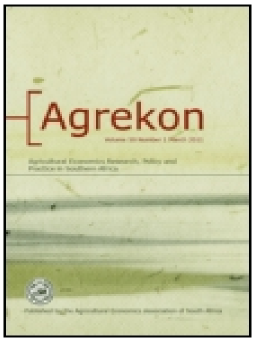

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Assessing the potential for electricity generation from animal waste biogas on South African farms

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ASSESSING THE POTENTIAL FOR ELECTRICITY GENERATION FROM ANIMAL WASTE BIOGAS ON SOUTH AFRICAN FARMS

B. Lutge* and B. Standish**

ABSTRACT

Electricity generation using animal manure is practised extensively in many parts of the world to improve farm profitability and to increase the contribution of renewable energy. This research assesses the financial viability of using pig and dairy manure to produce electricity on a small sample of farms in South Africa. Financial feasibility studies were carried out for both pig and dairy farms. This study also assessed the level of production and incentives that are necessary to make biogas a viable option for electricity generation. The results show that electricity generation on pig farms is potentially viable. This could be enhanced with various types of incentives. The sample of dairy farms on the other hand does not show much potential.

Keywords: Biogas, electricity generation, financial feasibility, manure, renewable energy.

JEL Classification: 4(c)

1. INTRODUCTION

The South African government has been investigating ways to reduce the environmental impact of energy production through renewable energy sources. The Department of Minerals and Energy (DME) has recognised the importance of renewable energy in its Integrated Energy Plan (DME, 2003). The medium-term goal is to produce 10 000gW of electricity from renewable energy sources by 2013. This is approximately 4% of the projected electricity demand for 2013 (DME, 2003). The National Energy Regulator of South Africa (NERSA) has also recently published the Phase II Renewable Energy Feed-In Tariffs (NERSA, 2009), expanding the list of potential sources that would qualify for a feed-in tariff. Biogas is on this list.

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Agriculture has made significant contributions in other parts of the world to assist with renewable energy targets through electricity generation from biogas (Redman, 2010). The objective of this research is to take the initial step towards determining whether on-farm produced biogas can become a viable option for South African farmers and as such make contributions to South Africa's renewable energy production.

2. METHODOLOGY

The analysis followed a three-pronged approach. First, data from individual farms was analysed to establish the financial viability of generating electricity through using the biogas from manure on farms. The second established the national potential for the use of biogas from manure in South Africa, and the third determined what incentives were needed make biogas electricity generation a financially viable option in South Africa.

Part of these analyses involved establishing the potential biogas yields from South African farms. Given the fact that very little biogas research has been conducted in South Africa and that there are very few on-farm anaerobic digesters in the country, this study had to establish realistic values for the analyses. The analyses were largely quantitative, based on information from various sources, including interviews and questionnaires, literature and estimates from industry. Similar approaches have been used in other studies (Binkley, 2010; Grelaud, 2007; Jackson, 2006). The development of the AgStar FarmWare software (EPA, 2010) used a similar approach to develop its models.

2.1. Estimating the financial viability of on-farm biogas projects

The financial viability of biogas has been assessed in several studies by using a cost benefit analysis that is based on estimates of investments, revenues, expenses and potential cost savings (Binkley, 2010; Grelaud, 2007; Jackson, 2006; Redman, 2010).

As data was not yet freely available on biogas in South Africa, a literature review was conducted to establish values that would not vary significantly between countries, for example the amount of manure produced by cows. Certain issues were, however, specific to South Africa, such as the cost and quantity of electricity used in farming. This data was gathered from interviews and questionnaires completed by farmers. Other data was collected from companies that and individuals who provide services in the biogas industry. A wide range of sources was used to estimate values for South African conditions. This was largely limited to the biological and technological aspects of biogas, while the economic and financial aspects were based on data from South Africa.

A questionnaire was sent out to farmers to establish their current farming practices and costs. Similar to the questionnaire of Jackson (2006), this questionnaire included information on animal types and numbers, manure handling, current electricity costs and current fertilizer costs. Cost data was not available for anaerobic digesters in the South African context as there are currently no on-farm anaerobic digesters in South Africa (Hayden, 2010; Lilje, 2010). An Excel spreadsheet developed by AGAMA energy, a company specialising in renewable energy applications, was used to estimate the capital costs of the digesters (AGAMA, 2010).

Jackson (2006) and Grelaud (2007), in their theses on biogas, interviewed 11 and three farms, respectively. In this study 15 questionnaires were sent to pig farmers and 12 to dairy farmers. Three pig farmers and three dairy farmers responded to the questionnaire.

2.2. Estimating biogas potential in South Africa

Having calculated the potential for biogas from farms in South Africa, an attempt was made to extrapolate this into estimating the potential electricity savings for the country as a whole. Numerous studies in the US and Europe (FAO, 2006; Tricase & Lombardi, 2009) have related the production of manure and/or biogas from an individual animal to country-wide (or state-wide) production, by using statistics for that country or state.

2.3. Estimating the incentives

A number of countries make extensive use of on-farm biogas for electricity generation. This is largely possible due to the availability of incentives. Some of these incentives include an electricity from biogas renewable energy feed-in tariff (REFIT in South Africa), grants and/or subsidies for the initial capital investments, or carbon credit-based payments. Using the spreadsheet model, the level of various incentives was determined. Similar policy options were investigated by Brown, Yiridoe & Gordon (2007) using sensitivity analysis.

