GreenCape

The business case for biogas from solid waste in the Western Cape

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Executive Summary

GreenCape has observed an increasing amount of interest and requests for information and market intelligence on the production of biogas from solid waste. This biogas document has been developed to assist those considering installing a biogas system. It outlines the factors affecting the financial feasibility of such an endeavour and forms part of GreenCape's sector development efforts to assist in the uptake of biogas technology and the development of the industry in the Western Cape and in the rest of South Africa.

The focus of this business case document is production of biogas for this anaerobic digestion (AD). The AD technology process breaks down complex organic molecules to simpler molecules in the absence of oxygen. AD technology uses a mixture organic material as a feed to produce biogas as a product and digestate as a by-product. The composition of the biogas produced can vary, but consists mainly biomethane and carbon dioxide. Applications include direct combustion; either for domestic use, such as cooking and heating; or industrial applications that include the fuelling of boilers and turbines; as well as to produce electricity. Biogas can also be either compressed or bottled and stored for later use. Another product of AD is a nutrient-rich digestate (liquid and solid) which can be used as an organic fertiliser.

The South African biogas industry is considered to be in a nascent or infant state, as there is a low rate of uptake and general inexperience in designing, constructing and operating of biogas facilities. However, more uptake of biogas technology and development of local expertise would assist the industry in maturing to a level where biogas technology and industry is considered established. The drivers that support and assist the South African biogas industry in maturing include economic, environmental, social and legislative factors. The need for the management of organic waste, along with increasing costs of disposal and the recognition of the potential for on-site energy use, are some of the key drivers for the uptake of biogas technology.

There are currently 21 biogas projects (existing or planned) in the Western Cape. Out of the 21 projects, five case studies (Zandam Cheese & Piggery, Uilenkraal, New Horizons Energy, Elgin Fruit Juices and Bayside Mall) are presented to highlight the motivation for the projects, the benefits and the challenges. These case studies represent a range of models that include type of feedstock, off take of products and utilisation of energy for both heat and / or electricity. The lessons learnt from these five case studies include that the business case for a biogas facility is highly site specific. However, there are some general requirements for success, including guarantee of consistent feedstock quantity and quality; reduction of waste management costs; and supplementation of electrical and thermal energy used on-site. Additionally, the economies of scale and cost of managing the digestate stream are key factors that influence viability.

Common challenges were present across the various case studies. These included lignocellulosic contaminants, odour, digestate management, grid feed-in and waste collection and separation. Furthermore, the current lack of operational skills and capacity within South Africa has presented itself as a key challenge that highlights the need for training and local capacity, building on all aspects of biogas project development (including design, construction, operation and maintenance).

A general business for biogas for a number of scenarios has been developed to demonstrate some key factors affecting biogas project viability. Some general observations concerning the capital (CAPEX) and operating (OPEX) costs of existing projects in a South African context can be made: digester, CHP/engine and peripheral equipment dominate the capital expenditure, but can be reduced by considering the digester and engine design. A cost curve for CAPEX against installed electricity generation capacity (MW_e) in the South African context has been generated. Average operating costs were determined to be R253 per hour per kW_e, similar to that reported by the South Africa Biogas Industry Association (SABIA).

Two specific scenarios (likely applications in the Western Cape) were analysed for this general biogas business case, namely: (a) a small-scale biogas installation in a commercial context, and (b) a medium scale biogas installation in an agri-processing context. The financial viability of these two scenarios was investigated using spreadsheet tool specifically developed by GreenCape for biogas pre-feasibility assessments. The tool requires a number of input parameters (including feedstock type and amount, electricity tariff, logistics, gate fees and financial variables) to generate output parameters (capital and operating costs, electricity and heat production and various financial indicators). The tool contains a number of assumptions (energy yield of feedstock types, feed to digestate ratio, default values for financial variables in the SA context etc.) that are all adjustable. In assessing the viability of the two scenarios, scale and waste management costs were identified to play a key role. The analysis suggests that small-scale commercial biogas facilities (<50 kWe) would not be financially viable under current landfill disposal and energy costs, whereas medium scale (>50 kWe; <1MW) biogas facilities at an abattoir were shown to be financially viable at the middle to high end of the size range when there are high waste management costs and full utilisation of energy on-site. For the scenarios investigated, increasing waste management costs was shown to have a stronger influence on financial viability than increasing energy costs.

Overall, it can be concluded that in the South African context, financial viability of biogas projects is highly site specific and only strong under certain conditions. These conditions include situations where large volumes of feedstock are available, waste management costs are high, and there are high energy requirements (electric or heat) on-site or in close proximity. Due to the relatively low energy costs in South Africa, increasing waste management costs may well be a stronger lever for promoting the uptake of anaerobic digestion (AD) of solid waste in the South African context.

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List of acronyms

AD	anaerobic digestion
CAPEX	capital expenditure
CH_4	methane
CHP	combined heat and power
CNG	compressed natural gas
CO_2	carbon dioxide
DBSA	Development Bank of Southern Africa
D:E	debt to equity
DFI	development finance institution
DSCR	debt service cover ratio
EPC	engineering, procurement and construction
GEF	Global Environment Facility
H_2S	hydrogen sulphide
IDC	Industrial Development Corporation
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Development Agency)
IRR	internal rate of return
kW	kilowatt
kW_e	kilowatt electrical
kW_{th}	kilowatt thermal
kW_p	kilowatt peak
kWh	kilowatt-hour
MRF	materials recovery facility
MSW	municipal solid waste
NPV	net present value
OPEX	operating expenditure
OREX	organic extruder (press)
PI	profitability index
PBP	payback period
RDF	refuse-derived fuel
ROI	return on investment
SABIA	South African Biogas Industry Association
SSEG	Small-scale embedded generation
UNIDO	United Nations Industrial Development Organization
VC	venture capital
WACC	weighted average cost of capital

1. Introduction

1.1. Objective

The aim of this biogas business case document is to inform those considering installing a biogas system of the factors affecting the financial feasibility of such an endeavour.

