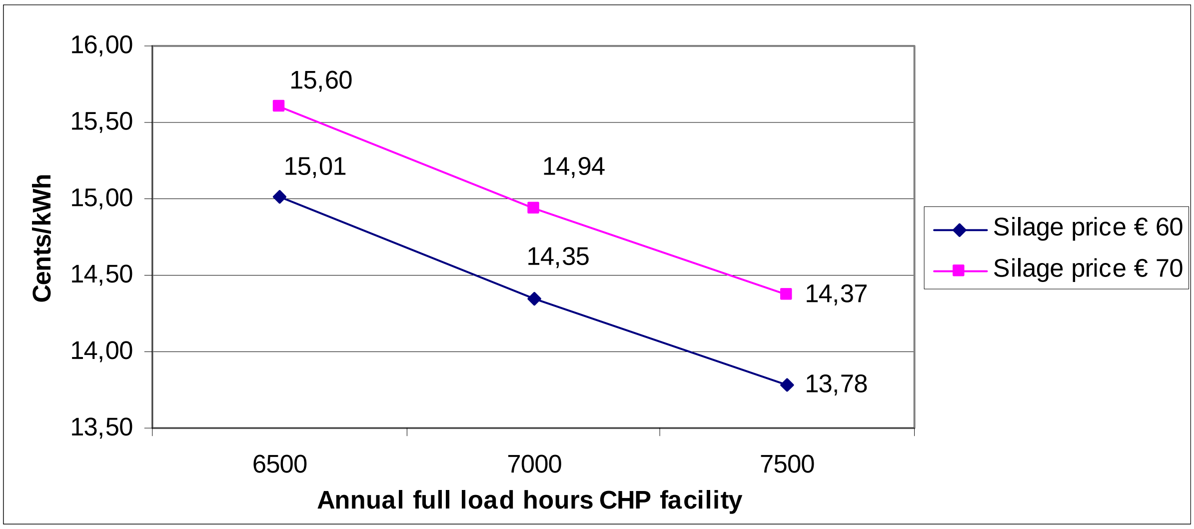
The cost of upgrading the biogas for the gas grid is dependent on both the size of the plant as well as the grid's quality requirements. According to Swedish research, the costs of upgrading the gas in plants with a capacity under 100 m^3/h raw gas are between 3 and 4 cents per kWh, and the equivalent figures for plants with a capacity between 200 and 300 m^3/h are 1 to 1.5 cents per kWh (PERSSON 2003, 65). An Austrian study calculated the costs of upgrading to enriched gas (over 90% methane) as 2.25 cents per kWh and the costs of feeding the gas into the grid as between 0.5 and 0.79 cents per kWh for grid level 2 (up to 70 bar) and between 0.3 and 0.4 cents per kWh for grid level 3 (up to 6 bar) (HORNBACHNER et al. 2005, 259, 246). After taking account of the legislative environment in Austria as it pertains to gas production, the costs of gas upgrading were fixed at 1.5 cents per kWh and the costs of feeding the gas into the grid at 0.35 cents per kWh.

5. Results

5.1 The cost of producing "green" energy

The data given in Figure 1 and Table 2 reveal total costs of around € 502,300 per year for producing 3,500 MWh of electricity, or 14.35 cents per kWh. Figure 2 shows how these costs change at different levels of full load hours. The cost of electricity rises by 0.59 cents per kWh at a maize silage price per tonne dry matter of € 70. It is worth noting here that the total cost of feed stock varies with the number of full load hours. A decrease in gas production as a result of any problems with the digestion process would lead to additional costs, but this is not accounted for in the calculations.