3. ESTABLISHING THE DATA

The purpose of this section is to report on the data that was used in the analysis.

3.1. Amount of biogas

A variety of methods has been used internationally to calculate the amount of biogas produced from animal manure. Given the variety of methods available, these need to be converted into a single unit for comparative purposes. There are essentially two measurements that need to be taken to estimate the amount of biogas produced, namely the actual amount of biogas and the amount of methane. Both of these are measured in one of two ways, either in m^3/t of manure or in norm litres per kilogram of volatilised solids (Nl/kg VS). These all need to be converted into a common unit.

Table 1: Dairy biogas yields (m^3/t manure)

Literature	Biogas (m3/t)	Methane (m3/t)	Biogas (Nl/kg VS)	Methane (Nl/kg VS)	Calculated Biogas (m3/t)	Comment
Navickas (2007)	30				30.0	
Hjort-Gregersen (1999)	20				20.0	
Nielsen (2004)a		22			36.7	
Amon et al. (2007)b			232.7		23.3	Average of 6 treatments
Amon et al. (2007)c				143.7	24.0	
Keymer (2004)	20.2				22.2	
Redman (2010)	20				20.0	Average (15–25)
Moller et al. (2004) c				148	24.7	
Burke (2001) c				159.1	26.5	
Brachtl (2000) Thome´–Kozmiensky (1995)b			250		25.0	Average (200–300)
Lilje (2010)			250		25.0	Range (150–350)
AVERAGE	22.6	22	244.2	150.3	25.0	

a Methane at 60% of biogas (Grelaud, 2007; Rao et al., 2010; Singh & Sooch, 2004)
Calculation: Amount of biogas (m3/t) = m3/t biogas ÷ 0.6

b DM% of 12.5% (Lilje, 2010); VS of 80% of DM (Keymer, 2004; Lilje, 2010)
Calculation: Amount of biogas (m3/t) = Nl /kg VS x 12.5% DM x 80% VS

c DM% of 12.5% (Lilje, 2010); VS of 80% of DM (Keymer, 2004; Lilje, 2010); Methane at 60% of biogas (Grelaud, 2007; Rao et al., 2010; Singh & Sooch, 2004)
Calculation: Amount of biogas (m3/t) = Nl /kg VS x 12.5% DM x 80% VS ÷ 0.6

Biogas contains approximately 60% methane (Grelaud, 2007; Rao, Baral, Dey & Mutnuri, 2010; Singh & Sooch, 2004). Therefore, to convert methane to biogas or vice versa, a factor of 0.6 was used. To convert Nl/kg VS to biogas one first has to convert the manure to a dry matter (DM) content. The DM content of dairy manure in South Africa is approximately 12.5% (Lilje, 2010), and that of pig manure approximately 9% (Lilje, 2010). The amount of volatilised solids in both dairy and pig manure (on a DM basis) is approximately 80%. Keymer (2004) estimates it at 85%, but Lilje (2010) estimates it to be closer to 75% in South Africa. To convert the Nl/kg VS to biogas when measuring methane requires a further conversion of 0.60 (Tables 1 and 2). From these estimates the amount of biogas can be calculated.

Using 11 sources of gas production from dairy manure and the four methods of estimating biogas, an average of 25.0m^3 biogas/t dairy manure was calculated. This is shown in Table 1.

Table 2: Pig biogas yields (m^3/t manure)

Literature	Biogas (m3)	Methane (m3)	Biogas (Nl/kg VS)	Methane (Nl/kg VS)	Calculated Biogas (m3/t)	Comment
Navickas (2007)	25				25.0	
Nielsen (2004)a		22			36.7	
Keymer (2004)	20.4				20.4	
Redman (2010)	20				20.0	Average (15–25)
Moller et al. (2004)b				356	42.7	
CROPGEN (2007)b				271.7	32.6	
Murphy (2005)					26.0	
Lilje (2010)c			450		32.4	Range (340–550)
AVERAGE	35.1	22.0	450	313.9	30.1	

NOTES:

a Methane at 60% of biogas (Grelaud, 2007; Rao et al., 2010; Singh & Sooch, 2004)
Calculation: Amount of biogas (m3/t) = m3/t biogas / 0.6

b DM% of 9% (Lilje, 2010); VS of 80% of DM (Keymer, 2004, Lilje, 2010); Methane at 60% of biogas (Grelaud, 2007; Rao et al., 2010; Singh & Sooch, 2004)
Calculation: Amount of biogas (m3/t) = Nl /kg VS x 9% DM x 80% VS / 0.6

c DM% of 9% (Lilje, 2010); VS of 80% of DM (Keymer, 2004; Lilje, 2010)
Calculation: Amount of biogas (m3/t) = Nl /kg VSx 9% DM x 80% VS

The average dairy cow in South Africa weighs 568kg and produces 7.2% wet manure as a percentage of body mass (Lilje, 2010). The average dairy cow in South Africa therefore produces approximately 41 kg of manure per day. An animal weighing 450kg constitutes an animal unit. A single animal unit will therefore produce approximately 32.4kg manure per day. Biogas production in South Africa is only really possible in Total Mixed Ration (TMR) dairy, where animals are housed and fed in a confined space and do not graze. A 200-AU milking herd under TMR conditions would therefore produce approximately 6.48 tons of manure per day. Given this, the amount of biogas from a 200 AU dairy herd was calculated at 162m^3 biogas per day.

Using eight sources of gas production from pig manure, a common unit (amount of biogas m^3/t) of 30.1 m^3 biogas/t pig manure was calculated. This is shown in Table 2 above.