1.2. Outline

The outline is as follows:

- **Section 2**: An introduction to anaerobic digestion providing an overview of the process, inputs required and products generated.
- **Section 3**: A brief overview of the current status of biogas in the Western Cape
- **Section 4**: Case studies of five biogas projects in the Western Cape. These range from small commercial installations with <50 kW_e capacity to large industrial facilities with energy-equivalent capacity exceeding 4 MW_e. These case studies illustrate the motivation behind establishing projects, the benefits realised, challenges faced, financial details, and noteworthy differences between installations. The information presented is based on industry site visit data, interview data and literature.
- **Section 5**: Key elements pertaining to financial viability. To illustrate the factors affecting financial viability, a number of biogas systems are modelled for a range of scenarios. Factors investigated include feedstock and installed system capacity, energy cost, extent of on-site energy use. Financial feasibility is considered in terms of internal rate of return (IRR) and net present value (NPV). Only the case of combined heat and power (CHP) is considered, i.e. no other uses such as use for either heat only, electricity only or a transport fuel. Furthermore, other important elements of overall project viability (e.g. securing finance and regulatory approvals) are also not discussed.
- **Section 6**: Conclusions. Drawing on the case studies and the findings from the scenarios modelling, the document concludes by highlighting significant factors affecting viability of biogas projects.

2. Biogas from anaerobic digestion: process overview

2.1. Background

Anaerobic digestion is the breakdown of complex organic molecules to simpler molecules in the absence of oxygen. This process is performed by microorganisms through a set of four interlinked metabolic steps[1]. The major product arising from this process is biogas - a mixture of (bio)methane (CH_4), carbon dioxide (CO_2) and trace amounts of other gases such as hydrogen sulphide (H_2S). Additionally, a nutrient-rich slurry, known as digestate, is formed as a by-product. A schematic of the anaerobic digestion process is shown below in Figure 1.

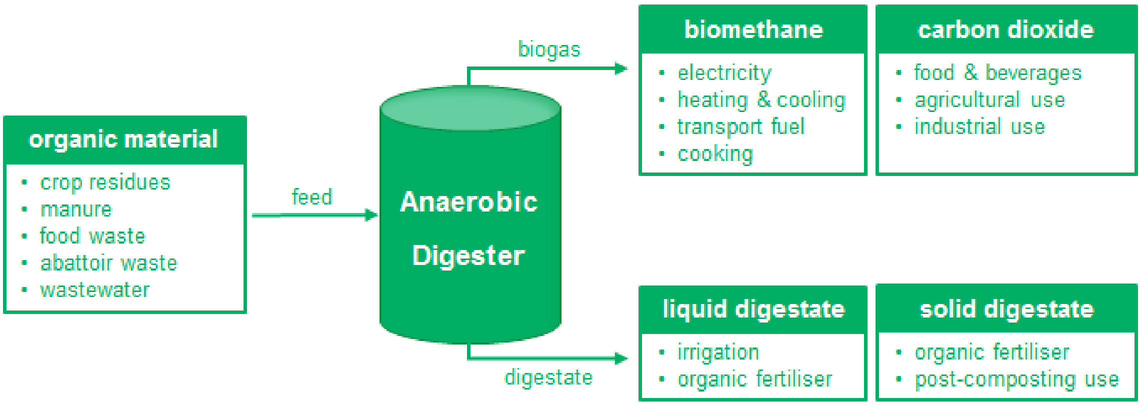

Figure 1: Schematic diagram of the anaerobic digestion process

The composition of the biogas produced can vary, and is influenced by parameters such as feedstock and process operating conditions. The typical composition for biogas is shown below in Figure 2.

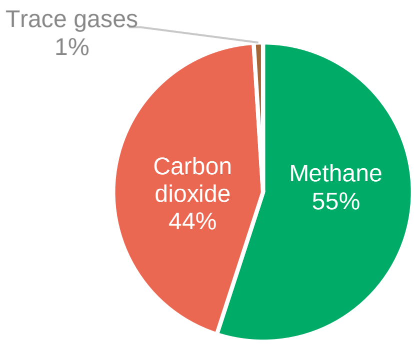

Figure 2: Typical biogas composition

Trace gases such as hydrogen sulphide are usually scrubbed from the biogas[2]. Carbon dioxide is sometimes a valuable product, as it has uses in controlled environment agriculture[3], food and

[1] These steps are: hydrolysis - the breakdown of carbohydrates, fats, and proteins, to sugars, fatty acids, and amino acids, respectively; acidogenesis - the formation of carbonic acids and alcohols; acetogenesis - the formation of acetic acid, carbon dioxide, and hydrogen; and methanogenesis - the formation of methane.

[2] Hydrogen sulphide can cause corrosion/damage to equipment.

[3] Enriching CO_2 levels in the cultivation atmosphere, thereby enhancing plant growth.

beverages, water treatment, oil recovery and other industries applications (Parson Brinckerhoff, 2011). However, biomethane is typically the most desired product due to its high energy content. As shown in Figure 1, biomethane can be used for a variety of purposes, including direct combustion: either for domestic purposes such as cooking and heating, or industrial applications including the fuelling of boilers and turbines. Biomethane can also be used to produce electricity, using a number of technologies. Table 1 shows the common electrical and thermal conversion efficiencies for various technologies.

Table 1: Biogas conversion efficiencies using different technologies

Technology	Electrical efficiency (%)	Thermal efficiency (%)	Total efficiency (%)
Combined heat and power (CHP)	33 – 45	35 – 56	~85
Micro gas turbines	26 – 33	None	26 – 33
Fuel cells	40 – 55		40 – 55
Engines (Pilot Injection, Gas-Otto)	30 – 44		30 – 44

Source: Fachagentur Nachwachsende Rohstoffe e.V. (2014); Rutz, et al. (2015)

CHP systems are generally most common, as they produce both electricity and heat, with high overall efficiencies. In addition to heating, biogas can also be used for cooling, with the use of absorption chillers (Tiepelt, 2016). Where the heat from a CHP system (i.e. co-generation) is used for the absorption chiller, this is referred to as “tri-generation”. The use of biogas for cooling (either through combustion to produce heat or via tri-generation) may be an opportunity in the South African context. This has not been explored extensively, but holds great potential in industries such as agri-processing, where there is a source of organic waste, as well as significant electrical and cooling requirements. That said, the cost of infrastructure to combust biogas to generate heat for absorption chilling or cooling via tri-generation needs to be compared to the cost of infrastructure to combust the biogas to generate electricity that can then be used in conventional cooling systems and for other (on-site) electrical needs. The relative merit will depend, among others, on the type and scale of all the energy needs (heating, cooling and electricity) on site.

