Socio-economic Analysis of Centralised Biogas Plants

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ABSTRACT: The development of biogas technology in Denmark has been widely encouraged by the government over the last 15 years. The overall reasons for the government concern has been the increasing awareness that centralised biogas plants make a significant contribution to solve a range of problems in the fields of energy, agriculture and environment. This has been documented through related monitoring and R & D activities. To achieve a satisfactory evaluation of centralised biogas plants, a thorough socio – economic analysis is required. Such investigation has been accomplished, and the results are presented in this summary.

1. Introduction

The work had three main objectives. Firstly, to establish a base of analysis corresponding to new centralised biogas plants under favourable conditions and equipped with best-known technology. Secondly, to carry out corporate economic analysis based on this, and thirdly, to carry out a comprehensive socio-economic analysis where as many derived effects, positive as well as negative, were quantified.

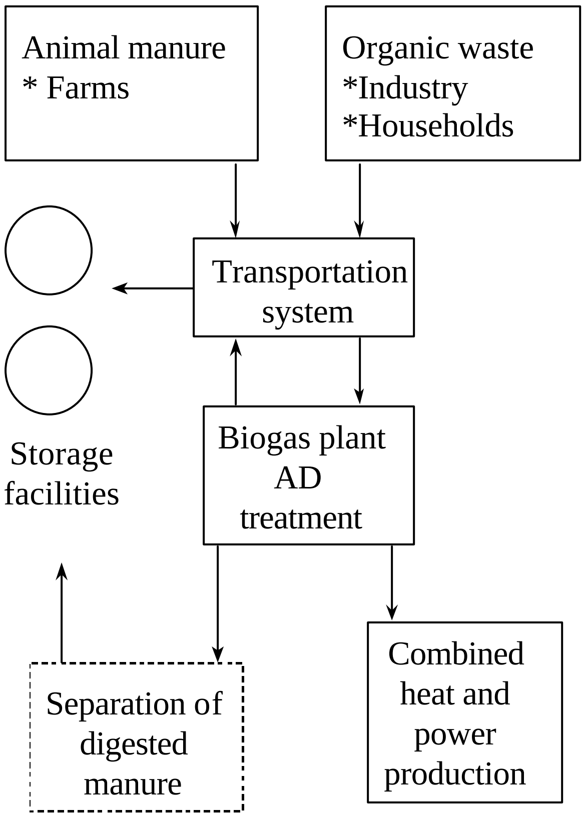
A centralised biogas plant is an installation that receives animal manure from a number of farmers and organic waste from food processing industries for anaerobic treatment. From the anaerobic digestion process biogas emerges, which is converted into heat and power.

The digested biomass is returned into storage tanks at the farms or near the fields where it is finally utilised as a fertiliser.
Most Danish plants are cooperatives owned by farmers or farmers and heat consumers.

In normal situations farmers neither pay nor withdraw profits from the biogas companies. But they benefit from cost savings in manure handling and fertiliser purchase as a derived effect from the operation of the plants.

Gate fees from the receipt of organic waste and energy sales serve to cover costs in manure transportation and plant operation. Biogas plants in Denmark benefit from tax exemption on heat sale and an electricity production grant of 0.27 DKK/kWh, which is anticipated as crucial to economic feasibility under Danish conditions. Figure 1. shows the structure of the centralised biogas plant concept.

Figure 1. Centralised biogas plant concept



2. Corporate economic analysis

The main focus has been on clarifying possible economy of scale and to identify break-even points for a number of key parameters.

The analysis included three plant sizes with per day treatment capacities of 300, 550 and 800 m^3 biomass. In Table 2.1 investment and production costs are presented for the mentioned plant categories. Figures are presented per m^3 biomass treated per year.

Table 2.1. Investment and production costs			
Per day treatment capacity, m^3	300	550	800
Investment costs DKK per m^3 biomass treated per year	405	325	272
Production costs			
-Transport	16	16	18
-Biogas plant	53	41	35
DKK per m^3 biomass treated per year	69	57	53

It appears from Table 2.1 that considerable economy of scale was found in investment costs and in production costs in the biogas plant itself. In transportation costs, the effect was found to be slightly negative, as transportation distances increase, when the amount of biomass treated is expanded.

All existing centralised biogas plants in Denmark receive industrial organic waste in order to increase biogas production. It is generally accepted that the admixture of waste is crucial to economic feasibility of the plants. Table 2.2 shows the break-even points of waste admixture and biogas yield based on Danish conditions.