The Agricultural Research Council's Engineering Services in South Africa (ARC, 2005) estimates that a typical 100 sow piggery will produce approximately 1 710 tons of undiluted waste per year. This equates to approximately 4.7 tons of manure per day and 141.4m^3 biogas per day for a 100 sow piggery.

3.2. Electricity generation potential

Numerous studies have estimated the generation capacity of biogas (Burke, 2001; Gebrezgabher *et al.*, 2009; Murphy, McKeogh, & Kiely, 2004; Redman, 2010; Tricase & Lombardi, 2009; Yeoh, 2004). Some of these estimates are presented in Table 3. From these values an average generation capacity can be calculated. Where the kilowatts were calculated using methane, a conversion of 0.6 (Grelaud, 2007; Rao, Baral, Dey & Mutnuri, 2010; Singh & Sooch, 2004) was used. The general electrical efficiency is calculated at 35%, while the heat generation efficiency of the various sources varies between 40% and 50% (Murphy *et al.*, 2004; Redman, 2010). Given these factors, one cubic metre of biogas produces approximately 2.03kW of electricity and 3.14kW of heat (as shown in Table 3).

Table 3: The electricity and heat generation potential from biogas

Literature	Electricity kW/m3 of biogas	Heat kW/m3 of biogas
Burke (2001)	2.22	
Tricase & Lombardi (2009)	1.89	3.8
Redman (2010)	2.00	3.3
Yiridoe, Brown & Gordon (2009)	1.82	
Gebrezgabher et al. (2009)	2.22a	
Murphy (2005)	2.04	2.3
Yeoh (2004)	2.00	
Nielsen (2004)	2.40	3.1
AVERAGE	2.03	3.13
NOTES: a Electrical efficiency = 37%		

Given the amount of biogas produced in a day, the following amount of electricity and heat can be generated by a 200 AU dairy herd and 100 sow piggery:

Dairy:		
Electricity:	162m3 x 2.03kW	= 329kW per day
Heat:	162m3 x 3.13kW	= 507kW per day
Pigs:		
Electricity:	141.4m3 x 2.03kW	= 287kW per day
Heat:	141.4m3 x 3.13kW	= 443kW per day

This relates to an electricity generation capacity of 13.7kW and 11.9kW for a 200 AU dairy herd and a 100 sow piggery, respectively.

3.3. Estimating the capital investment

There are two types of anaerobic digesters that could potentially be used in South Africa. The first is a covered lagoon and the second a complete mix digester, sometimes referred to as a Constantly Stirred Tank Reactor (CSTR) digester. AGAMA biogas has conducted feasibility studies on biogas projects of various forms in South Africa and has developed a spreadsheet to estimate the capital costs of various digester types in South Africa (AGAMA, 2010). This spreadsheet was used to develop a function to estimate the capital costs of digesters of various sizes. A range of manure volume was used to establish the potential costs at various sizes of anaerobic digesters. The function that represents cost per ton of manure at various sizes of anaerobic digesters is illustrated in Figure 1.

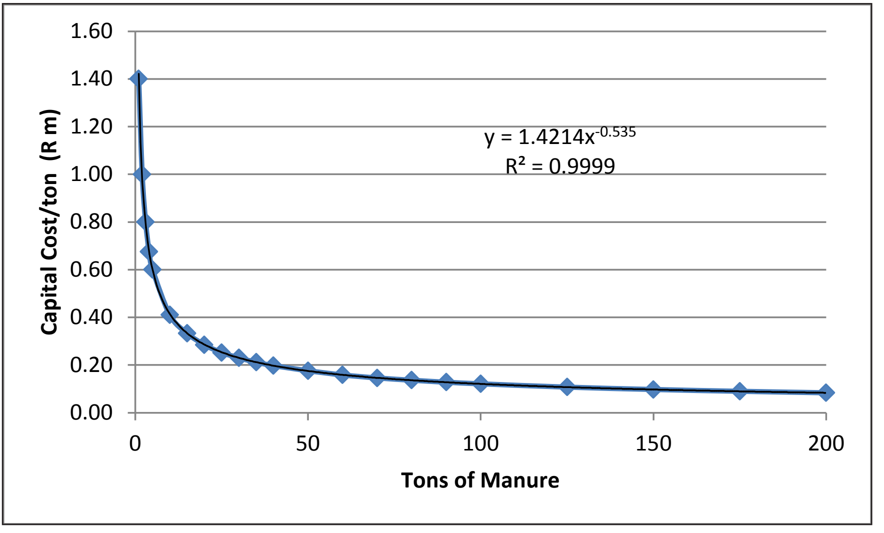

Figure 1:Estimated capital cost function of a CSTR digester per ton of manure added (calculated from AGAMA 2010)

A similar process was used to calculate the initial investments for a lagoon digester and, in this case, was calculated from the amount of biogas produced as a basis for estimating digester size. This is illustrated in Figure 2.

