Project no. **SES6-CT-2004-502824**

Project acronym: **CROPGEN**

Project title: **Renewable energy from crops and agrowastes**

Instrument: Specific Targeted Research Project

Thematic Priority: SUSTDEV: Sustainable Energy Systems

D23: Cost-benefit analysis to determine whether farm energy production can lead to measurable advantages in the longer-term productivity cycle

Due date of deliverable: Month 36

Actual submission date: Month 36

Start date of project: 01/03/2004 Duration: 39 months

Organisation name of lead contractor for this deliverable

University of Vienna (BOKU-IFA)

Revision [0]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

D23: Cost-benefit analysis to determine whether farm energy production can lead to measurable advantages in the longer-term productivity cycle

Introduction

The production of biogas from crops involves a range of costs that include: crop production, capital investments, and expenses for the operation of the anaerobic digestion plant and associated fuel processing facilities. As with most commercial applications the implementation of this technology will only take place when there is a sufficient number of benefits. Income from the process can be derived from a number of sources and in particular the prices that can be realised by selling the energy. There are, however, also other benefits of the process including the use of agricultural by-products like manures and harvest residues, which are in many cases regarded as wastes and can now be used as valuable substrate. The digestate obtained as an end-product of the process along with the biogas can serve as a valuable bio-fertiliser which can be sold or used within the crop production process to replace mineral fertiliser and therefore reducing the costs of crop production.

This report will identify costs that are generated by the anaerobic digestion of energy crops and will assess the benefits that can be obtained.

Costs related to the anaerobic digestion of energy crops

Crop production costs have been clearly identified and laid out in detail in a number of publications including KTBL (2002) and Nix *et al.* (2004). There is, however, little data available relating specifically to crop based anaerobic digesters. The data presented here have been obtained by a study on Austrian biogas plants that has been conducted by IFA-Tulln. The whole set of data is also published elsewhere (Laaber *et al.*, 2007). Austria and Germany are the countries where anaerobic digestion of energy crops is most widely used so it appears to be reasonable to assume that these values are representative for a technology that is already implemented. However, new developments in process design and the realisation of the technology on a wide range also in other European countries could lead to a further reduction in costs.

Substrate costs:

For energy crops determination of the production costs varies according to the crop and circumstances of the farm and farmer under which they are produced. The greatest costs can be assumed based on rented land and all crop operations conducted by contractors. Examples of crop production costs are shown in Table 1. Contract costs include equipment, labour and fuel. Variable costs include seed, fertiliser and sprays. Total costs include land rental.

Table 1: Crop production costs

costs	contract costs €/ha	variable costs €/ha	total €/ha	total €/tonne dry matter
maize	499	329	1098	91.5
grass (yr1)	414	197	881	
grass (yr2,3)	736	183	1188	
grass 3 yr av			1086	98.7
beet	542	540	1352	84.5
triticale	450	273	993	70.9

Crop production costs therefore vary between €66 and €98 per tonne of dry matter. A digester will require approximately 11,000 tonnes of fresh crop material (e.g.maize) to produce enough methane to fuel a 500kW$_{electricity}$ generator, producing 4,161 MWh per year. This would require 275 ha of maize costing €301,950. This is equivalent to 378 kWh per tonne, 7.3 ct/kWh$_{el}$ which agrees with the IFA-Tulln values of between 4.7 and 7.4 ct/kWh$_{el}$ calculated for a range of crop based anaerobic digestion plants in Austria (Laaber et al., 2007). Manures and other by-products that are generated at the farm have no substrate costs. When wastes are used as co-substrate it is possible to increase the profit by gate fees, however, in most countries where green electricity is subsidised, the subsidies are lost or reduced when industrial wastes are used as co-substrate. For large plants the costs are usually higher than for smaller plants. Smaller plants usually use higher amounts of manure as co-substrate and are able to produce the required amount of substrates on their own fields. Larger plants very often have to buy additional substrate and distances for transport are higher.

Investment costs:

For anaerobic digestion plants that use energy crops as the main substrate, investment costs are between 3 000 and 5 000 €/kW$_{electricity}$ (Laaber et al., 2007). These values refer to typical plants as they are built in Austria and Germany, which consist of a two stage digester and a final storage tank and where the biogas is used to produce electricity. The variation in investment costs is very much dependent on the technology that is used to realise the plant. The prices for components like feeders, stirrers, CHP, etc. and materials (concrete, steel) may also vary according to the demand. Thus at 3500 €/kW$_{electricity}$ a 500kWelectricity plant will cost approximately €1.75 million.
A simplified model for determining the capital costs for a digester system is shown in Figure 1.