Key preconditions for the calculations

Gas yield from organic waste:	75 m^3 biogas per m^3 waste
Slurry	22 m^3 biogas per m^3 slurry
Biogas sales price	2 DKK per m^3 biogas (0,27 €)
Investment grants	0 %

Table 2.2. Break-even levels of waste admixture and biogas yields			
Per day treatment capacity, m^3	300	550	800
Break even level of waste admixture, %	21	13	10
Break even biogas yield, m^3 biogas / m^3 biomass	34	27	25

The variation in the break even level of waste admixture and biogas yield level reflect the above-mentioned economy of scale. The table also shows that a plant based solely on manure will not be economically feasible under Danish conditions, as the level of biogas production will not correspond to the costs of running the plant.

2.1. Corporate Economic Conclusions

Centralised Biogas plants are economically feasible under Danish preconditions without investment grants if gas yields of 25-34 m^3 biogas per m^3 biomass treated are obtained. These levels can normally be achieved by waste admixing rates of 10-21 % of total biomass amount treated. The specific waste ratio required depends on the treatment capacity of the plant, as considerable economy of scale has been found. The analysis has not given evidence that biogas production based solely on liquid manure is economically feasible under Danish preconditions. Calculations indicate that a treatment fee of 14 DKK/m^3 manure would balance economy, if paid by the farmers, and no organic waste was supplied.

3. Socio – economic analysis

As mentioned Danish Plants benefit from tax exemption and production grants. In the socio economic analysis this must be excluded. That explains why one plant scenario may be feasible in the corporate economic analysis, and not feasible in the socio-economic analysis. Conventional economic analyses and corporate investment analyses of projects do not take into proper account so-called externalities. Externalities or external effects do neither imply expense nor income elements for the corporate or private investor. However, externalities are important economic effects seen from a welfare-economic point of view, and in socio-economic analyses, since these derived costs or benefits will accrue to some members of the society.

The socio economic analysis looks at the project or activity in question from the point of view of the society in its entirety. A project may inflict burdens or contribute gains for the society e.g. concerning employment, pollution of the environment etc. relative to the reference activity or a 'business as usual' situation, which must be taken into account when evaluating a project from the point of view of the society. Many actors and sectors in the economy may be influenced from the project. Including such consequences in the welfare economic analysis is important.

Biogas projects have implications not only in the agricultural sector, but in the industrial and energy sectors as well, and among the environmental consequences, mitigation of pollution, green house gas (GHG) emission reduction and reduced eutrophication of ground water etc. are important external effects.

3.1. Approach

The present socio-economic analysis is carried out at different levels, where the levels in succession take into account still further of the external effects related to the biogas scheme. Four levels have been chosen for the analysis. Termed Result 0,1,2,3 these differ according to which socio-economic elements and externalities that are included in the analysis:

Analyses at higher levels include all effects from lower levels. This hierarchy is shown in table 3.1 below.

Table 3.1. Socio-economic aspects included split on levels (termed Result 0,1,2,3) of the analysis

Socio-economic analysis of biogas plants Level of analysis	Res. 0	Res. 1	Res. 2	Res. 3
Aspects included:				
Energy and resources:				
Value of energy production (Biogas, electricity)	R0	R0	R0	R0
Capacity savings related to the natural gas grid	R0	R0	R0	R0
Environment				
Value of GHG reduction (CO^2, CH_4, N^2O-reduction)			R2	R2
Savings related to organic Waste treatment		R1	R1	R1
Value of reduced N-eutrophication of ground water			R2	R2
Agriculture				
Storage, handling and distribution of liquid manure		R1	R1	R1
Value of improved fertiliser value		R1	R1	R1
Value of reduced obnoxious smells				R3
Investments and O&M-costs				
Investments. Biogas Plants	R0	R0	R0	R0
O & M of Biogas Plants, incl. CHP units for process heat	R0	R0	R0	R0
Investments and O & M for liquid manure transport	R0	R0	R0	R0

O& M = Operation and maintenance.

As seen from table 3.1 "Result 0" do not include externalities in the socio-economic analysis, and benefits concern the energy production from the plant only. Analyses at the higher levels, however, take externalities into account, and further cost and benefit elements enter the analysis. Thus, the socio-economic levels of analysis are characterised by:

- *Result 0*: Energy production (biogas and electricity) from biogas plants. Externalities are not included.
- *Result 1*: Benefits in agriculture and industry are added to the analysis.
- *Result 2*: Environmental externalities concerning GHG emission (CO_2, CH_4, N_2O-emission) and N-eutrophication of ground water are furthermore included.
- *Result 3*: A monetised value of reduced obnoxious smells from digested biomass is moreover included in the socio-economic analysis.

