THE ECONOMICS OF BIOGAS IN DENMARK – A FARM AND SOCITAL ECONOMIC PERSPECTIVE

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Abstract

Denmark has been one of the leading European Countries in using Biogas for Combined Heat and Power (CHP), since the 1980'ties. However, in the last two decades, the increase has been limited. A new energy policy aimed at increasing the profitability of Biogas was introduced in the spring of 2012. The analysis here shows that the new agreement will improve the profitability of biogas plants and increase the biogas production although the political ambition of an increase from 4 PJ to 14 PJ by 2020 seems unlikely. The analysis shows that biogas plants can be profitable even if the input is a mix of manure and solid fractions/farm yard manure given the present level of support. The analyses show that although maize increases the gas output somewhat, it increases the profit only slightly as the costs of the input is high (41€ per tonne). The overall production costs are around 0.53 € per m3 methane. Even without an investment subsidy of 30%, the case 2012, is profitable. Financing the biogas plants is a challenge. The interest used of 4.25% requires bank guaranties which in practice can be hard to get. Using a more likely interest of 7-8% reduces the yearly profit to 400.000 €. The socioeconomic analyses show that the costs of biogas as a measure to reduce CO2 emissions, are around 135 € per tonne CO2 and using maize is an expensive way to reduce emissions of CO_2 as the CO2 reducing effect is limited. The new Danish energy agreement gives subsidies to biogas used in the natural gas grid. The upgrading, including pressure adjustment, is 0.16 € per m3 methane. The analysis shows that the profit from upgrading biogas is only to be preferred if the sales prices of heat are very low. The socioeconomic cost of upgrading is, in most cases, not better than CPH. In order to reduce the cost of reducing CO2 emissions, the input to the biogas plant has to be based on farm yard manure and deep bedding as well as slurry.

Keywords: biogas, economics, upgrading biogas, cost of CO_2 reduction, environment

1. Introduction

The EU targets on renewable energy, which biogas production contributes to realize, are established to reduce EU's dependence on fossil fuels and to mitigate the climate changes. Denmark is obligated, by 2020, to decrease its total GHG emissions by 20% in the non-ETS quota sectors (housing, transport and agriculture), compared to 2005 emission levels, and to increase its share of renewable energy in the Danish energy supply system to 30% (Council Directive 2009/28/EC), (Council Decision No 406/2009/EC). Along with several initiatives, the Danish politicians made a "Green Growth" agreement in 2009, stating that up to 50% of all Danish manure should be utilized in a biogas plant by the year 2020.

Currently (2012) only 8% of the manure produced in Denmark is used for energy purposes, which puts the need for expansion of the Danish biogas production in perspective (Olesen et al., 2012). The majority of the Danish centralized biogas plants were built in the period 1987-1996, and approximately 20 of these plants are still operative today. Alongside this development, around 60 smaller farm scale biogas plants were established, who are responsible of the small but constant increase in Danish biogas production from the mid 90'ties until now. The energy from manure-based biogas production has doubled from 1.5 PJ/year in the year 2000 to 3.0 PJ/year in 2010, which is most of the total Danish biogas production of 4.2 PJ per year (Energistyrelsen, 2010).

The new Danish energy agreement was implemented in the spring, 2012. To promote the utilization of Danish manure to energy purposes, the governmental support for biogas-based energy was increased from 0.380 €/Nm³ methane to 0.497 €/Nm³ methane, under the condition that the biomass input consists of at least 75% manure. Furthermore, it became possible to get a subsidy for injection of biogas into the natural gas grid. Finally, to kick-start the production, an investment subsidy of 30% was given to a number of biogas plant projects in 2012. The higher governmental support, the high investment subsidy, and increased production and sales opportunities have together improved the regulatory framework and the potential income in the Danish biogas sector.

The purpose of the paper is to analyse whether the new energy deal makes Danish biogas profitable from a company perspective. What are the conditions for profitability in terms of input, price, subsidy and use of maize and etc. Will the price conditions in the new energy agreement be enough to boost biogas production in Denmark to fulfill the political ambitions? Is the new option to sell biogas to be upgraded as a profitable option? Looking at the socioeconomic perspective, is biogas a cost effective option is that also the case when it is based on maize or when only part of the heat is used? Compared to Germany the Danish biogas subsidy been too low or is it the German subsidy level which is too high?

The paper discusses the different methods used to achieve high degrees of biogas and green energy, but also the need to include both company and socio economic analyses in the assessment.