Biogas can also can be stored on site, which would enable its use as a peaking fuel. Biogas can also be compressed and bottled for sale. Compression enables its use as a transport fuel, but requires the biogas to be upgraded to a higher methane content (i.e. via removal of carbon dioxide) and trace gases (such as hydrogen sulphide which can cause corrosion) to be removed. Such upgrading is typically costly.

Another product of anaerobic digestion is a nutrient-rich digestate (liquid and solid) which can be used as an organic fertiliser. Settling or other separation of the solid and liquid components may be undertaken. The liquid portion is typically used directly for irrigation and may require concentration to reduce logistics cost if it is to be used far off-site. The solid digestate can be used directly as a fertilizer or as an additive in composting.

3. Biogas in the Western Cape: status quo

3.1. South African context

The South African biogas industry is small compared to many other countries. It is estimated that there are currently around 500 digesters in South Africa, with 200 of these located at wastewater treatment works, and the remaining 300 being used for other purposes (Tiepelt, 2016). Of these digesters, the majority are small-scale domestic digesters, with only several dozen commercial or industrial scale digesters in operation. Due to the low rate of uptake, and general inexperience in designing, constructing and operating biogas facilities, biogas is considered a nascent or infant industry in South Africa.

As illustrated in Figure 3, there are thus some “innovators” and possibly “early adopters”. Among other, what is required is more extensive uptake of the technology and development of local expertise to reach a “tipping point” so that the industry matures and it biogas becomes an established technology and industry in South Africa. The intent with this business case document (and of other government and industry-led initiatives in this space[4]) is to assist in the uptake of the technology and development of the industry.

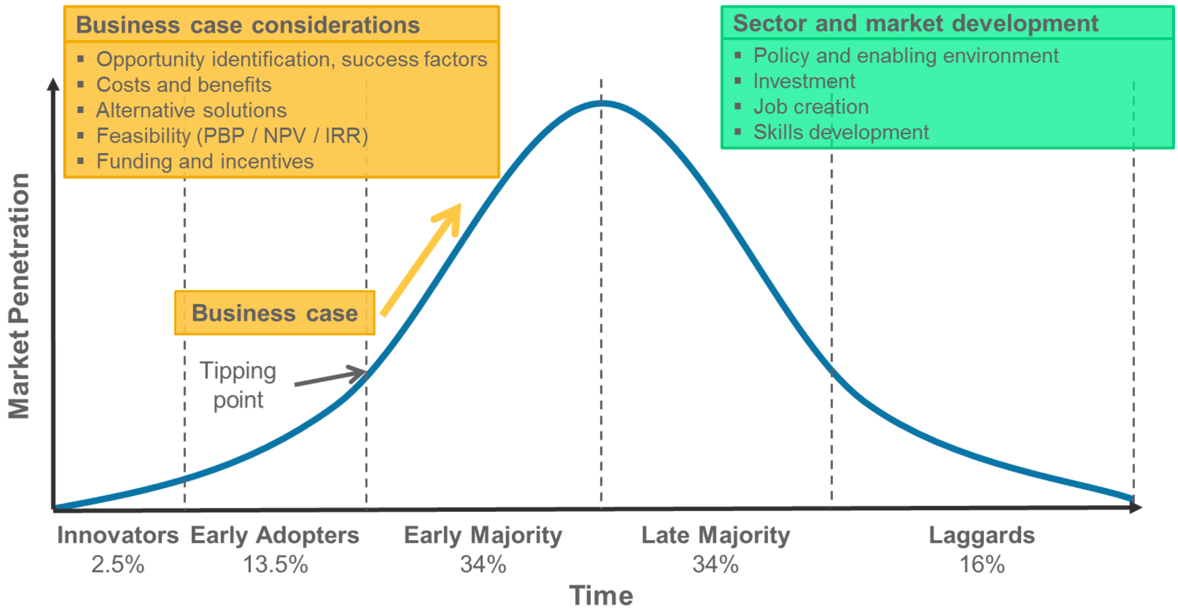

Figure 3: Roger’s diffusion of innovation model showing key elements for consideration to build a business case and for market and sector development

[4] These include the Department of Energy/SABIA/GIZ National Biogas Platform and the GEF/UNIDO: Waste-to-Energy Biogas (SA) Project.

There are a number of drivers for the uptake of biogas in South Africa. These include:

Economic

- **Waste disposal costs:** Generally relatively low in South Africa, but becoming higher for particular types of organic waste such as abattoir waste, which now requires disposal at landfills that meet particular requirements.
- **Electricity price increases**: Consistently above inflation, with over a 300% increase since 2004.
- **Fluctuating fertiliser prices**: Dependant on international prices (SA is a price taker) and exchange rates.

Environmental

- **Climate change mitigation** by reducing methane (CH_4) emissions due to unmanaged waste decomposition. This is noteworthy as CH_4 has a global warming potential equivalent 25 times that of CO_2 (Intergovernmental Panel on Climate Change, 2007).
- **Reduced landfill usage** and more sustainable waste management through:
  - increased landfill lifespan
  - decreased likelihood of water table contamination due to nutrient leaching.
- **Cleaner energy** production and heat generation
- **Increased energy security**, as the energy produced can be utilised during periods of load shedding, and gas can be stored for later use.
- **Nutrient-rich by-product** (liquid and solid digestate fertiliser), which reduces demand for carbon-intensive artificial fertiliser production, which is associated with 3 - 8 kg CO_2-eq emissions per kg nitrogen fertiliser produced (Brentrup & Pallière, 2008).
- **Potentially lower agricultural carbon footprint,** which is potentially beneficial for exports to regions with increasingly environmentally conscious consumers, such as the European Union[5].