The aspects included in table 3.1 are quantified for the analysis. Considerable effort has been put into the assessment of the biogas scheme externalities. However, important further external effects have not been quantified and monetised for the analysis due to lack of data. Among such aspects can be mentioned:

- Increased flexibility in agriculture and options for extending production at farms associated to biogas plants.
- Effect for the security of energy supplies.
- Veterinary aspects are not well documented.
- Employment effects and effects for the trades and industries.

3.2. Monetised externalities

Expressed in specific units (DKK/ton of biomass) monetised externalities included in the analysis are shown in table 3.2. The results shown apply for the biogas plant outlined for a treatment capacity of 550 ton/day.

Table 3.2. Monetised externalities

Monetised externalities: Socio-economic value per ton biomass	Biogas plant size: 550 ton/day (20% waste)
Agriculture	***Monetised***
Storage, handling and distribution on liquid manure.	
Storage savings for liquid manure	1.00 DKK/ton liquid manure
Transport savings in agriculture	0.50 DKK/ton liquid manure
Value of improved fertiliser value	5.41 DKK/ton treated
Value of reduced obnoxious smells	5.00 DKK/ton liquid manure
Industry	
Savings related to organic waste treatment	125 DKK/ton org. waste
Environment	
Value of GHG reduction (CO_2, CH_4, N_2O-reduction)	22.38 DKK/ton treated
Value of reduced N-eutrophication of ground water:	2.92 DKK/ton treated
Liquid manure	2.77 DKK/ton liquid manure
Org. waste spread on farm land in reference case	12.19 DKK/ton org. waste
Org. waste not spread on farm land in reference case	-22.50 DKK/ton org. waste

A quantification for the 550 ton/day biogas plant of the monetised externalities is shown in table 3.3. The table shows the annual costs and benefits taken into account at the four levels of the socio-economic analysis. A socio-economic rate of calculation of 6% p.a. has been used, and the analysis covers the period 2001-2020. Values shown are in year 2000 price level. (1€ = 7.43 DKK).

It is seen in table 3.3 that the biogas scheme is not attractive under Result 0, where it has been assumed that benefits only concern energy production from the plant. Result 0 shows a socio-economic deficit of about 6.6 mio. DKK/year. However, taking into account agricultural benefits, and industry cost savings in waste disposal Result 1 shows socio-economic break-even. If the described environmental benefits (GHG emission reduction and reduced N-eutrophication of ground water) furthermore are included, result 2 shows a surplus of about 5.1 mio. DKK/year.

And including the value assumed for reduced obnoxious smells from liquid manure on fields relative to the reference the socio-economic surplus add up to about 5.8 mio. DKK/year. Thus from an extended socio-economic point of view, under Result 3 assumptions, the biogas scheme is highly attractive.

Table 3.3. Annual costs and benefits. Results based on biogas plant outlined for treatment of 550 ton per day				
Socio-econonic results *Annual costs and benefits*	Biogas plants size: 550 ton/day (20 % waste)			
Costs (levellised annuity)	Res. 0	Res. 1	Res. 2	Res. 3
		Mio. DKK/year		
Investments:				
Biogas production/ biogas plant	5.409	5.409	5.409	5.409
Transport material	0.876	0.876	0.876	0.876
Operation and maintenance:				
Biogas production/biogas plant	4.521	4.521	4.521	4.521
Transport material	0.195	0.195	0.195	0.195
Total	**11.001**	**11.001**	**11.001**	**11.001**
Benefits (levellised annuity	Res. 0	Res. 1	Res.2	Res.3
Energy production:				
Biogas sales	3.910	3.910	3.910	3.910
Electricity sales	0.456	0.456	0.456	0.456
Agriculture:				
Storage, handling and distribution of liquid manure		0.241	0.241	0.241
Value of improved manurial value		1.379	1.379	1.379
Value of reduced obnoxious smells				0.723
Industry:				
Savings related to organic waste treatment		5.019	5.019	5.019
Environment:				
Value of GHG reduction (CO_2, CH_4, N_2O-reduction)			4.492	4.492
Value of reduced N-eutrophication of ground water:			0.586	0.586
Total	**4.366**	**11.004**	**16.083**	**16.806**
	Res. 0	Res. 1	Res. 2	Res.3
		Mio. DKK/year		
Difference as annuity:				
Benefits –costs	**-6.635**	**0.003**	**5.082**	**5.805**

3.3. GHG emission reduction costs

In the present analysis GHG emission reduction has been assigned the external value of 250 DKK/ ton CO_2 equivalent reduced (33.6 €/ton CO_2 equivalent). Such value has been used in a recent study by the Danish Energy Administration. A recent EC report[1] concerning CO_2 capture and sequestration mention as short term aim reduction costs below 30 €/ ton CO_2, and 20 €/ ton CO_2 as a long term aim.