2. Danish biogas

The new Danish energy agreement has increased the value of biogas. As table 1 illustrates, the governmental support for Danish biogas has increased by approximately 30% compared to the old energy agreement. The table, furthermore, illustrates the natural gas price, the extra costs related to upgrading the biogas to natural gas quality, the values of unused quotas, and a possible green value of biogas.

Table 1. Energy price (old and new agreement)

Item	Old energy agreement, CHP (€/Nm³ methane)	New energy agreement CHP (€/Nm³ methane)	New energy agreement, natural gas grid (€/Nm³ methane)
Governmental subsidy	0.380	0.497	0.497
Natural gas price	0.312	0.312	0.312
- Upgrading costs	0	0	0.168
(Quota value)	0	0	(0.048)
(Green value)	0	0	(?)
Total	0.692	0.810	0.642

Source: Tafdrup, 2012; KEMIN, 2012

As mentioned, table 1 also illustrates a quota value in relation to biogas on the natural gas grid. This value is not a reality yet, but a certificate system has been implemented in the Danish natural gas grid, so consumers are able to buy the CO_2-neutral biogas instead of the standard natural gas. If the price becomes equivalent to the CO_2 quota price (20€ / tonne), it would be equivalent to a price of 0.048 €/Nm3 methane. The table finally contains a green value, which is the value companies / consumers are willing to pay for the CO_2-neutral energy in order to improve the companies green image.

The change in the regulatory framework, providing the possibilities for upgrading biogas to natural gas quality and injecting it into the natural gas grid, has a huge effect on the sales possibilities of biogas. Earlier, the biogas producers were forced to sell their biogas to the local CHP plant, and with no alternative buyer, a relative low price on biogas was standard. With the new energy agreement, the biogas producers have an alternative buyer, which improves their situation when negotiating energy prices. The change, furthermore, enables a production of biogas in remote areas far from any CHP plants, which is necessary, if the target of degassing 50% of the Danish manure production is to be realized. In Germany the subsidy related to upgraded biogas is only given if the upgraded biogas used for local CHP production which does limit the use.

With the new energy agreement, an investment subsidy of 30% is available for a biogas plant project, if their application was approved by the end of 2012 and with the building starting in 2013. This has resulted in 42 applications and the approval of support for 19 new biogas projects in Denmark. The plant size ranges between a reactor capacity of 50,000 tons per year for farm scale biogas plants, to larger centralized biogas plants with the capacity to process almost 500,000 tons of biomass per year.

Finally, the ability to boost the biogas production with energy crops, and still be eligible for the governmental support, has also improved the conditions for the biogas producers. After the approving of the new energy agreement, a debate was initiated concerning whether it was wise to subsidize biogas based on energy crops. The concern was that biogas, based on energy crops, does not reduce GHG emissions as efficiently as manure, and that it would not contribute to the realization of the target of degassing 50% of the Danish manure production by 2020. On that foundation, it was agreed to reduce the eligible share of energy crops in the biogas input mix, from 25% in 2012 to 10% towards 2020, and maybe even to 0% in the following years.

3. Analytical framework

The potential for a sustainable biogas production in Denmark does not only depend upon the legislative framework, but there are several other factors also inflict on the economic sustainability of the production. The dry matter content in the Danish manure is one of the most uncertain parameters when estimating the biogas potential for a given biogas plant. This uncertainty exists because the dry matter content varies drastically with the type of manure. The dry matter content in cattle manure is generally the highest, whereas the manure from pigs, especially sow slurry is lower. The standard Danish values for the dry matter content for 2012 are 4.5% for sow slurry, 6.1-6.6% for slaughter pig manure, and 9.3% for cattle (Århus Universitet, 2012). But other estimates show much lower values. The most up-to-date values on the dry matter content in the Danish manure are a bit lower than the standard values. Birkmose et al. (2012) estimate the dry matter content in manure from slaughter pigs to be 5.5 and 4.0% for sow slurry. The dry matter content in cattle slurry is estimated to be 7.5%. It is assumed that it respectively takes 11.5 tons of cattle manure, or 10.8 tons of pig manure to produce 1 ton fiber fraction with a dry matter content of 33%. These are the dry matter contents used in the following estimations. Maize does increase gas production, but payment of 41 € per ton has to be made to the farmers. Increasing crop prices (e.g. wheat) will also increase the maize price which has to be paid (Jacobsen et al., 2013).