Social

- **Job creation:** Direct job creation is estimated to be 4-10 FTE/MW_e (GreenCape analysis)
- **Investment:** Investment in physical infrastructure has multiplier effects in the economy. (The scale of investment for biogas facilities is discussed in section 5).

Legislative / Policy

- **Changes in legislation**: On 23 August 2016, the change of landfill classification came into effect under National Norms and Standard for the Disposal of Waste to Landfill. These changes require non-infectious abattoir waste to be disposed of at Class B landfills[6]. As most local municipalities do not have a Class B landfill, they are obligated to refuse to accept abattoir waste. Unless an abattoir invests in alternative waste treatment technologies, it will be necessary to transport abattoir waste to a Class B landfill, which could increase waste management costs substantially. A further driver in the Western Cape is that the provincial Department of Environmental Affairs and Development Planning (DEA&DP) intends to put measures in place to divert all organics from landfill by 2026. The initial aim is to reduce organics to landfill by 50% by 2021.

[5] Note that a full life cycle analysis (LCA) would need to be done to confirm that the biogas system has a lower carbon footprint to business as usual or a system to which it is to be compared.
[6] Note if the material is infectious it needs to go to a Class A hazardous landfill.

- **Renewable energy incentives and programmes** such as the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). Although the intent of the REIPPPP was to encourage waste-to-energy projects as well, no biogas projects have been successful in the various bidding rounds for utility scale renewables.

3.2. Biogas in the Western Cape

3.2.1. Energy potential from biogas

Figure 4 provides an estimated total electricity potential for the Western Cape (i.e. including the potential from agricultural value chains, municipal solid waste and wastewater treatment works) and places this in the SA context.

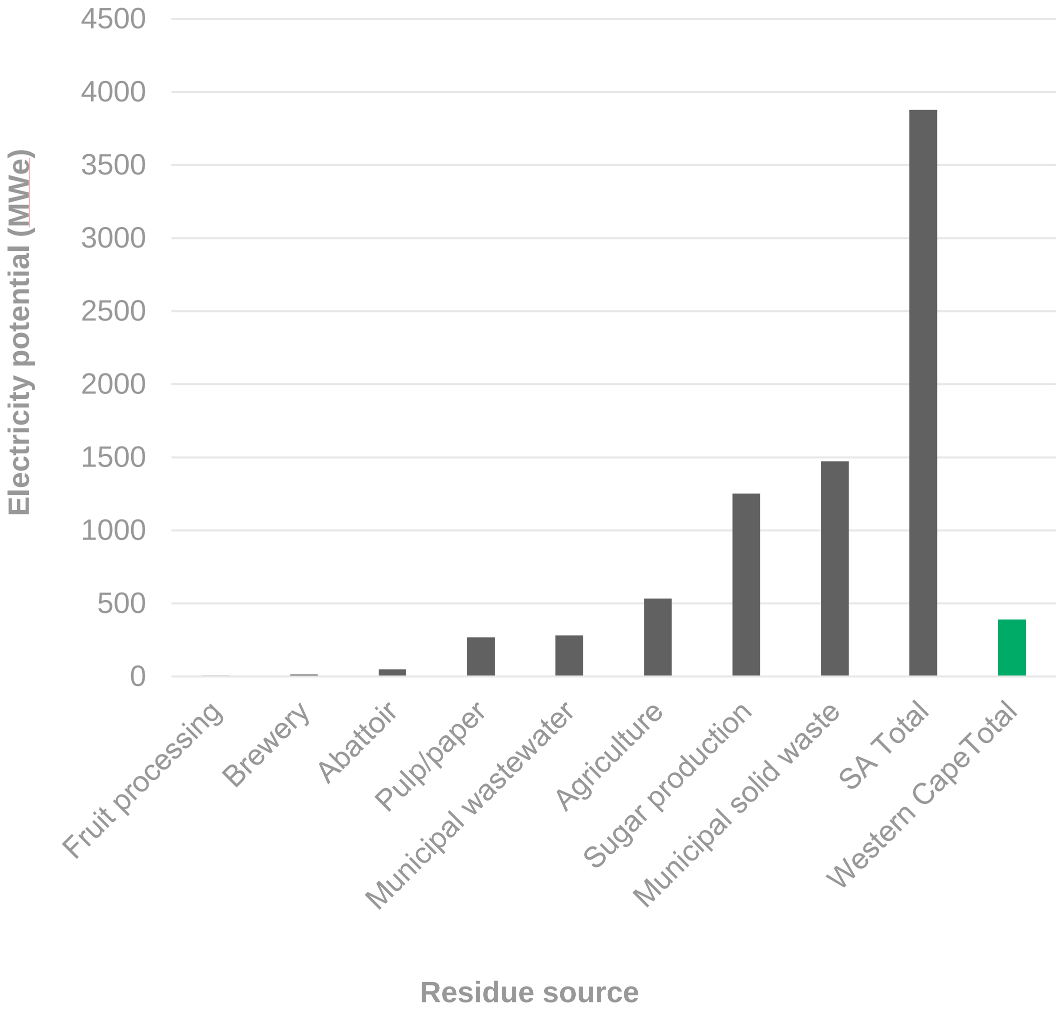

Figure 4: Estimates of electricity generation potential from biogas per sector and as a total for South Africa and the Western Cape

The grey bars indicate estimates of electricity generation potential from biogas, both per sector and as a total for South Africa (Department of Environmental Affairs, 2015). In comparison, the green bar indicates the relative total potential for the Western Cape (GreenCape analysis based on estimates of biogas generation potential from Department of Environmental Affairs, 2015).

These estimates shows that **the potential in the Western Cape is small relative to the total potential in South Africa.**

3.2.2. Investment and job creation potential

Based on the above analysis and industry data on installation cost (see section 5.1 later), biogas investment potential in the Western Cape is conservatively estimated at R4 billion, but could be as much as R13 billion. Based on this potential, together with gathered industry data, job creation is estimated at 320 to 3950 direct jobs, at a job intensity of 4 to 10 jobs per megawatt of installed electrical capacity.

3.2.3. Biogas projects in the Western Cape

Table 2 presents a list of current and planned biogas projects in the Western Cape.

