Economic and Environmental System Analysis of a Biogas Plant

Sebastian Gollnow, Torsten Rehl and Enno Bahrs[1]

Abstract **– The paper assesses the environmental and economic benefits of a biogas combined heat and power plant. The system is analysed using GHG abatement cost methodology based on a life cycle approach. A system analysis was performed to identify the marginal implications on the total market system. The study's focus was to identify the major driver for competitive GHG abatement. The investigated plant produces 4.5 MWh of electricity and 1.7 MWh of thermal energy per year. Agricultural wastes as well as energy crops are used as substrates. First results show the big potential of by-products (mainly thermal energy) to minimise abatement costs and improve the GWP profile of the plant concept.**

INTRODUCTION

Anaerobic digestion is a specific combined biological-technological system fulfilling different functions at the same time such as reduction of greenhouse gas impacts, production of energy or disposal of organic materials. However, more and more discussions arise about the cost efficiency of single technologies to reduce GHG emissions. Therefore the objective of this study was to analyse the procedure of abatement cost calculation for biogas plants and to identify key drivers.

In a first step a consequential life cycle assessment was conducted for an existing biogas based combined heat and power plant (CHP). The analysis includes both the direct environmental effects of replacing various energy carriers and energy systems and indirect effects of a changed handling of raw materials e.g. waste management and farming practices.

Based on the Life Cycle Assessment (LCA) results abatement cost for GHG emissions are estimated for two scenarios. The first scenario assumes that thermal energy cannot be utilised and electricity is the main output. The second scenario assumes that thermal energy is supplied to households and replaces fossil heating systems.

METHODOLOGY

The analysis is based on the LCA guidelines of the methodology according to DIN EN ISO 14040:2006/14044:2006 standards.

Data administration, classification, characterisation and analysis are done with the GaBi 4.4 software. The CML method was used for the impact assessment as well as to identify hot spots within the life cycle.

System expansion is used to allocate environmental burdens of by products. The functional unit (FU) for a biogas plant is defined as a one year plant operation as specified in Tables 1, 2.

DATA COLLECTION

Data were collected at an already established biogas system nearby Stuttgart in the south west of Germany. Data on emissions originating from the exploration, refining and combustion of fuels in tractors and trucks were taken from the GaBi database (Eyerer, 2006), GEMIS (Fritsche, 2006) and Ecoinvent (Frischknecht 2003) while data on emissions from manure, digestate management, composting, energy crop cultivation etc. were estimated based on data from the national inventory report (Dämmgen 2010).

SYSTEM SPECIFICATION

The biogas plant is characterised by the plant operation data shown in Table 1. It uses one-stage digestion technology operating at mesophilic temperatures. The CHP under investigation produces 4.5 MWh of electricity and 1.7 MWh of thermal energy per year.

Table 1. Biogas plant operation data.

Parameter	Unit	Value
Digester size	m³	3,500
Electrical power	KW	625
Thermal power	KW	700
Electrical power supplied	kWh/yr	4,500,000
Thermal power supplied	kWh/yr	1,700,00

The biogas plant is fuelled with agricultural by-products (liquid manure from dairy cattle), corn silage and waste from industrial food production (Table 2). Corn silage is produced on nearby farms.

Table 2. Input substrates of the investigated biogas plant.

Substrate	Unit	Value
Corn silage	t/yr	9,700
Liquid manure	t/yr	6,500
Agricultural wastes	t/yr	780

[1] University of Hohenheim, Department of Farm Management, Germany (s.gollnow@uni-hohenheim.de).

PE INTERNATIONAL, Consulting company, Leinfelden Echterdingen, Germany (t.rehl@pe-international.com)

University of Hohenheim, Department of Farm Management, Germany (bahrs@uni-hohenheim.de).