Instead of boosting the biogas production with energy crops, the biogas producer could use separated manure to increase the dry matter content in the reactor. The gas potential in separated manure is not as high in relation to its price, compared to that of maize silage. The lower gas potential results in a lower business economic surplus compared to a production where maize silage is applied. But from a welfare economic point of view, the use of separated manure is the best biomass to use, as it also reduces GHG emission, and thereby provide a very low marginal abatement costs (MAC), whereas the MAC from a maize silage-based biogas production has a MAC more than twice as high.

4. Case analysis

The following section describes the 2012 case biogas plant, regarding the plant size, the biomass input mix, the biogas production, and the energy output. It is estimated that a new centralized biogas plant in Denmark, on average, will have a capacity to degas approximately 700 ton biomass per day, which amounts to almost 260,000 ton biomass per year. The biomass input mix is based statements from new and planned Danish biogas plants. The input mix does not provide the highest possible profit for the biogas producer, but it is the most likely combination as the allowed share of maize-silage will be reduced to 10% over the coming years. Furthermore 12% of fiber fraction was added to boost gas production. It is assumed that organic industrial waste is no longer is available for the biogas producers, as it already is fully utilized by the current Danish biogas production. The table below illustrates the capacity of the biogas plant, the shares of different biomasses in the input mix and their dry matter content, along with the total biogas and methane production.

Table 2. Biomass input and production – 2012 case biogas plant

Biomass type	Input amounts	Dry matter content	Methane	Biogas	Methane	Biogas
	(ton/year)	(%)	(1000 Nm3/year)		(Nm3/ton input)	
Cattle manure	86,553	7.5	1,039	1,598	12.0	18.5
Pig manure	112,737	4.9	1,237	1,904	11.0	16.9
Seperated pig manure	17,344	30.0	1,082	1,665	62.4	96.0
Seperated cattle manure	13,316	30.0	831	1,278	62.4	96.0
Maize silage	25,550	33.0	3,182	4,895	124.5	191.6
Extra (serie-operation)	-	-	737	1,134	-	-
Total	255,500	11.5	8,108	12,474	31.7	48.8

Note: The methane yield from maize can sometimes be lower than estimated here
Source: own calculations

A part of the produced biogas is utilized in the engine in the biogas plant as process energy, which receives a governmental subsidy of 10 €/GJ. It is estimated that the process energy is equivalent to approximately 2 m^3 methane per ton biomass input. Furthermore 1% of the biogas is lost through flaring, and 10% of the biogas is lost through lack of demand for biogas-based heat in the summer period. The final amount of biogas available for sale is 6.7 million Nm^3 methane per year. The production in the first year is reduced by 25% as the system is not performing at maximum capacity right from the start.

5. Company results

The standard centralized biogas plant of 250,000 tonnes per day is estimated to have a plant-investment cost of 10.7 million €, followed by additional investment costs in e.g. trucks, land, and pipeline, which bring the total initial investment costs up to 13.2 mill. €. This initial investment cost is then eligible for the governmental support of 30%, which, in this case, is equivalent to almost 4 mill. € in 2012. Besides the initial investments, there will, after 10 years, be a need for reinvestments of approximately 2 million €. The annual maintenance costs are 0.2 million €. A total of three people will be employed with a salary of 0.2 mill € per year.

Finally, there are the transport costs. It is estimated that the new centralized biogas plant will have an average distance to its manure suppliers of 14 km. Few plants have invested in manure pipelines to transport the manure and so the main part of the manure is transported by truck. This is one of the most costly parts of biogas production, especially because the manure mainly consists of water. The annual cost of transporting 200,000 tonne of manure amounts to approximately 0.5 million €.

The interest used is 4,25%, but in many cases, this requires that the farmers can used their farm as collateral for the investment. This can, together with funding from the special credit cooperation (Kommunekredit), give a low interest. In the case that the farmers have low equity and more external capital is needed, it is likely that the average interest would be around 7-8%.

Table 3 presents the costs related to a standard centralized biogas plant with the capacity of 700 ton biomass per day. The biomass, in this example, consists of 78% untreated manure, 12% separated manure, and 10% maize silage. The annual costs over the 20 year plant lifetime, are in this case estimated to be more than 2.8 mill. €. The costs per m3 input and produced gas (not sold) gas production is also shown.