Table 2: List and status of biogas projects in the Western Cape

	Client(s)	Project Developer(s)	Location	Status
1	Elgin Fruit Juice	GCX Africa	Grabouw	Operational
2	Uilenkraal Dairy	Cape Advanced Engineering	Darling	Operational
3	Zandam Cheese	ibert	Durbanville	Operational
4	Waste-Mart, Afrox	New Horizons Energy	Athlone	Operational
5	Bayside Mall	JG Afrika, WEC Projects, BiogasSA	Table View	De-commissioned
6	Ceres Fruit Juice	Veolia	Ceres	Operational
7	RCL Foods	Trigen	Worcester	Pilot operational Jan 2015
8	Distell Stellenbosch	Veolia	Stellenbosch	Operational
9	SABMiller (InBev)	Unknown	Newlands	Operational
10	Rhodes Food Group	Unknown	Stellenbosch/ Franschhoek	Operational
11	Vyvlei Dairy	Bio2Watt	Malmesbury	Awaiting IPP signoff or private offtake agreement
12	Interwaste[7]	Black & Veatch	Wellington	Expected 2019
13	Reliance Composting [8]	Reliance Composting	Klipheuwel	Raising funding
14	ArcelorMittal, Saldanha Bay Municipality	West Coast Power Solutions / Optimus Investments	Saldanha Bay	Pending Saldanha Bay Municipality Council and National Treasury decision
15	Winelands Pork	GCX Africa	Stikland	Halted - changed to a pyrolysis plant
16	Confidential	Alveo Energy	Citrusdal	Design stage
17	Confidential	Global Energy	Swartland	Design stage
18	FairCape	New Horizons Energy	Kuiperskraal	Planning stage
19	Distell Worcester	Veolia	Worcester	Constructed, to be operational 2018
20	Distell Epping	Veolia	Epping	Planning stage, design to commence 2017, expected 2019
21	Waste to Food	Closing the Loop	Philippi	Constructed

[7] Drakenstein Intergrated Waste Management Facility
[8] Organic Recycling Facility

4. Case Studies

4.1. Zandam Cheese & Piggery

4.1.1. Introduction

Zandam Cheese is a cheese company established in the late 1950s by the Delle Donne and & Monaco family. Zandam also doubles as a piggery feedlot, with up to 7,000 pigs on-farm. The company is known for its specialty Italian cheeses and innovation in the sector, having won multiple national awards, including four top three placements at the 2016 South African Cheese Awards. The company's innovative and forward-thinking approach is evident in other areas of its operation, such as the adoption of a number of sustainability initiatives. The following case study will focus on Zandam's biogas installation.

4.1.2. Process overview

Pig manure slurry from ~650 sows at the adjacent piggery, is fed into an anaerobic digestion process (~48 tons of manure per day). The biogas produced is used in a CHP engine to produce electricity and heat. The digestate is separated into solids and liquids. The liquids are then pumped to maturation dams and later used for pasture irrigation. Further technical specifications are shown below in Table 3.

Table 3: Zandam Cheese biogas project

Location	Durbanville, Cape Town
Project developer	ibert (Pty) Ltd
Project owner	Ibertzandam (Pty) Ltd
Feedstock	Pig manure 35 – 45 m^3/day at 6% solids (~40 tons/day)
Energy output	75 kWe baseload ~100 kWth average
Technical specifications	▪ 500 m^3 dual chamber bio-reactor (AD) ▪ 200 m^3 storage tank ▪ MAN 75 kWe CHP (PH1) ▪ Thermo-Gas-Lift technology for heating, mixing and desulphurisation ▪ Screw press to increase solids concentration in feed
Sources	Unterlechner (2016); Delle Donne (2016); Unterlecher (2017); Hager (2017)

The electricity generated is used in the cheese facility for purposes such as refrigeration, chilling, lighting, driving motors and air compression. Similarly, the heat generated by the CHP is used for pre-heating water used in the operations, e.g. for pasteurisation, steam production, hot water supply and cleaning.

4.1.3. Benefits

Electricity cost savings: As of 2016, Zandam pays Eskom R1.10 per kWh of grid electricity purchased, with yearly price increases generally significantly exceeding inflation. With the biogas installation, Zandam pay ibert R1.01 per kWh of electricity, with yearly increases fixed according to inflation. Zandam thus save on electricity, likely with increasing savings every year.

Heating cost savings: Diesel fuel previously used for the boiler has been substituted by heat from the CHP.

Reduced environmental impact: In addition to economic benefits, the biogas installation has had positive environmental benefits. Before biogas, the pig manure effluent was disposed of directly to maturation dams, leading to uncontrolled methane (a potent greenhouse gas) emissions to the environment and an effluent with a high chemical oxygen demand. The methane is now captured and utilised, and the effluent released has a reduced chemical oxygen demand before being sent to the maturation dams.

4.1.4. Challenges

Due to Eskom grid-feeding regulations[9], the system has been designed with control system that ensure electricity is produced at a rate below the facility's consumption, in order to avoid feeding power back onto the grid. This leads to inefficiencies as the generator output must be limited in off-peak hours or completely curtailed. Also, the manure slurry is only 6% solids, due to the use of water for flushing, and thus a screw press had to be installed to dewater the feed.

Figure 5: Zandam biogas installation

[9] Zandam is connected to Eskom's Low Voltage grid, and therefore is not permitted to feed excess electricity produced back onto the grid.

4.1.5. Investment and financing

The plant capital costs amounted to R8.5 million, which was split between Zandam (the client) and ibert (the project developer). Zandam paid for all immovable infrastructure, such as the digesters, accounting for 32% of the capital. In return, ibert paid for all movable components, such as stirrers, control systems, and the CHP equipment. It took approximately 5 months to secure financing agreements for the project.

The agreement between Zandam and ibert operates as follows:

- ibert pays Zandam a rental fee for the use of the immovable parts (hereafter referred to as “the rental agreement”).
- ibert sells electricity to Zandam at a price of R1.01/kWh, increasing annually in line with the inflation rate (“the fixed escalation agreement”).