The electrical energy produced is supplied to the national grid. The thermal energy is fed into a distribution network and supplies public buildings, a swimming pool and houses in a nearby village. Consequences occurring due to the introduction of the biogas plant are analysed as well (Fig. 1). With this biogas plant it is no longer necessary to use an open slurry tank for liquid manure and the composting of the agricultural waste is avoided.

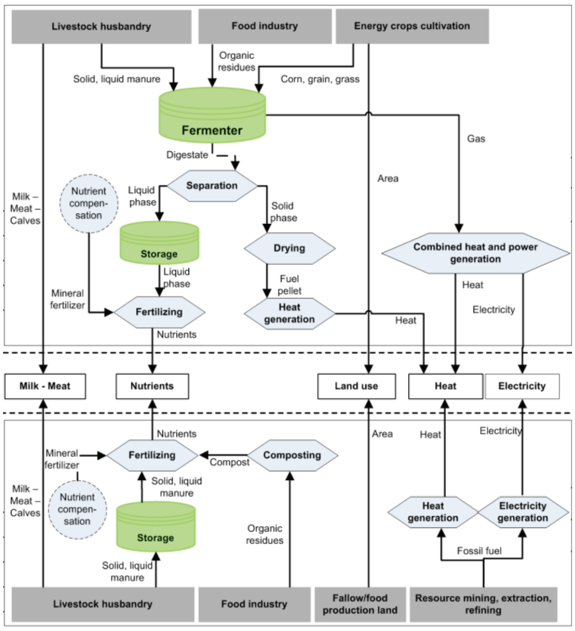

Figure 1. Biogas system and its interactions with other systems.

Results

It has turned out that in comparison to the replaced reference system the biogas system considerably reduces emissions of GHG emissions. In a first estimation on abatement costs it can be concluded, that an efficient utilisation of thermal energy can considerably decrease GHG abatement costs.

Costs for the provision of one kWh electricity (el.) from the national grid are 0.06 € and for one kWh thermal (th.) energy 0,10 € (WBGU, 2008). The costs for the provision of one kWh el. from the biogas plant are 0.18 €. Thermal energy is seen as a by product and therefore all costs are allocated to the electricity output. The CHP plant provides 0.377 kWh th. per 1 kWh el. produced. Figure 2 illustrates that the biogas plant production costs for 1 kWh el. are 0.12 € higher compared to the reference system. If thermal energy is utilised, costs for energy provided by the CHP are 0.08 € higher than for the reference system.

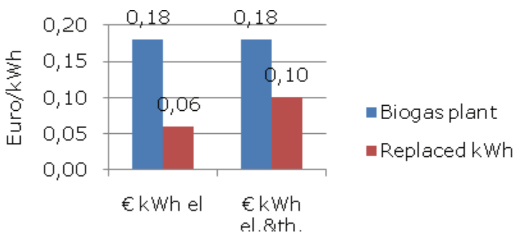

Figure 2. Comparison of cost related to the production of 1 kWh el. and 1 kWh plus 0.377 kWh th.

Figure 3 shows that the biogas plant saves 0.64 (scenario 1) and 0.74 kg CO_2 e per kWh (scenario 2) compared to the reference system.

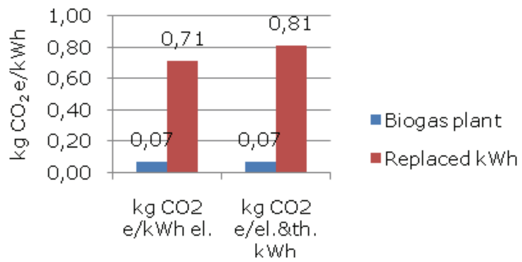

Figure 3. Comparison of energy related GHG emissions for scenario 1 and 2.

GHG abatement costs for scenario 1 (only electricity is utilised) are 188 € per ton of CO_2 e mitigated. For scenario 2 the abatement costs are 58% lower. The abatement of one ton of CO_2 e costs 108 €.
It can be concluded that the utilisation of by-products is a key aspect for economical feasible GHG mitigation.

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