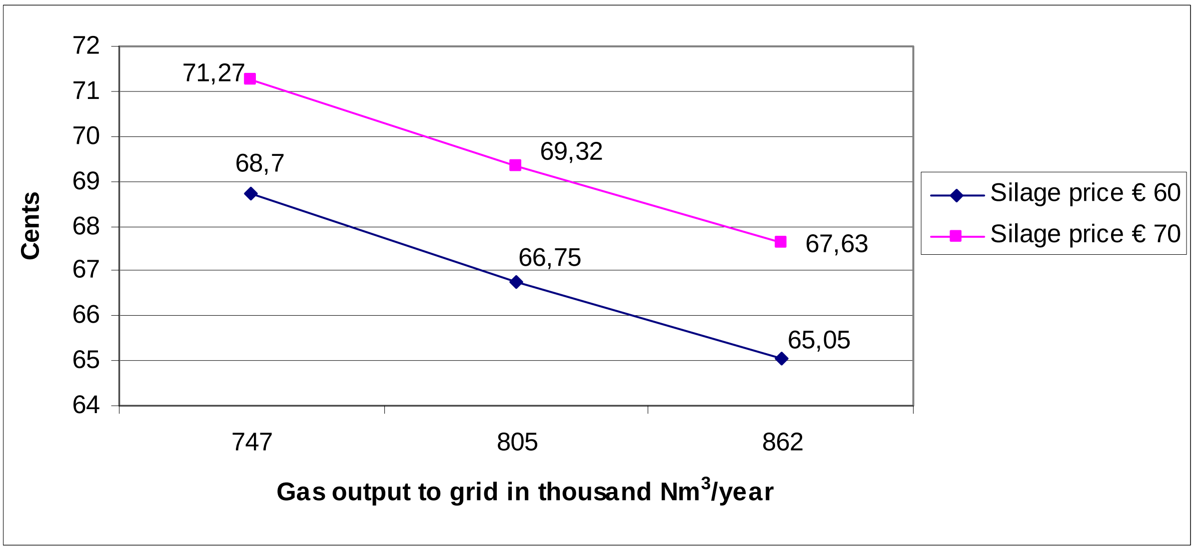
Figure 2: The cost of producing electricity from biogas in relation to the level of full load hours in the CHP plant and the price per tonne dry matter of maize silage



5.2 The cost of producing biogas for feeding into the gas grid

A CHP plant operating at 7,000 full load hours uses 921,000 Nm^3 of methane. This volume could produce 805,000 Nm^3 of upgraded biogas. The € 537,000 annual costs are the sum of the costs for biogas production (€ 388,180 - see Table 2) and the upgrading process (€ 149,000 i.e. 804,590 Nm^3 times 18.5 €). Figure 3 illustrates how these costs per Nm^3 of upgraded gas change dependent on annual production levels and the price of maize silage.

Figure 3: The costs of producing and upgrading biogas for feeding into the gas grid as they relate to changes in production levels and the price per tonne dry matter of silage maize