These types of contractual agreements are typical in the South African industry, though differing slightly among projects, for the following reasons:

- The **shared capital agreement** spreads initial capital outlay between both parties, therefore each party pays a smaller amount than if the installation was paid for by a single party.
- The **rental agreement** guarantees the client a minimum annual income/savings amounting to the cost of rental, regardless of the amount of energy purchased.
- The **fixed escalation agreement** guarantees the client a predictable energy cost. This is generally desirable for the client, as South African electricity prices have been increasing at above-inflation rates in recent years. Additionally, as the client only pays for each unit of energy supplied by the project developer, the project developer is incentivised to deliver the agreed amount of energy. This reduces the risk of monetary loss to the client arising from project downtime, inefficiency or other causes of energy supply losses. For the project developer, this guarantees a secure, long-term offtake agreement. This is desirable for the project developer, as the vast majority of financiers will not provide funding without such an agreement. As such, the project developer is more likely to obtain access to funding. Additionally, it allows the project developer to develop a bankable project as they can predict their likely income, regardless of changes to grid prices.

4.2. Uilenkraal Dairy

4.2.1. Introduction

Uilenkraal is a total mixed ration (TMR) dairy cattle feedlot located in Darling. The farm is a major producer of milk, supplying around 30% of a major Western Cape milk distributor’s requirements. Uilenkraal also operates a commercial animal feed milling facility. The following case study will focus on Uilenkraal’s biogas installation.

4.2.2. Process overview

Cow manure slurry from 1,500 lactating cows is fed into an anaerobic digestion process. Uilenkraal had the initial advantage of having automated manure scrapers installed in their feedlot, which allowed manure collection. Wash water from the dairy plant is used to dilute the manure to the required solids percentage before being fed into the bio-digester.

The biogas produced is used in locally manufactured CHP engines to produce electricity and heat. The digestate liquid effluent is used for land fertilisation, while the fibre solids are used to produce animal bedding. Further technical specifications are shown in Table 4.

Table 4: Uilenkraal biogas project[10]

Location	Darling, Western Cape
Project developer	Cape Advanced Engineering
Feedstock	Cow manure, at 1 - 14% solids Feed amount variable over project lifespan[11]
Energy Output	500 kWe installed capacity
Technical specifications	▪ 7,000 m^3 lagoon digester (hybrid mixed, heated, plug flow) ▪ 20 – 40 day hydraulic retention time ▪ 2 x 250 kW CHP ▪ Electrical system designed for up to 1 MW, with addition of further CHPs
Sources	Taylor (2015); Basson (2016); Claasen (2015); Engineering News (2015); Taylor (2017)

The electricity generated is used to offset Eskom electricity purchases, which are significant, due to the milling and dairy operations. Uilenkraal has an annual average demand of ~240 kWe and an occasional peak demand of 750 kWe. The electricity is used predominantly (60%) for the feed mill, as well as the dairy (20%) and irrigation (20%). The biogas installation has the potential to produce peak output up to 1 MWe with the addition of further CHP units.

4.2.3. Benefits

Electricity cost savings: The electricity generated is used to offset Eskom electricity purchases, which were on R160,000/month on average at the time of interview. With both CHPs in in operation, the plant has met up to 95% of electricity needs, reducing the bill to R12,000/month.

Animal bedding production: Digestate fibre solids are mixed with sawdust and composted. This composted mixture can then be used as a bedding material for the cattle feedlot. This serves as an alternative for sand, which was previously used.

[11] At the time of interview, the power generating plant was operating at <50% capacity, with an estimated feed of ~260 t/day manure. Maximum feed is estimated at 175–350 ton/day.

Figure 6: Uilenkraal, digestate composting

4.2.4. Challenges

Once again, embedded generation regulations have been cited as a challenge. The plant has sufficient feedstock and gas to produce excess electricity to feed onto the power grid, but obtaining the permission to do so is challenging. The installation experienced crusting, the formation of a thick, solid layer on the surface of the digester, after about two years of operation. This was determined to be caused by straw from animal bedding entering the digester. The crusting can be mitigated by macerating / chopping the feedstock before input into the digester. Additionally, the plant experienced a digestate sludge pump failure at one stage.

4.2.5. Investment and financing

The plant capital costs amounted to ~R11 million. Uilenkraal owns ⅔, while Cape Advanced Engineering (CAE) are ⅓ owners. Similarly to the previous case study, Uilenkraal pays CAE per unit of energy produced for plant operation, maintenance and renewal, at a rate of R0.50/kWh. The plant is expected to pay itself back over a period of 10 years.

Figure 7: Uilenkraal dairy feedlot (photo: Jarrod Lyons)

4.3. New Horizons Energy Athlone

4.3.1. Introduction

New Horizons Energy Athlone is a waste management facility accepting 500–600 ton/day of general waste. This project differs from previous case studies in a number of ways, namely:

- **Feedstock**: The facility accepts mixed, high organic, waste, including source separated Municipal Solid Waste (MSW) instead of being limited to the use of pure organic waste. This has dramatically increased the flexibility of the plant to accept waste otherwise destined to landfill.
- **Gas separation**: The biogas generated from the facility is separated into compressed bio-methane and liquefied carbon dioxide.
- **Organic compost**: The digestate from the plant is suitable for use as a compost.
- **Recyclables**: As part of the operations, any recyclables are recovered, baled and provided to recycling companies.
- **Refuse derived fuel** (RDF): From the resultant waste the operation prepares a RDF suitable for power generation, cement manufacture or plastics to oil facilities.

4.3.2. Process overview

The waste is processed in a materials recovery facility (MRF) to separate it into various fractions - organics, recyclables and non-recyclables using a number of physical separation methods. These methods are detailed in Table 5 and Figure 8.

