Jens Wegener, Wolfgang Lücke and Jörg Heinzemann, Göttingen

# The use of manure in biogas plants

## The potential of German agriculture for the reduction of greenhouse gas emissions

*In 2004, the source group agriculture emitted 6.4% of the national greenhouse gas (GHG) emissions. Thus, it is an important emitter. Thanks to the use of renewable energies, however, emissions are also avoided in agriculture. Based on the theoretical possibility of fermenting the entire technically available manure in biogas plants, 16.2% of the GHG emissions produced by agriculture as a source group can be compensated for in the overall balance.*

Industrial engineer Jens Wegener and Dr. Jörg Heinzemann are scientists in the Department of Crop Science – Division of Agricultural Engineering (director: Prof. Dr. Wolfgang Lücke), Georg-August Universität Göttingen, Gutenbergstrasse 37, D-37075 Göttingen; e-mail: *jwegene@gwdg.de*

### Keywords

Biogas, green house gas reduction, manure-management

In 2004, agriculture as a source group accounted for 6.4% (65,114,300 million tonnes of $CO_2$-equivalent) of the national GHG emissions [1] and is thus an important emitter. This raises the question of whether these emissions can be compensated for by reducing GHG emissions elsewhere. The energetic use of biomass can make a significant contribution towards the achievement of this goal. In the agricultural sector, this currently applies in particular to the use of biogas plants. Below, the GHG reduction potential provided by the use of the technically available manure will be investigated.

The use of biogas plants allows the emission development of manure to be technically influenced under two aspects. The fermentation process has a direct influence on the outgassing behaviour of manure and reduces methane ($CH_4$) emissions during storage and spreading, whereas laughing gas ($N_2O$) emissions grow. All in all, however, biogas production has a reducing effect on the $CO_2$ balance [2]. Energetic use in biogas plants provides even more significant reduction. This is possible because the regenerative production of secondary energy substitutes for fossil energy carriers. In this study, a balance of these factors will be presented for the animal groups of cattle and pigs, which are the main emitters of manure.

### Methods

The following approach is chosen in order to determine the GHG reduction potential of the use of technically available manure in Germany. First, $CH_4$ and $N_2O$ emissions from manure management are measured. For each kind of emission, the percentage of the considered animal groups (cattle and pigs) is established. The emitted quantities of substances upon which the calculations are based and their distribution over the animal species considered are shown in *Table 1*. Subsequently, emission reduction factors (*Table 2*) are used to calculate potential avoidance during the storage and spreading of fermented manure as compared with raw slurry if the manure is used in biogas plants. Finally, the emissions thus calculated are converted into $CO_2$ equivalents. The factors used in these calculations are 23 for $CH_4$ and 296 for $N_2O$ [3].

For the calculation of emission reduction resulting from the energetic use of the $CH_4$ gained during fermentation, the technically available energy potential of manure is assumed to be 96.5 PJ (26.8 billion kWh) [4]. First, equation 1 is used to determine how many tonnes of $CH_4$ correspond to this energy content.

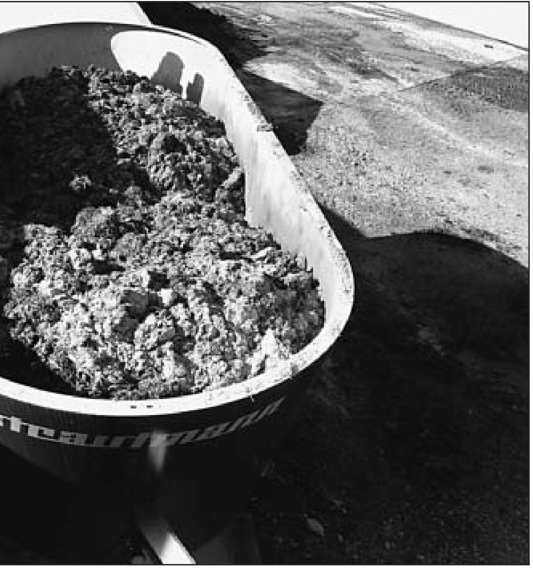
$$EE = EP \cdot \varphi / E \qquad (1)$$

with
EE energy equivalent
EP technical energy potential [kWh]
E energy content of methane [$kWh/m^3$]
$\varphi$ density of methane [$t/m^3$]