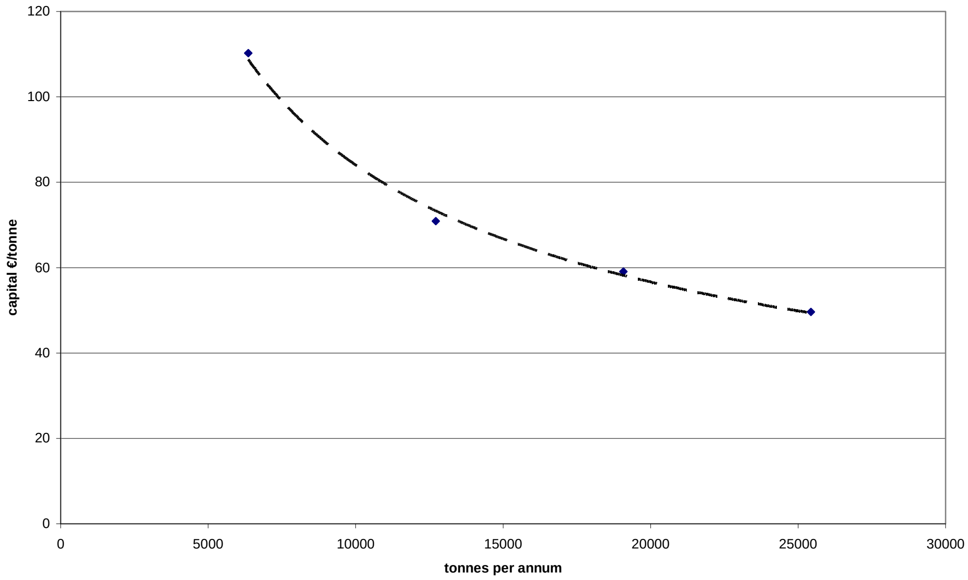

Figure 1: Models for digester capital costs

The cost of the digester is determined by the amount of substrate to be processed which will affect the size of the digester. The amount of substrate can be calculated from either the capacity of the farm to produce material (according to its area) or in the case of CHP by the required electrical output from the CHP. For the above example of 11,000 tonnes treated, the capital cost of the digester can be taken as € 1.006 million. The capital cost for a CHP unit supplying 500 kW$_{electricity}$ is assumed to be € 546840 (Murphy and McCarthy, 2005). Thus the total installation cost is approximately €1.55 million.

Cost of operation:

The operational costs are in the range between 2.0 and 4.5 ct/kWh$_{el}$. These costs include maintenance of the CHP (10-40%), labour costs (15-40%), maintenance and repair of the biogas plant (10-15%), insurance (8%), other utilities (10-15%) (Laaber et al., 2007).

Cost benefit analysis

For an anaerobic digester producing enough biogas to supply a combined heat and power unit producing 500kW$_{electricity}$. The CHP unit is assumed to run for 95% of the time (allowing for maintenance and repair) and has an electrical production efficiency of 32%. The value of the electricity is taken as that for the Austrian tariff for CHP units up to 500kW$_{el}$ of 14.5 ct/kWh$_{el}$. A cost analysis for these criteria is shown in Table 2.

Table 2: Cost benefit analysis for 500 kW$_{el}$ digester using energy crop.

crop: maize	11,000 tonnes FM	
	275 ha at €1098 / ha	€302,000 / year
digester	500 kW	
investment	3,500 €/kW	€1,750,000
	25 year life span	€70,000 / year
cost of operation	4,161,000 kWh$_{el}$	
	3.25 ct/kWh$_{el}$	€135,232 / year
total		**€507,232 / year**
electricity produced	4,161,000 kWh$_{el}$	
	14.5 ct/kWh$_{el}$	**€603,345 / year**

Using the above model, Table 2 indicates that the operator would make €96,113 profit per year from the sale of the electricity. Plant operators can further enhance their income by selling some of the heat, although this tends to be limited unless the digester can be placed close to new housing or industrial units with a demand for heat. If 10% of the fuel energy to the CHP can be recovered and sold as heat then 1,387,000 kWh$_{heat}$ is available. At 4ct/kWh$_{heat}$, this would generate €55,480 per year additional to the electricity. The sale of heat is therefore of significance in the economics of the digester.

A way to reduce crop production costs is to use the digestate as bio-fertiliser. The average price for fertiliser is €219 per tonne (Nix et al., 2004, KTBL, 2002). If maize requires 125kg Nitrogen per hectare and the fertiliser contains 25% nitrogen then 0.5tonne of fertiliser is applied per hectare (at a cost of €109.5/ha). If digestate replaces 75% of the mineral nitrogen requirement then the crop requires only 125kg/ha of fertiliser (costing €27.38/ha), a saving of €82.125 per hectare. This would be equivalent to a reduction of €29072.25 in the crop production costs in the above example.

Benefits related to the anaerobic digestion of energy crops

Benefits are mainly dependent on how the energy can be used. In countries like Austria and Germany guaranteed feed-in tariffs for electricity over a period of up to 20 years have resulted in a large increase of biogas plants in the past years. The efficiency and economic viability of the plants, especially for larger plants in rural areas may be limited if there is no demand for the surplus heat. According to Laaber et al. (2007) economies of scale are of minor importance when the plant size is larger than 250 kW_{el}. On the other hand a centralised system could be more efficient if further cost intensive upgrading of the biogas e.g. for car fuels or for feed in into the natural gas grid is considered. Further examples of socio-economic impacts are given in deliverable **D30b**, as is a comparison of crop based anaerobic digestion with other farm related activities.

Literature

Laaber, M., Madlehner, R., Brachtl, E., Kirchmayr, R. and Braun, R. (2007). Aufbau eines Bewertungssystems für Biogasanlagen - „Gütesiegel Biogas“. Final Report.

KTBL (2002) Betriebsplanung Landwirtschaft 2002/2003. Darmstadt, Kuratorium für \technik und Bauwesen in der Landwirtschaft e.V.

Laaber, M., Madlehner, R., Brachtl, E., Kirchmayr, R. & Braun, R. (2007) Aufbau eines Bewertungssystems für Biogasanlagen - "Gütesiegel Biogas“. Tulln, Austria, Universität für Bodenkultur Wien Interuniversitäres Department für Agrarbiotechnologie, IFA-Tulln Institut für Umweltbiotechnologie.

Murphy, J. D. & Mccarthy, K. (2005) The optimal production of biogas for use as a transport fuel in Ireland. *Renewable Energy,* 30**,** 2111-2127.

Nix, J., Hill, P. & Edwards, A. (2004) *Farm Management Pocketbook,* London, The Andersons Centre.