Table 5: New Horizons Energy

Location	Athlone, Cape Town
Project developers	Clean Energy Africa (Pty) Ltd and Waste-Mart Energy (Pty) Ltd
Feedstock	500 – 600 ton/day high organic mixed waste (200 – 300 ton/day organics)
Gas output	1200 Nm^3/hr biogas, separated into approximately 760 Nm^3/h bio-methane and 18 tons per day CO_2 (760 Nm^3/hr CH_4, 740 Nm^3/hr CO_2)
Technical specifications	▪ MRF: manual sorting, magnetic and physical separation, air blowing, an Organic Extruder Press. ▪ 98% methane purity
Sources	Shmulevich & Otterman (2016); Friedman (2017); Otterman (2017)

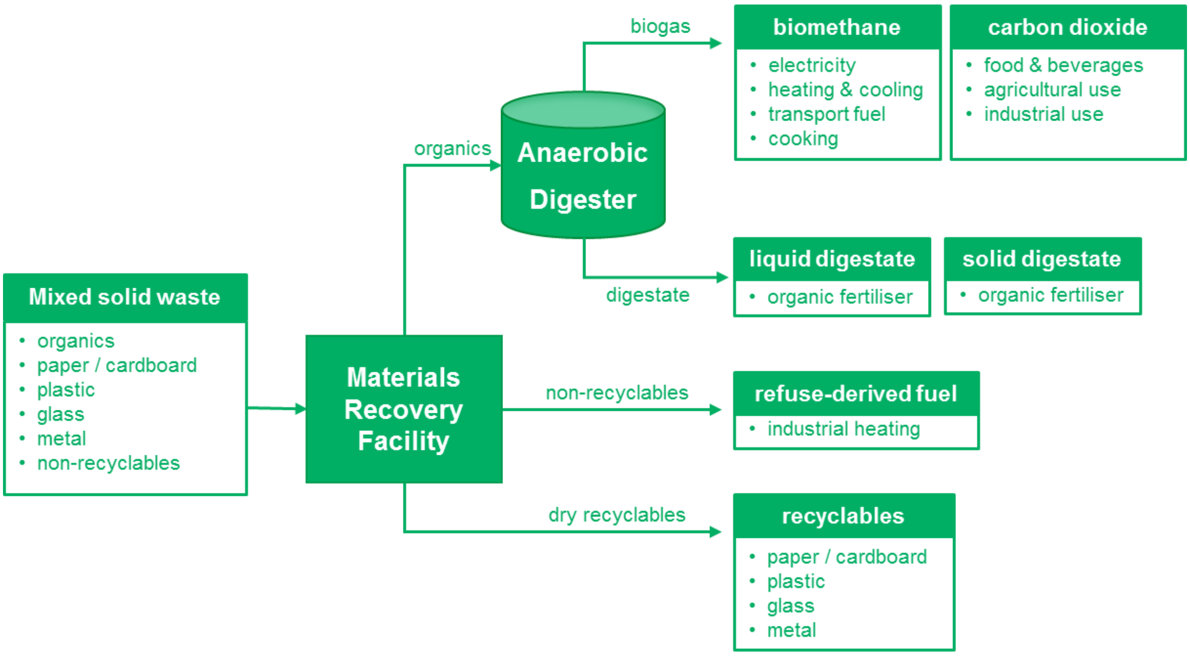

Figure 8: Process flow diagram of New Horizons Energy, Athlone

4.3.3. Benefits

As New Horizons Energy is not producing biogas for their own consumption, the benefits derived from the project differ from previous case studies:

Compressed biomethane: Suppliers of gas in the Western Cape namely, Mossel Bay and Chevron have been experiencing diminishing gas production capabilities in the recent past. Furthermore, the major supplier of LPG in the country, Sasol, is geographically distant, leading to significant costs in transportation the gas. As such, the Western Cape faces a gas supply shortage in comparison to the north-eastern areas of South Africa[12]. At the time of writing, this shortfall was so significant, that transporting LPG can be feasible even for distances greater than 1000 km. In comparison, transporting compressed biogas is viable for 200 km at most. Biomethane can serve as a substitute for LPG, and hence there exists a shortfall in the market, which can be (partially) fulfilled by the biomethane supplied by New Horizons Energy.

CO_2 capture and usage: With most biogas plants, CO_2 is vented, whereas New Horizons Energy compresses and bottle the gas. Captured CO_2 has a wide variety of uses, which are depicted above.

4.3.4. Challenges

Low availability of organics: One of the major challenges is the low organics in the MSW, which results in less organics diverted to the AD and a greater percentage of waste to landfill. This could be addressed by supplementing the MSW with waste in high organic content (>90%).

Refuse derived fuel: Due to the MSW feedstock's composition and variability, obtaining RDF with a consistent, high calorific value is a challenge.

[12] However, this may be less of a concern in the in future with the recent Sunbird LNG project on the West Coast.

Liquid digestate: Offtake or disposal of liquid digestate is a challenge, largely due to the location of the facility. As it is located in an industrial area, there is a lack of agricultural offtakers in the area. In addition, due to the fact that the liquid consists almost entirely of water, logistics costs to potential off-takers are generally higher than the sale value of the product.

4.3.5. Investment and financing

Total investment in the project is estimated at R400 million, making it the most expensive biogas projects in the country. This is largely due to the gas separation, cleaning and compression, which adds approximately 30% to capital costs, while the MRF also adds significant costs. Waste-Mart, a waste management company, owns a 25% share in the project and supplies a portion of the feedstock to the plant.

4.4. Elgin Fruit Juices

Note: at the time of this site visit, the company itself was operating the digester at Elgin Fruit Juices. As of late 2016, the process operator has moved to another biogas plant, with GCX Africa being appointed to oversee the operations. Revisions have been made where appropriate.

4.4.1. Introduction

Elgin Fruit Juices (EFJ), a subsidiary of the Two-a-Day Group, is large fruit juicing operation situated in Grabouw.

4.4.2. Process overview

Mixed organic waste, including off-specification apples and pears, and fruit and vegetable waste, is fed into an anaerobic digester[13]. The gas produced is fed to a CHP to produce electricity and heat. Further technical specifications are shown below in Table 6.