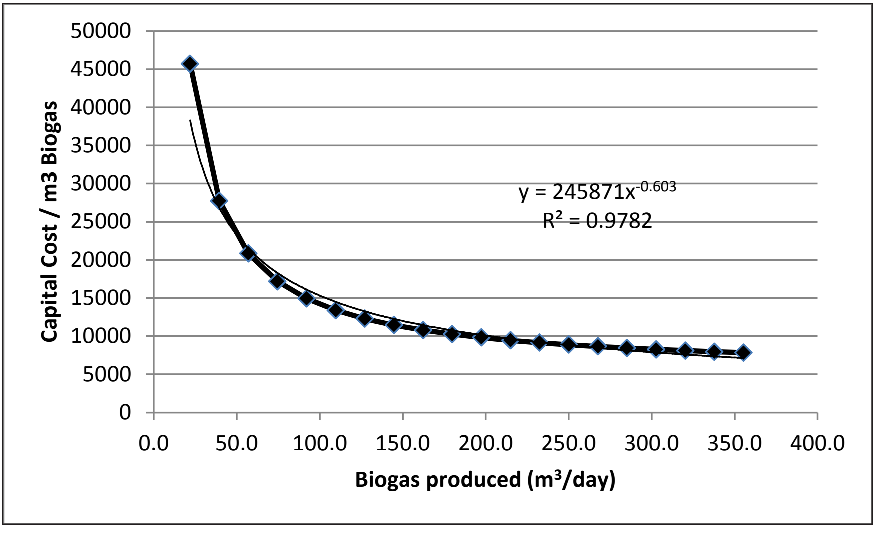

Figure 2: The estimated capital cost function of lagoon digesters per m^3 of biogas produced (calculated from AGAMA, 2010)

3.4. Assumptions

The discount rate used in the various studies that estimated the viability of biogas varies considerably. Jackson (2006) cites a range of 2.5% to 7% in studies that he investigated, but used a discount rate of 2.8%. A similarly low discount rate of 2.5% was used by Walla and Schneeberger (2008). These are all based on circumstances in the USA. In Thailand, Pipatmanomai, Kaewluan and Vitidsant (2009) used 6%. The most common discount rate is 8% (Grelaud, 2007; Mallon & Weersink, 2007; Mueller, 2007). The lifespan of a biogas plant also varies. The lifespan of biogas projects can vary from 10 years (Jackson, 2006) to 15 years (Engler, Jordan, McFarland & Lacewell, 2007; Pipatmanomai, Kaewluan & Vitidsant, 2009). The most common figure used is 20 years (Gomez *et al.*, 2010; Grelaud, 2007; Mueller, 2007; NERSA 2009; Redman, 2010). A 20-year lifespan was used in this study.

The repairs and maintenance costs are estimated at 3% of initial investment (AGAMA, 2009), while operating costs are set at 3% of initial investment (Jackson, 2006; Mallon & Weersink, 2007). Jackson argues that the maintenance and repairs of a lagoon digester could be lower than those of a CSRT digester. However, for this study they were both set at 3%.

The basis of the electricity costs has been taken from the Final Integrated Resources Plan prepared by the Department of Energy (DOE, 2011). The Final

Integrated Resource Plan for Electricity (DOE, 2011) has predicted their price of electricity until 2030. The electricity price is expected to peak in 2021. From then to 2030 a marginal decrease is expected. However, in 2010, NERSA allowed Eskom a 25% increase for each of the following three years (2010–2012). For 2013 Eskom has been granted a 16% increase (NERSA, 2012). This study therefore used a combination of the actual increases given and the predicted future price. The actual increases from 2010 to 2013 were used. From 2014 to 2030 the predicted future price was adjusted using the new 2013 actual price. The actual price the farmers in this study paid is 149% higher than the price published by the DOE. The electricity price in this study is thus increased by 149% as outlined in Table 4. The cost of raising capital was priced at 10%.

Table 4: Electricity price increase from 2010 to 2030

		Years									
	Staring price	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DOE price (c/kW)	41.6	52.0	65.0	75.4	88.3	95.3	98.6	105.0	112.0	116.3	118.5
Farmer price (c/kW)	62.0	73.0	87.9	104.3	122.2	131.9	136.4	145.3	155.0	161.0	163.9
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
DOE price (c/kW)		120.6	120.6	118.5	117.9	117.9	117.9	117.4	116.3	114.2	113.1
Farmer price (c/kW)		179.8	179.8	176.6	175.8	175.8	175.8	175.0	173.4	170.2	168.6
Source: Calculated from Final Integrated Resource Plan For Electricity (DOE, 2011)											

4. RESULTS

The average electricity cost of the pig farms was R328 260 (for an average of 481 sows), although there were variations among the farms. These variations in the electricity cost can be attributed to a number of factors. For example, all farms have more than one transformer, with each one charged at different rates. The different farmers also use their electricity for different purposes. A large part of the electricity cost of piggeries is heating. One of the farms (Farm 3) has a number of new houses with underfloor heating, which is more cost effective than the traditional lamp heaters. The farmers also use electricity for pumping and irrigation. On some farms this is linked to the piggery electricity costs (pumping slurry) but on another farm additional water is pumped from the river for irrigation.

The dairy farms also had considerable variability in electricity costs. The electricity costs in dairies are generally much lower than those of pig farms, largely because dairies do not have heating costs. The main electricity uses of dairies are refrigeration and pasteurisation. There is some heating required in pasteurisation, but the majority of the electricity costs are related to cooling the milk in the storage tanks. Dairy farms also use electricity for milking, pumping and irrigation. On one of the farms this contributes 23% of the electricity costs.

With the data available it was not possible to isolate the electricity costs directly allocated to the piggery or dairy, therefore the overall pig or dairy farm electricity costs were used in the analysis. Given that there was considerable variation in the electricity costs between farms, the analysis was done for each of the farms instead of using the average price.