Monetising the value of CO_2 reduction is very difficult and considerable uncertain. This is e.g. reflected by results from the very comprehensive EU-project, ExternE, that express the interval of 32-1173 DKK/ton CO_2 for the *damage costs* due to CO_2 emission. In the present socio-economic analysis, therefore, the CO_2 *reduction costs* achievable via utilising biogas plants are calculated for comparison.

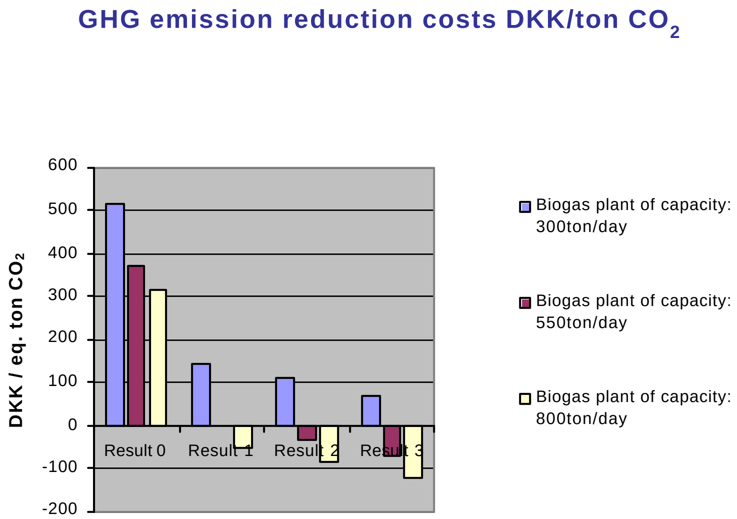
The CO_2 reduction cost calculated and presented below for biogas schemes makes the alternative, the biogas scheme, break-even with the reference situation. Thus, if a calculated equivalent CO_2 reduction cost is below the former assumption of 250 DKK/ ton CO_2 equivalent reduced, the biogas project, of course, is attractive according to the previous assumptions. Results of the socio-economic analysis

[1] European Commission: Future needs and challenges for Non-Nuclear Energy Research in the European Union. Discussion paper. February 2002.

expressed by this key-number allow decision-makers to interpret results based on diverse CO_2 reduction cost aims.

To illustrate economy of scale concerning the size of plants, results of the socio-economic analysis of the biogas plants described in table 2.1 are shown in Figure 3.1.. The figure presents equivalent CO_2 reduction costs achievable via biogas plants with the treatment capacities 300, 550 and 800 ton biomass per day.

Figure 3.1. Socio-economic GHG reduction cost achievable from biogas plants outlined for treatment capacities of 300, 550 and 800 ton per day



From Figure 3.1 it is seen that GHG reduction costs based on Result 0 assumptions are in the order of magnitude of 400 DKK/ton CO_2 equivalent. The economy of scale shows gains for larger plants, indicating that the increased transport costs and transport fuel consumption for the larger plants are counterbalanced by the overall benefits.

All three plants become attractive based on Result 1 assumptions, due to GHG reduction costs below 250 DKK/ton CO_2 equivalent. Result 1, 2 and 3 show socio-economic GHG reduction costs below zero. Thus showing, that biogas projects may contribute important GHG reduction while concurrently generate considerable socio-economic gains.

3.4. Main conclusions

The main conclusions of the socio-economic analysis of centralised biogas plant are:

- Based on Result 0 assumptions, none of the plants are attractive. Thus, the socio-economic value of the energy production, covering a 20 year period, cannot justify the deployment of biogas plants.

- However, based on Result 1 assumptions, where agricultural benefits and benefits in industry concerning treatment of organic waste are included in the socio-economic analysis, this picture changes, and in particular larger plants are favourable for the society at large.
- If furthermore the benefits environmental externalities are taken into account (Results 2 and 3) the utilisation of biogas plants in the configurations considered becomes very attractive from the socio-economic point of view.

A further result is, that admixture of organic waste from industry is very important both for the corporate economy and for the socio-economic result. For the socio-economic result, admixture of organic waste contribute important combined benefits concerning e.g. increased production of biogas and energy sales, savings related to organic waste treatment, improved fertiliser value (NPK) and increased CO_2 reduction.

As mentioned already, a number of aspects relevant for the socio-economic analysis have not been included in the analysis, due to lack of data. These aspects would mainly contribute positive effects for the socio-economic analysis, however some negative veterinary effects may include socio-economic cost elements.

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