Table 3. Total annual costs for a biogas production

Annual costs	€ pr. year	€ pr. tons input	€ pr. m^3 biogas	€ pr. m^3 methane
Electricity	192,842	0.75	0.02	0.02
Investments	950,099	3.72	0.08	0.12
Reinvestments (year 10)	115,162	0.45	0.01	0.01
Maintenance	217,868	0.85	0.02	0.03
Transport of manure	662,155	2.59	0.05	0.08
Transport of energy crops	318,436	1.25	0.03	0.04
Running costs	372,279	1.46	0.03	0.05
Total	2,828,843	11.07	0.23	0.35

Source: Jacobsen et al., 2013

The income from a standard centralized biogas plant depends on who the buyer is. By selling the biogas to a local CHP plant, the biogas producer will not get paid for approximately 10% of his energy production due to the low demand for heat in the summer period. On the other hand, if the biogas producer chooses to upgrade his biogas for injection into the natural gas grid, extra costs for upgrading the biogas to natural gas quality will appear. In the best case scenario, the centralized biogas plant is situated near a very large CHP plant which has the capacity to receive and sell all the biogas which is produced. If the centralized biogas plant is located far from the nearest local CHP plant instead, it might be more profitable to inject the biogas into the natural gas grid, despite the extra upgrading costs.

Table 4 illustrates the income from the sale of the methane produced at the standard centralized biogas plant. Besides the methane sale, degassing the manure increases its fertilizing value from which the biogas producer also gains an income. Finally, the biogas producer has to buy the energy crop and pay for the separation of the manure which is used to boost the energy production.

Table 4. Total income and costs

Income	€/year	€/tons input	€/m³ biogas	€/m³ methane
Gas sale	5,607,523	21.95	0.45	0.69
Increased fertilizer value	206,777	0.81	0.02	0.03
Purchase of biomass	-1,714,657	-6.71	-0.14	-0.21
Total costs	2,828,843	11.07	0.23	0.35
Total profit	1,270,800	4,97	0,10	0,16

Source: Jacobsen et al., (2013)

As the calculations show in table 4, a centralized biogas plant who sells the biogas to a local CHP plant will gain an annual profit equivalent to 5 € per tons biomass, or 1.3 mill. € per year. When using a higher interest of 7.5% and lower yields from maize the annual profit is 400.000 €per year.

If the centralized biogas plant were to upgrade its biogas and inject it into the natural gas grid, the calculations would be rather different. The income from gas sale would increase by 6% as all the gas is sold, but the additional costs due to the upgrading is assumed to be 0.13 €/Nm^3 methane, equivalent to 4.35 € per ton biomass. In total the profit is a little lower than for the CHP option.

There is a need for approximately 20-30 new biogas plants, besides the existing 20 in order to reach the target of 50% of all the manure produced being used in a biogas plant. This substantial increase of new biogas plants mean that they cannot all be located near a local CHP plant, as the available manure becomes increasingly scarce. Some of the new biogas plants need to be located near the more remotely located farms, where there are no local CHP plants. Therefore, upgrading to natural gas quality and injecting the biogas into the natural gas grid, becomes the only option, but again the higher the quantity, the cheaper the cost of upgrading per unit. Alternatively the biogas plants have to be placed in livestock intensity and be based on the farms not delivering manure to a biogas plant today. This calls for a high degree of participation in biogas production which can be difficult to achieve.

6. Socioeconomic results

Beside the costs and benefits included in the business economic calculations, the production of biogas also provides some environmental benefits which are not included in the business economic calculations.

One of the side effects from degassing manure is that the foul odour emission from manure is drastically reduced. Therefore, when the farmers are fertilizing the fields with the degassed manure, the inconvenience for the neighbours is reduced, which generates a positive welfare economic value. No precise estimates of the odour emission reduction value exist, but studies shows that the odour emissions are reduced by approximately 50% (Jørgensen, 2009). Furthermore, degassing manure will result in decreased ammonia emissions when distributed on the fields. The biogas plant also functions as a storage and distributer of the manure, which is a benefit for farmers with too much manure compared to their land size.

Degassing manure also has the ability to reduce nitrogen leaching to the surrounding water. The effect of reduced nitrogen leaching to the root zone is estimated to be 0.11 kg N/ton manure. Less nitrogen leakage represents a welfare economic benefit through the reduction of a negative externality. The welfare economic value of reduced nitrogen leakage to the root zone is estimated to be 4.1 € per kg N. When degassing the manure from standard sized centralized biogas plant, a welfare economic gain of 0.4 mill. € is generated from reduced nitrogen leakages.