Given the rapid increase in the electricity price in recent years, an analysis was done to estimate what price increase is needed for biogas to become a viable option on the farms that were investigated. This would be seen as a NPV = 0 in Table 5. This analysis clearly shows that for a dairy enterprise to become viable for biogas electricity generation, the price would have to be at least 300% higher than current forecasts. A lagoon digester would in all likelihood be viable at the forecasted price. However, for a CSTR digester to be viable on a piggery, the electricity price would need to be close to 90% higher than forecast.

Table 5: The percentage that the electricity price would have to increase, and the maximum electricity price for the different farms and digesters to show a zero (0) NPV

		Farm 1	Farm 2	Farm 3	Average
Pigs CSTR	Percentage increase	83%	41%	321%	89%
	Maximum price (c)	305.5	235.4	702.7	315.5
Pigs Lagoon	Percentage increase	-	-	138%	6%
	Maximum price (c)	-	-	397.3	176.9
Dairy CSTR	Percentage increase	348%	246%	1311%	254%
	Maximum price (c)	747.8	577.6	19047.6	590.9
Dairy Lagoon	Percentage increase	148%	86%	694%	95%
	Maximum price (c)	414.0	310.5	1325.4	325.5

4.1. Fertilizer costs

All farmers interviewed use their slurry as a fertilizer on their pastures or crop lands. On two of the farms the slurry fertilizes the lands used for growing pig feed.

In no case was the slurry sufficient to meet total fertilizer requirements and all farmers have to buy additional inorganic fertilizer. Calculating the value of slurry on a field should be done with caution. The value of slurry is very dependent on the animal feed, the soil, and how and when it is applied. As such, Manson (1994) advises that each sample needs to be analysed before using it on crop lands, to determine its usefulness. Without having the nutrient value of the slurry it is not possible to accurately calculate the value of the slurry. Given that the farmers still fertilize with inorganic fertilizers suggests that the slurry is not sufficient to meet the crops' nutrient demands. Generally the digestate from a biodigester would not have as high a nutrient value as the slurry, therefore the farmers in this study would not receive any additional benefit from using the digestate over the slurry.

4.2. Viability analysis

Tables 6 and 7 show the basic data for each farm, namely number of animals and amount of manure produced per day, together with the resultant biogas yield. The electricity generation potential is also given for each farm. Electricity usage (megawatts per year) was calculated using the electricity costs of the farmers.

Only one of the pig farms (Farm P3) could potentially produce enough electricity to run the entire farm. Farm P1 is very close to potentially producing enough electricity, but on Farm P2 potential electricity production is considerably less than current usage. On average, however, the amount of electricity that could be generated is close to what is required (500mW vs 529mW). Currently all piggeries use electricity to generate heat in the piggeries. Converting this conventional electrical heating to heat generated by the power plant would significantly reduce the farms' electricity costs. Although there is considerable variation in the amount of electricity used in heating a piggery, depending on how the heat is produced, Marcon (2009) says that up to 85% of electricity in a piggery is used for heating. Given that up to 85% of a piggery's electricity costs could be used for heating, the three pig farms would all be able to cover their electricity costs. Such a conversion would, however, require considerable construction work. It would probably become an option when new houses are built or old houses are totally refurbished (Lilje, 2010). This potential heat generation was therefore taken into account and in all farms the full electricity costs were used in the calculations. Thus, should conversions be made to the heating of piggeries, the piggeries could be taken off the grid.

Table 6: Summary of the pig farms indicating the NPV, IRR and payback periods

	Pig Farm 1		Pig Farm 2		Pig Farm 3	
Animal and manure data						
No of sows:	524		500		420	
Amount of manure (t/day)	24.5		23.4		19.7	
M3 biogas/day:	739		705		592	
Electricity data						
Electricity generated per day (kW):	1492		1424		1196	
Electricity output (kW):	62		59		50	
Electricity generated (MW/yr):	545		520		437	
Electricity used (MW/yr):	579		774		236	
Capital and initial investment	CSTR	Lagoon	CSTR	Lagoon	CSTR	Lagoon
Biogas plant	R6 288 243	R3 384 713	R6 152 753	R3 322 296	R5 674 004	R3 100 111
EIA costs	R250 000	R250 000	R250 000	R250 000	R250 000	R250 000
	R6 538 243	R3 634 713	R6 402 753	R3 572 296	R5 924 004	R3 350 111
Maintenance and operating cost	R392 295	R218 083	R384 165	R214 338	R355 440	R201 007
Potential electricity cost saving	R358 672		R480 000		R146 109	
Potential fertilizer cost saving	-		-		-	
NPV	(R12 372 321)	R93 472	(R744 1167)	R2 708 826	(R20 257 955)	(R855 4506)
IRR	-	8.2%	-	14.3%	-	-
Payback	No payback	12.5	No payback	9.0	No payback	No payback
Discounted payback	No payback	18.9	No payback	11.1	No payback	No payback

