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Life-cycle-assessment Biogas

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Renewable energy sources, including biogas, are generally considered eco-friendly. The objective of this paper is to compare the effects of differing primary and secondary biogas production processes on ecology as a whole, as well as with each other. All analyses were done according to ISO 14040 et sqq. The results of the life-cycle-assessment are based on energy production and assessed with the Eco Indicator `99 method. Producing renewable raw materials is the most important partial process, followed by applying the emissions from digested material and from the CHP. With improvements in energy conversion and utilization, important ecological savings can be realized.

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Keywords

Biogas, LCA, renewable energies

The Renewable Energy Sources Act (EEG) was enacted in the year 2000 and amended in 2004. It was made to enforce sustainable electricity generation from renewable energy sources. In terms of the EEG renewable energies are wind, water, geothermal, sun and biomass. The goals of the EEG are defined in Article 1 (1); sustainable energy supply in terms of protecting climate, nature and environment. Other goals of this law, long-term economic stability and worldwide conflict prevention, should not be taken into account in this consideration.

Biomass is expected to take a leading position in electricity generation in the future of Germany. Especially biogas should become the major component of electricity supply. However, biogas as a source of environmental friendly produced energy was confronted with damage to its image. On the one hand the production of biomass (keyword: maize monoculture), biomass transport and the application of biogas slurry are criticised by public. On the other hand biogas is regarded as a technology that saves fossil resources and reduces carbon dioxide emissions compared to conventional electricity generation from fossil fuels.

The amendment of the granted remuneration by the EEG in 2004 and the creation of a bonus for the production and utilisation of biomass for electricity generation led to an investment boom in the biogas sector. Especially the sector of biogas plants with an installed electric power of 500 kW and larger, which are solely using specially produced biomass, grows rapidly. Related to this boom, the production of energy crops as input for these biogas plants was extended in large parts.

This strong numeral increase of biogas plants and the total power installed leads to the question, if biogas plants can be considered as a sustainable kind of electricity production in terms of the EEG. The here given compendium examines this question.

Method

The object of investigation is a notional biogas plant with an electric power of 1.0 MW, used as standard scenario. Several sensitivity analyses are accomplished, based on this standard scenario: the production of several kinds of energy crops as well as mixtures of manure/energy crops versus manure/biowaste were analysed as input to the biogas process. A gas-Otto-CHP plant and a fuel cell were compared with each other as alternative electricity generation processes. Alternative intensities of heat utilisation from the CHP plant were calculated. Finally the ecological effects of different kinds of biogas slurry treatment and application were analysed.

The ecological effects of the biogas process and its sub-processes were analysed with the life-cycle-assessment (LCA) method according to EN ISO 14040 sqq. The aim of the biogas process is defined as feeding electricity to the grid; the structure of this study is related to the aim definition. The scope of this LCA study includes all steps of the supply chain of the biogas process. All steps (modules) of the biogas process were analysed separately and holistic; most important impacts were determined.

A LCA study includes

1) goal and scope definition,
2) inventory analysis,
3) impact assessment and
4) interpretation of the results.

The LCA method includes iterations of and changing between the single methodological steps. The goal of the study is the answer to the question given in the introduction “is electricity from biogas plants a sustainable kind of energy conversion?” Additional the most important influences on the whole process chain should be detected and improvements should be suggested. The scope of the study reflects the biogas production process as complete as possible. This means, the production of the energy crops, transport processes to and from the plant, the erection and demolishing of the biogas plant, the emis-

sions from the plant and the utilisation of the biogas slurry are included. Within the scope definition the functional unit, one Terrajoule of electricity fed to the grid, was defined. All data taken into account in this study are related to this functional unit.

The study should provide general information about the ecology of biogas production. Therefore average data derived from comparable processes, materials, of methods were used. If this was not practicable, e.g. fuel cells, exceptions from this rule were accepted.

The Eco indicator ’99 (H) method was used for impact assessment. The use of this method results in dimensionless figures, so that the results of modules or different processes can be compared with each other. The Eco indicator ’99 (H) is a method for normalisation, weighting, and sorting inventory data to several impact categories. In a second step the weighted results are transformed by special weighting scheme to make them comparable with each other. All results are calculated with the Eco indication ’99 (H) method, so all results of the single impact categories are aggregated and given in the same unit (eco points). This unit was made for the comparison of ecological effects between systems.