Finally, the degassing of manure contributes to the reduction of GHG emissions in the agricultural sector. Table 5 illustrates the GHG emission reductions related to the degassing of different types of manure.

The calculations show that the total GHG reductions are 18,500 tons CO_2-eq. per year. As noted before the reduction from Maize, leaving aside the energy substitution, is limited.

Table 5. GHG emission reductions from degassing pig and cattle manure on a centralized biogas plant

GHG	Cattle manure	Pig manure	Fiber Fractions (pigs)	Maize
	(kg CO_2-eq./t)			
Natural gas substitution	19.0	18.7	171.3	184.3
Nitrious oxide	12.8	11.2	35.9	0
Methane reduction	1.9	13.2	96.7	-60.2
Carbon storage in soil	-1.4	-1.4	-12.8	0
Total effect	32.3	41.7	291.1	124

Source: Olesen et al. (2012)

Besides the above mentioned welfare economic benefits, the biogas production also increases NO_x emissions, which causes damages of 0.3 € per ton degassed biomass. The total cost of the CO_2 emissions is 141 €/tonne CO_2. This is much higher than the current CO_2 quota price of 5-10 € per ton. It is assumed that the Danish socioeconomic costs will be high as they are converted into consumer prices. It is estimated that the change in calculation methods (interest, conversion to consumer prices etc.) on its own have increased the calculated CO_2-emission price by more than 50 € per tons CO_2.

German analyses indicate a CO_2 cost of 300 – 1.100 € per ton CO_2, and this is based on the lower direct costs. The higher Germany costs are mainly due to the fact, that only part of the heat is utilized and that a substantial part (50%) of the input is maize.

Table 6. Socioeconomic results – Biogas plant – 700 ton/day

Item	€/year	€/tons input	€/m^3 biogas	€/ m^3 methane
Total costs	5,301,670	20.75	0.43	0.65
Total income	3,133,556	12.26	0.25	0.39
Total value of dead weight loss	730,373	2.86	0.06	0.09
Total value of externalities	300,884	1.18	0.02	0.04
Total deficit (NPV 20 year)	2,597,603	10.17	0.21	0.32
Total CO_2-eq reductions. (ton)	18,454	0.07	0.00	0.00
MAC (€/ton CO_2-eq.)	141			

Source: Jacobsen et al. (2013)

7. Conclusions

As a results of the new energy agreement from 2012 and a new policy objective of using 50% of livestock manure to produce biogas, Danish politicians have changed both objectives and the framework for future biogas production. Based on 18 planned facilities the average size is expected to be approx. 700-750 m^3 per day or 250,000 tons annually. The new energy agreement gives basically a direct subsidy of DKK 15.4 € per GJ. However, increases in other taxes reduce the net effect to 13.8 € per GJ. The increased grants provide a significant boost in earnings, but the selling price in real terms will decline over time as the grants are phased out over time. The calculations show that larger plants have lower costs per. m3 of methane produced. This is due to lower operating costs. The transport distance from the farms to the biogas plant is a key parameter here. The analysis shows that almost 40% of all costs related to transportation costs. The large plants can expect that transport costs per. m3 of methane produced can be increased slightly due to longer driving distances. The withdrawal of support for the construction investment of 30% cost the biogas plant 0.3 million € per year. Losing this support can complicate financing, but the biogas plant should still make a profit without the investment support. Analyses show that the cost of upgrading biogas for distribution via the natural gas grid is roughly the same for the analyzed upgrading techniques. The total cost of the upgrade is set to 0.13 per. m^3 of methane incl. pressure equalization. Profits after upgrading will be less than when selling to CHP when an acceptable price on heat is given.

It is estimated that with the new energy deal biogas production will increase in the coming years by another 20 plants taking the use of animal manure to 20-25%. However, financing and location of facilities designated as key challenges must be resolved as well. It is a problem when banks do not what to use the asset value of the biogas plant as collateral when giving loans. Farmers are then struggling to provide enough equity on their own farms to ensure the loans to the biogas plant. In other words the analysis indicate that achieving the objective of using 50% of livestock manure in biogas production will be very difficult to achieve by 2020.

The socio-economic cost, by increasing biogas production has increased with the latest energy plan and the change in calculation methods adopted. Conversely, one must expect that society will have to pay a higher price towards the goal of elimination of fossil fuels in 2050. On the other hand the EU's declining CO_2 quota price does make Green Energy like biogas relatively more expensive.

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