Table 7: Summary of the dairy farms indicating the NPV, IRR and payback periods

	Dairy Farm 1		Dairy Farm 2		Dairy Farm 3	
Animal and manure data						
No of cows:	250		375		300	
Amount of manure (t/d)	11.0		16.0		9.1	
M3 of biogas/day:	275		401		227	
Electricity data						
Electricity generated per day (kW):	556		810		458	
Electricity output (kW):	23		34		19	
Electricity generated (MW/yr):	203		296		167	
Electricity used (MW/yr):	172		262		50	
Capital and initial investment	CSTR	Lagoon	CSTR	Lagoon	CSTR	Lagoon
Biogas plant	R4 333 518	R2 287 563	R5 159 755	R2 655 426	R3 959 26	R2117 862
EIA costs	R250 000	R250 000	R250 000	R250 000	R250 000	R250 000
	R4 583 518	R2 537 563	R5 409 755	R2 905 426	R4 209 726	R2 367 862
Maintenance and operating cost	R275 011	R152 254	R324 585	R174 326	R252 584	R142 072
Potential electricity cost saving	R106 250		R162 349		R31 000	
Potential fertilizer cost saving	-		-		-	
NPV	(R15 984 663)	(R6 681 734)	(R17 177 351)	(R5 790 203)	(R17 724 597)	(R9 349 668)
IRR	-	-	-	-	-	-
Payback	No payback	No payback	No payback	No payback	No payback	No payback
Discounted payback	No payback	No payback	No payback	No payback	No payback	No payback

All dairy farms show potential to produce enough electricity (222mW vs 161mW). Dairy farms could therefore potentially produce their own electricity and be taken off the national grid. In dairies refrigeration systems can also be converted to using heat instead of electricity, but again this would require significant investment in new equipment.

From tables 6 and 7, it is evident that electricity generation from CSTR digesters is currently not a viable option for either pig or dairy farms. None of the pig farms has a positive NPV for any of the CSTR digesters. One of the contributing factors for this is that all the pig farmers already use the slurry as a fertilizer and would get no additional benefit from using the digestate. The lagoon digester is, however, viable on two of the farms (Farms P1 and P2). Both of these farms have much higher electricity costs than Farm P3. None of the dairy farms has a positive NPV.

The major expense in a biogas operation is the initial capital investment. This is the main reason why biogas may not currently be a viable electricity generation option on farms. A sensitivity analysis was conducted on a range of herd sizes to determine at what level of capital investment pig and dairy farms could potentially become viable. The average of the three pig and dairy farms was used to estimate the capital costs of a digester in order to have a zero NPV at a range of animal numbers (Figure 3). Given that the amount of biogas produced per kilogram of manure is the same for both a lagoon and a CSTR digester, the minimum cost to make either a lagoon or a CSTR viable is the same.

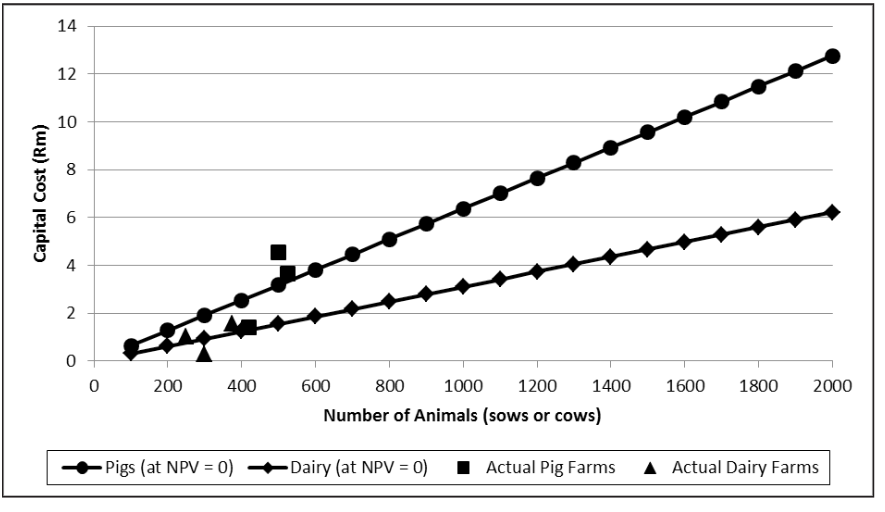

Figure 3: Capital cost at which the various enterprise and digester-type combinations have an NPV of zero

Figure 3 clearly shows that the cost of a digester on a pig farm can be higher than that of one on a dairy farm. The dairy farm's capital investment must be very low in order to make it viable, for example, the capital cost for a 1 000 cow dairy herd would be in the region of about R3m. On the other hand, the capital costs of a piggery digester can be significantly higher (Figure 3). A piggery with 600 sows would need a capital investment of approximately R4m. Given that a lagoon digester could be constructed for under R4.5m the potential exists for piggeries to achieve this, but for dairies the number of animals involved (approximately 1 600) would require a large digester, which is unlikely to be achieved with an investment of only R4.5m.

Given that the per animal digester costs decrease as the herd size increases, an estimate of the break-even point was calculated. Using the average electricity price of the different farms (R664 per sow), an estimate was made of how many sows are required to make the biogas plant viable. The outcome of this is represented in Figure 4, which indicates that for a lagoon digester at least 400 sows, and for a CSTR digester over 1 200 sows are required to make a biogas plant viable.