Other normalisation and weighting methods can lead to different results. Data collection, grouping, and assessment were done using the LCA software Sima Pro (Version 6.0).

Results

The results of the standard scenario (maize based energy crop/manure mixture, gas-Otto-CHP plant, no external heat use, manure application according to good agricultural practice GAP) are given in *Table 1* for the whole process and the single modules.

In this scenario the strongest influence on the overall results is caused by the production of the energy crops (input to the biogas process) sharing 83.5 % of the overall result. The CHP emissions cause 11.3 %, the consumption of electricity from the grid causes 4.5 %, transport of input and output materials causes 4.8 % and the erection and demolishing of the biogas plant causes 1.0 % of the overall result. The utilisation of the biogas slurry, which causes negative effects from application emissions and positive effects from fertilising, improves the overall results by 2.9 %.

Altogether, the impact category land use, related to the production of energy crops, has the strongest influence on the overall ecological effects (62.3 % of the module energy crops, 52.0 % of the overall results). There are some methodological questions, which restrict this result. It must be critically discussed, if the Hemeroby-concept, used for the assessment of the land use, is suitable for agricultural production systems. If the direct effects of land use are not taken into account for the overall result (1,150 Eco points remain for indirect land use effects), the influence of the energy crop module on the overall result is reduced to 3,780 Eco points. For this reason the overall result is reduced to 5,590 Eco points. Due to the importance of the land use impact, energy crops with high yield/area ratios, e.g. maize or fodder beets, show ecological advantages in relation to crops with a low yield/area ratio. Actually plant breeders are trying to improve the biomass production of their crops to achieve this goal. Generally waste and therefore biowaste as input to production processes is taken into account without any ecological burden. In this study only the transport related to the utilisation of the bio-waste is calculated as an ecological effect of the input process of the biogas plant; the ecological effects of the whole production process are reduced by the effects of the energy crop production (83.5 % of the total LCA result). Due to the unclear availability of bio-wastes in a certain region, the transport distance was enlarged (517 instead of 463 Eco points).

If a fuel cell instead of the Gas-Otto engine would be used as a CHP plant emission level would be reduced to 204 Eco points (conventional 1,090 Eco points); also higher efficiency rates would be achieved. These higher efficiency rates lead to proportional reductions of all upstream processes, e.g. transport and energy crop production. The LCA result of the fuel cell scenario is 6,990 Eco points (27.4% less than the standard scenario); only 6,160 Eco points are caused by the energy crop production in this scenario.

The use of the waste heat from the CHP plant can result in noticeable ecological benefits, if fossil resources are saved by this heat use. In the waste heat using scenario, an utilisation of 23.7 % of the heat from the CHP plant is expected. The heat is used to replace natural gas fed heating in multiple dwelling. The saving of fossil resources leads to a reduction of the LCA result of 1,490 Eco points. The generation of artificial heat consumers, e.g. wood chip drying, would cause no savings and so no ecological benefits.

If the biogas slurry is not applied to the soil regarding GAP, but using high emission technology and no method to incorporate the fertiliser into the soil, the ammonia emission level increases. This causes a change of the results of the slurry application module from ecological benefits to negative results of the whole module (1,890 Eco points). This result is mainly caused by increased emission of acidic and eutrophic emissions as well as the loss of fertilising substances.

Table 1: Results of standard scenario (Eco points)

Module	Total	Input	CHP-emissions	Electricity from grid	Transport	Manure utilisation	Biogas plant
eco points	9630	8040	1090	436	463	-275	98

Conclusions

Concluding, it can be said that the use of area and energy are the most important impacts to the overall LCA result. The emission from the CHP plant and the emission from the biogas slurry application also take a good deal of the LCA result. The LCA result can be improved either by higher yields per area or bio-waste is used as an input to the biogas plant. Savings of fossil fuels by the utilisation of waste heat from the CHP plant can lead to important savings of the overall LCA result. If all possible reduction potentials are used, biogas causes just minimal ecological effects.