Based on this quantity, subsequent calculations show how much energy in the form of electricity and heat can be gained from the manure, and reduction performance as com-

*Table 1: Emissions in farm manure management in the year 2004 and their share from cattle and pigs, referring to animal stock data 2000 [1, 6]*

| Emissions | Percentage of cattle in 2000 [%] | Percentage of pigs in 2000 [%] | total emission in 2004 [t] |
|---|---|---|---|
| $CH_4$ | 60 | 39 | 250000 |
| $N_2O$ | 62 | 14 | 9000 |


Werkbild

pared with fossil energy carriers is determined with the aid of reference parameters. For these calculations, the following assumptions are made:

- An emission factor of 641.3 g $_{CO2/kWhoutput}$ in the local electric power grid for the generation of electricity [5]
- An emission factor of 253.6 g $_{CO2}$/kWh$_{output}$ for the generation of thermal energy in a natural gas heating system
- An average efficiency of 35% for electricity generation and 40% for heat decoupling in the block-type thermal power station of the biogas plant
- An average self-energy consumption of the biogas plants of 8% (factor 0.92) of the electric energy produced and 40% (factor 0.60) of the thermal energy produced
- An energy content of methane of 9.97 kWh/m$^3$ at a density of 722 g/m$^3$
- It is assumed that the entire useful energy generated is used in the form of electricity and heat.
- For manure as an agricultural by-product of animal husbandry, no emissions from the previous chain are taken into account.

Based on these assumptions, GHG reductions are calculated as follows according to equation 2:

$$R = (F \cdot E / \varphi) \cdot \eta \cdot SC \cdot EF \qquad (2)$$

with

R – GHG reduction [t CO2 equivalent]
F – fuel used [t]
E – energy content of methane [kWh/m$^3$]
φ – density of methane [t/m$^3$]
η – electric or thermal efficiency of the block-type thermal power station in the biogas plant [%]
SC – factor for self-consumption of heat or electricity
EF – emission factor of the reference system [t/kWh]

**Results**

The reduction potential provided by the fermentation of the technically available manure during storage and spreading is 3,356,146 t $CO_2$ equivalent per year. The available energy of the technical manure potential of 96.5 PJ corresponds to an energy equivalent of 1,941,185 t $CH_4$. Given the mentioned assumptions, this allows another 7,166,803 t $CO_2$ equivalent per year to be avoided by substituting for fossil energy carriers. The total technical emission savings potential in manure management thus adds up to 10,522,949 t $CO_2$ equivalent per year. This enables 16.2% of the GHG emitted in 2004 to be compensated for.

## Literature


[1] Umweltbundesamt: Deutsches Treibhausgasinventar 1990-2004. Nationaler Inventarbericht 2006. Berlin, 2006
[2] *Amon, T., und H. Döhler*: Qualität und Verwertung des Gärrestes. In: Fachagentur für nachwachsende Rohstoffe (FNR): Handreichung Biogasgewinnung und –nutzung. Gülzow, 2005
[3] Intergovernmental Panel for Climate Change (IPCC): WGI Third Assessment Report, 2001
[4] *Kaltschmitt, M., D. Merten, N. Fröhlich und M. Nill*: Energiegewinnung aus Biomasse. Externe Expertise für das WBGU-Hauptgutachten 2003 „Welt im Wandel: Energiewende zur Nachhaltigkeit". Berlin, Heidelberg, 2003
[5] Globales Emissions-Modell Integrierter Systeme (GEMIS): Ergebnisse aus GEMIS 4.2. Stand Oktober 2004
[6] *Dämmgen, U.*: Nationaler Inventarbericht 2004. Teilbericht für die Quellgruppe Landwirtschaft. Landbauforschung Völkenrode, Sonderheft 260, 2004


| Substrate | emission changes as compared with raw slurry | |
|---|---|---|
| | $CH_4$ | $N_2O$ |
| fermented cattle slurry | - 67% | + 30% |
| fermented pig slurry | - 75% | + 38% |

*Table 2: $CH_4$- and $N_2O$ emission alteration factors for fermented slurry as compared with raw slurry [2]*