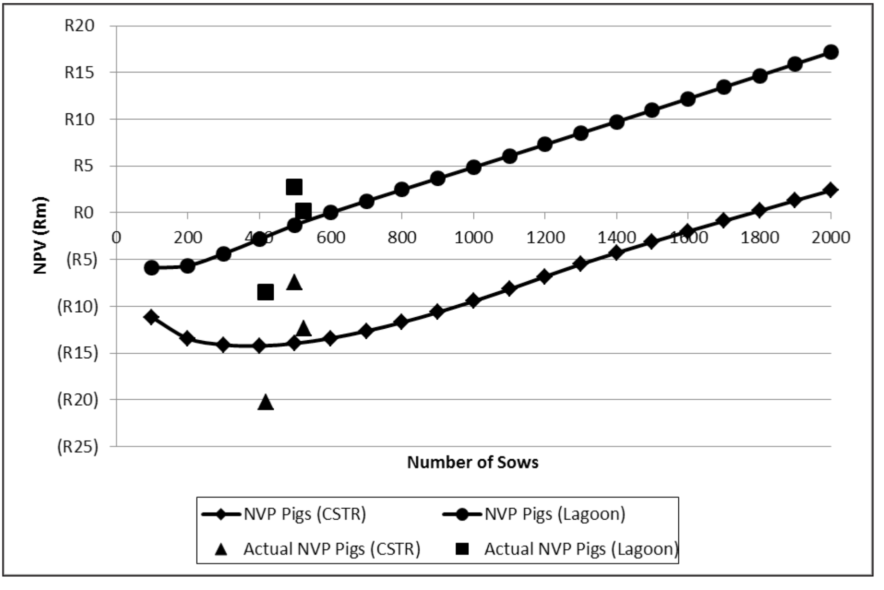

Figure 4: NPV of two types of digesters (lagoon and CSTR) across a range of pig herd sizes (100 to 2000).

A similar average electricity price of the different dairy farms (R328 per cow) was used to estimate the size of a dairy herd required to make a biogas plant viable. A lagoon digester would start becoming viable at approximately 1 500 cows, while for a CSTR digester in excess of 5 500 cows would be required (Figure 5).

It is these size requirements that constrain the potential for the use of biogas from dairy cows in South Africa. The Milk Producers Organization estimates that there are 3 332 milk producers with an average herd size of 209 (MPO, 2010). Yet less than 10% of dairies have herds of more than 300 and many of these are pasture-based dairies, which are not suitable for biogas plants (Burger, 2008). It is thus unlikely that there would be many dairy farms with such a large number of dairy cows.

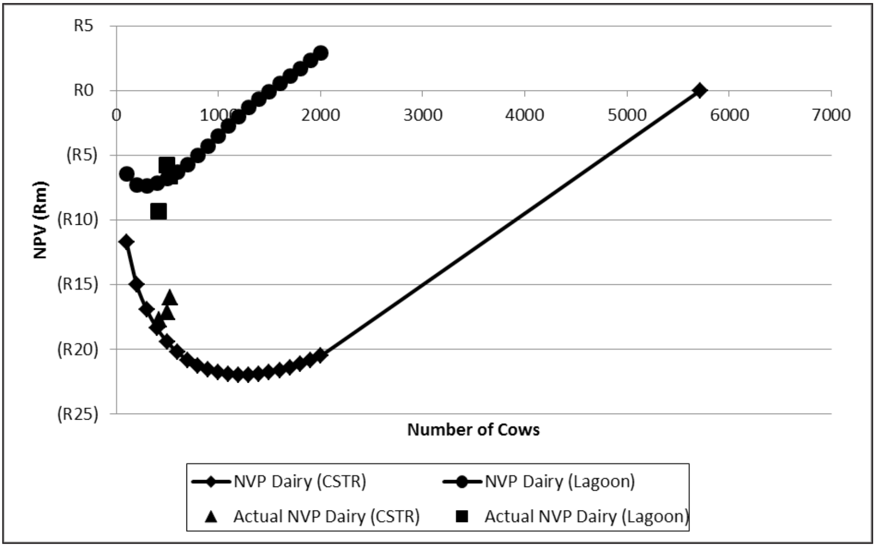

Figure 5: The NPV of two types of digesters (lagoon and CSTR) across a range of dairy herd sizes (100 to 6000)

4.3. Incentives

The White Paper on Renewable Energy (DME, 2003) outlines three main opportunities for incentives. These include investment incentives, production incentives and a set-aside option. The investment incentives include a direct subsidy or a tax incentive to stimulate investment. The production incentive guarantees producers a certain feed-in tariff and the set-aside option means setting aside a block of renewable energy supply for which producers receive a subsidy per kW of electricity produced. The Department of Minerals and Energy (2003) indicates that currently all three are viable options.

4.3.1. Feed-in tariff

The current Renewable Energy Feed-in Tariff (REFIT II) allows for the generation of electricity from biogas, which can be sold to the grid at 96c per kW (NERSA, 2009). This is, however, only possible when the generation capacity is over 1mW. Of the six farms studied, the highest capacity is 62.2kW. It would require an 8 400 sow unit for this to become a viable option. This would only be possible on very few farms in South Africa.

Only the dairy farms and one of the pig farms produce enough electricity that could potentially be sold at the 1mW minimum threshold. If a farmer was able to sell all additional electricity to the grid, as is practised in some countries such as Germany, additional income could be generated to recoup the initial capital investment. The four farms that produced enough electricity for sale all improved their NPV but remained unviable (Table 8).

Table 8: NPVs of the farms who could sell surplus electricity

			Farm 1	Farm 2	Farm 3
Pig farms	Additional income		-	-	R192 383
	NPV (Rm)	CSTR	(R12.3)	(R7.4)	(R16.0)
		Lagoon	R0.9	R2.7	(R4.3)
Dairy farms	Additional income		R30 015	R31 807	R112 414
	NPV (Rm)	CSTR	(R15.3)	(R16.5)	(R15.2)
		Lagoon	(R6.0)	(R5.1)	(R6.9)

4.3.2. Investment incentives

Clearly, reducing the need to borrow capital increases the chances of the biogas plant becoming viable. This additional capital could be in the form of an investment subsidy as is prevalent in a number of countries around the world, such as France and the USA (DME, 2003; Grelaud, 2007). Grelaud (2007) indicates that up to a 40% investment subsidy is available in France. Given the number of pigs at the different pig farms in the study, the average investment of R3.52m would require a subsidy of slightly more than R1m (33.5%) to make them viable. For CSTR digesters the subsidy would have to be greater than 100%, which would not be feasible. For a dairy farm, the subsidy for both a lagoon and a CSTR would be in excess of 100%.