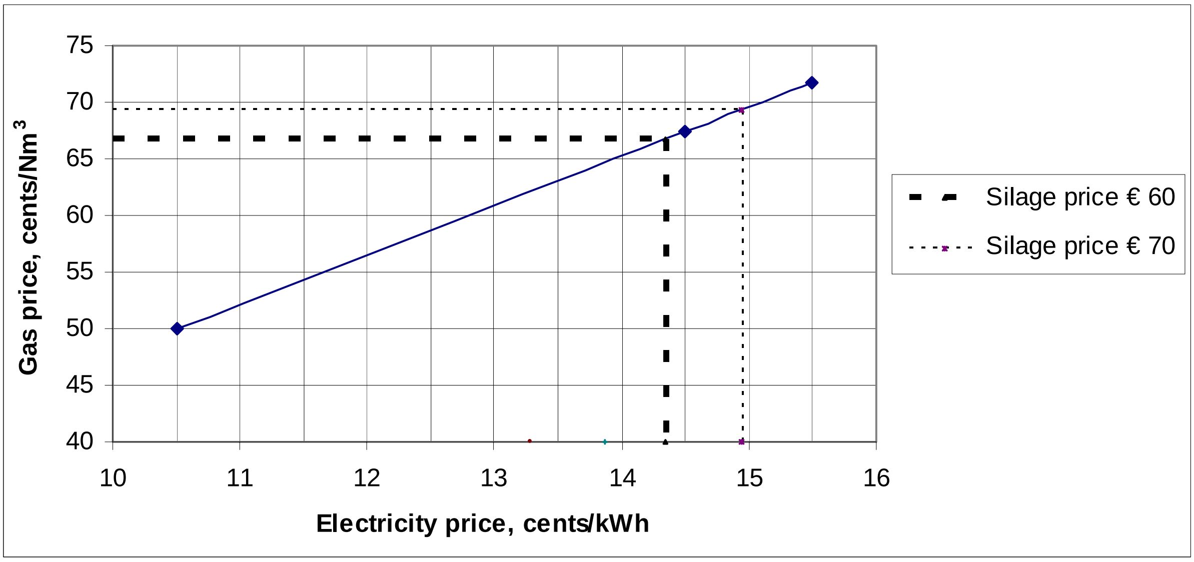


5.3 Competitive gas prices

Competitive prices are those that would lead to the same business result (the same annual profit or loss) for both electricity production and production of gas for use in the natural gas grid. An electricity tariff of 14.5 cents per kWh, at a maize silage price of € 60 and with 7,000 full load hours, generates an annual profit of € 5,187. The operator of a biogas plant feeding upgraded gas into the national gas grid would make the same level of profit at a price for his product of 67.4 cents per Nm^3. Given these electricity and gas prices, a maize silage price of € 70 would produce an annual loss of € 15,514. Figure 4 gives the equivalent competitive gas price for electricity prices between 10.5 cents and 14.5 cents per kWh and 7,000 full load hours.

A change in maize silage price influences the business result and breakeven point, as Figure 4 demonstrates. Assuming 7,000 full load hours and a maize silage price per tonne dry matter of € 60, the breakeven point occurs at a price of 14,35 cents per kWh for electricity and a price of 66.75 cents per Nm^3 for gas. If the maize silage price is € 70, then the breakeven point occurs at an equivalent price of 14.94 cents for electricity and 69.32 cents for gas.

Figure 4: The competitive price relationship between gas and electricity production and a comparison of breakeven prices at different levels of silage maize price per tonne dry matter, assuming 7,000 full load hours



6. Discussion and conclusions

The feed stock costs and annual gas production levels were varied in the model calculations. In practice, other elements of the calculation are likely to vary too, such as investment costs, gas upgrading costs and operating costs. As such, the calculated costs per kWh electricity or per m^3 gas should be seen as guideline values only. As regards the issue addressed by this research, namely the relative competitiveness of upgrading biogas for use in the natural gas grid compared to electricity production from the same material, cost changes that would be the same for both alternatives are irrelevant. Consider, for example, a change in the cost of the feed stock. This affects the price per kWh electricity and per m^3 upgraded gas, as well as the breakeven price. But it has no affect on the relative competitive position of both alternatives. However, a change in the costs of the gas upgrade process or of electricity production alone would impact the competitive gas price.

The upgraded biogas must compete with natural gas. At the time of writing (September, 2005), natural gas cost around 77 cents per kg at the gas station or 47 cents per m^3 (excluding VAT). The costs of grid use and the margin taken by the gas station are estimated at 5.5 cents per m^3 (HORNBACHNER et al. 2005, 287) and 4 cents per m^3 (see WEITZ 2003, 111 f.) respectively. If these costs are taken off the net gas station price for natural gas, then we get a guideline value for the price per m^3 a supplier would expect to get for upgraded biogas. This price is well below the cost per m^3 for this gas. As such, the production of biogas for fuel in the current circumstances does not represent a viable economic alternative to the production of "green" electricity with its guaranteed tariff.

In producing fuel from biogas, about twice as much energy is captured than with electricity production, assuming the heat produced in the latter process has no market. Although fuel production represents an ecologically more favourable use of biogas, the model calculations suggest it is not a competitive economic alternative. This is due to the favourable conditions afforded "green" electricity through the associated "green" energy tariff, which biogas for fuel does not get. In order to correct this bias, upgraded biogas would also need to qualify for a tariff exceeding the current price for natural gas.

In the model calculations, the estimated costs for upgrading the raw biogas come to about 28% of the total costs. There is, however, potential to reduce these costs. The development of new upgrading processes (chemical separation techniques, membrane technology) are expected to reduce costs. Costs would also be reduced under the kind of conditions prevalent in other countries with regard to feeding gas into the gas grid, such as those in Germany, Sweden, Denmark and Switzerland. However, a reduction in these costs would still not enable biogas to compete with natural gas. Even if the costs of upgrading the biogas could be cut in half, this would only reduce the total cost of producing upgraded biogas by 10 cents per m^3. Such cost reductions would, however, contribute to a reduction in the level of support or subsidy required to allow biogas to compete with natural gas.

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