4.3.3. Carbon credits

Carbon credits are units that someone can get through the development of a project that reduces greenhouse gas (GHG) emissions, such as a farmer developing a biogas plant. These units are tradable in terms of the Clean Development Mechanism (CDM). Methane is one of the four main GHGs and by using a biogas plant these methane emissions are reduced. Binkley (2010) outlines a formula by which carbon credits can be calculated for a biogas plant. The first step is to convert the volume of methane into the equivalent of metric tons per year (Mg/yr).

CH_4 (Mg/yr)	=	Amount CH_4 recovered (m^3/year)
	x	molecular weight of CH_4 (16)
	x	Mg/L conversion (1 000 000 Mg/L)
	x	mol/L @ Standard Temperature and Pressure (STP) (1mol/24.04L)
	x	m^3 to L conversion (1 000 L/m^3)

The calculations used in this research are based on biogas that contains 60% methane. Thus, a biogas plant producing 1 000m^3 of biogas per day would equate to 145.8Mg of methane per year.

1000m^3 biogas per day x 0.6 methane x 365 days x 16 ÷ 10^6 Mg/l ÷ 24.04 mol/L x 1 000 = 145.8 Mg per year

The second step is to convert the combusted methane to carbon credits using a conversion factor of 18.25 Mg per year.
For a 1 000 m^3 per day of biogas this would equate to 2 660 carbon credits.

145.8 Mg per year x 18.25
= 2 660 carbon credits

Based on these calculations and standard values, carbon credits were calculated for the average dairy and pig farms in this study. An average price of R300 per carbon credit was used for this exercise. It was also assumed that the cost of registering the carbon credit project would double the cost of the environmental impact assessment from R250 000 to R500 000. In addition, an annual cost would be required to maintain the carbon credit project and the operating costs were increased from 3% to 4% to cover these costs. Using these assumptions, the average pig farm would generate an additional income of R541 600 per year and the average dairy farm R240 052 per year (Table 9).

Table 9: NPVs of farms with carbon credits included

			Farm 1	Farm 2	Farm 3
Pig farms	Additional income		R798 020	R562 604	R472 587
	NPV (Rm)	CSTR	R0.9	R0.6	(R12.3)
		Lagoon	R8.4	R8.0	(R0.4)
Dairy farms	Additional income		R219 775	R319 966	R180 991
	NPV (Rm)	CSTR	(R13.3)	(R12.5)	(R15.8)
		Lagoon	(R3.6)	(R0.8)	(R7.0)

With the potential carbon credits included in the calculations, the pig farms become potentially viable. Two of the pig farms with a lagoon digester become viable (Table 9). The one pig farm not viable is the one with very low electricity costs. With the CSTR digester, two of the pig farms become viable (Table 9). On the dairy farms, however, the NPVs are all still negative, for both digesters (Table 9). Burger (2008) states that 1 000 cows is the minimum requirement for companies that sell carbon credits. With 1 000 cows the lagoon digester will become viable (NPV > R4.4 m), while for the CSTR digester the NPV is still negative. Piggeries therefore have the potential to become viable, while the dairy industry does not appear to have that potential.

4.3.4. Incentive combination

In order to make these farms viable, a combination of incentives may be required. Incorporating income from carbon credits, investment incentives and the potential sale of surplus electricity shows that both piggeries and dairies may potentially become viable, although a high investment incentive would be required (Table 10). Whereas a dairy would only become viable if a lagoon digester is used, a piggery could become viable with a CSTR digester. Both of these require incentives of 39.3% and 19.9%, respectively (Table 10).

Table 10: Investment subsidy required to make a farm viable if carbon credit and electricity sale income are included

	Additional income(R)	Incentive subsidy (% of investment)	NPV at investment subsidy
Pig (lagoon)	R541 600	0%	R4 484 322
Pig (CSTR)		53.8%	R0
Dairy (lagoon)	R297 961	70.0%	R0
Dairy (CSTR)		>100%	(R3 397 356)*

* NPV at 100% investment subsidy

It is clear that incentives improve the potential of biogas plants, but at present only piggeries would really benefit enough to make them viable. Even with all the incentives, dairy farms do not produce enough biogas to make them a viable option.

5. CONCLUSION

This study set out to assess the financial feasibility of producing electricity from biogas on South African pig and dairy farms. Only a small sample of farmers was willing to cooperate in the study and the results should therefore be treated as a case study rather than results that could be generalised across the country.

It was found that it is technically feasible and possible to produce electricity from biogas, but that it is financially marginal. This study concludes that, under the proposed legislative framework, producing biogas for the purposes of electricity generation is not a viable business proposition for the dairy farms that were analysed. This is mainly due to the high capital cost of a biogas plant. The piggeries that were studied are more suitable for this type of electricity generation. Although the contribution of piggeries in South Africa could not be estimated, there are significantly more pig producers in the size range that would make biogas a viable option.

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