Table 6: Elgin Fruit Juices

Location	Grabouw, Western Cape
Project Developer	Developed by Beckedorf BioEnergy GmbH, previously operated by Elgin Fruit Juice Currently operated by GCX Africa
Feedstock	Mixed organic waste – specifically fruit and vegetables and other food waste[14]
Energy Output	527 kWe 550 kWth, used to generate 500 kg/hour of 10 bar_g steam (at maximum capacity)
Technical specifications	▪ 2 700 m^3 digester ▪ Jenbacher 12 cylinder CHP
Sources	Naicker (2016); Mostert (2015); GCX Africa (2016); altenergymag (2015); Fourie (2017)

[13] Note: At the time of writing, meat and abattoir waste was included in the mixed organic waste fed to the anaerobic digester. This is not the done currently with GCX Africa.
[14] Note: at the time of writing (prior to GCX Africa taking over the plant) the anaerobic digester had the following feedstock: 40 ton/day apples and pears, 6 ton/day vegetable waste, 1.5 ton/day blood and 0.5 ton/day floor sweeping from poultry, 1-2 ton/day blood and 1 ton/day manure from abattoir, 2-3 ton/week floor sweepings and 4-5 ton/week from abattoir, 4.8 ton/day mixed / unsorted waste from fruit/veg producer, 3-5.4 ton/week processed meat, and 3-5 ton/month food waste. Total average of 56 – 58 ton/day.

During peak juicing season, the majority of the electricity generated is used in the juicing process. However, during off-peak season, there is an excess production of 200 – 300 kWe. The heat generated is used to offset coal requirements for a boiler, producing 500 kg/hour of 10 bar_g steam used in the process. Digestate produced is stored for use as a fertiliser.

One of the installation's notable points is the fact that using the biogas plant, EFJ serves as a waste management solution for other organic waste producers in the region.

4.4.3. Benefits

Electricity cost savings: Elgin Fruit Juice can produce approximately 3,700 MWh/year of electricity, thus significantly offsetting their electricity bill.

Heating cost savings: Coal previously used for the boiler has been substituted by the use of heat from the CHP to produce steam.

Centralised waste management solution: EFJ accept waste from at least seven other organic waste producers in the region, acting as a centralised organic waste solution. The centralisation of solutions can be more feasible due to economies of scale. EFJ charge a gate fee for wastes accepted from third parties; in order to incentivise third parties, this gate fee is lower than landfill gate fees.

4.4.4. Challenges

Grid feeding: as noted with other biogas installations, one of the challenges encountered is the feeding of excess electricity to the grid, or wheeling to a third-party off-taker.

Odour: The decomposition of stockpiled organic wastes resulted in odour complaints. An aldehyde sprayer system was installed to address this; however, the sprayer system was not effective enough. As a result, the waste feedstock and stockpile management has been altered by GCX Africa. This has eliminated odour problem and the sprayer system is thus no longer required.

Digestate management: Difficulty in finding offtakers for digestate were noted in the past, with digestate being used for irrigation. A screw press was acquired to concentrate the digestate and produce a more saleable product.

Skills and training: Prior to GCX Africa, the staff occasionally fed unsuitable material to the digester (plastics, bottles). This can lead to process issues such as pipe blockages. This has been eliminated under GCX Africa's operation of the plant.

4.4.5. Investment and financing

The plant capital costs are estimated at R20 million, covered by the client.

4.5. Bayside Mall

Note: At the time of this site visit, the digester at Bayside Mall was operational. However, the plant was de-commissioned in 2016 due to the costs being too high. Although the plant was originally envisaged to generate electricity, the scale was not large enough to make this economically feasible and thus there was an unfavourable cost-benefit ratio. Revisions have been made where appropriate.

4.5.1. Introduction

Bayside Mall is a large shopping mall in Table View, Cape Town with over 100 commercial tenants and 8 million visitors annually. The mall has significant water and energy requirements, which motivated the implementation of several sustainability measures, one of which was a biogas installation.

4.5.2. Process overview

Mixed organic waste is collected daily from retailers and the mall common areas. The waste is sorted by hand, macerated and blended with water before being fed into the digester. Further technical specifications are shown below in Table 7. The energy generated from the biogas was used to reduce grid purchases, saving about 590 kWh/day.

Table 7: Bayside Mall

Location	Table View
Project developer	JG Afrika WEC Projects (EPC) Biogas SA
Feedstock	570 kg/day (largely food waste)
Proposed energy output[15]	Total: 215 MWh/yr Electrical: 92 MWh_e/yr, ~13 kW_e Heat: 123 MWh_e/yr, ~18 kW_e
Technical specifications	30 500 m^3/yr biogas production 35 °C – 39 °C mesophilic operation 21 day hydraulic retention time
Sources	Heydenrych (2015); Vice (2016); Bayside Mall (2015); Vice, et al. (2016); du Preez (2017)

4.5.3. Benefits

Proposed energy savings: It was proposed that the energy generated from the biogas reduce grid purchases and save about 215,000 kWh/yr. Assuming an electricity price of R1.47/kWh[16], savings for energy consumption was estimated at R316,000/yr. Bayside Mall's electricity costs[17] are approximately R10 million/yr (Vice, 2016). Thus, energy savings could be ~13%.

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[15] The plant was originally envisaged to generate electricity but the scale was not large enough (du Preez, 2017).
[16] City of Cape Town 2016/17 Commercial Customer Small Power User 1 tariff
[17] Including charges for: energy consumption, network demand, energy demand and network access for the period of July 2011 – July 2012.

Proposed greenhouse gas emissions reduction: The emissions reductions of the project could amount to approximately 710 ton CO_2-eq per year.

Proposed waste management savings: Prior to the biogas system, organic waste was disposed of at landfill by a private waste management company. The savings that could be accrued from the avoidance of landfill gate fees (i.e. excluding energy savings) was expected to pay back the project costs (R2.5 million) in 10 years, at an internal rate of return of 10.3%.

4.5.4. Challenges

Waste collection and separation: Waste is generated at multiple sites throughout the mall, and must hence be collected in separate 240 litre bins. Additionally, the waste gathered is not separated at source, and must be sorted by hand before feeding into the digester[18].

4.6. Case study synthesis

With the above case studies in mind, the biogas business case generally requires the following:

- a significant and consistent volume of a digestible feedstock, economies of scale can play a significant role in feasibility.
- significant waste management costs
- the need for a significant amount of electrical and thermal energy

Additionally, other factors that affect the business case include:

- the (cost of) management of the digestate stream

Key challenges in the South African biogas industry include skills and training. Due to the industry's infancy in the country, there is a lack of operational skills and capacity. In certain cases, due to poor plant operation, local operators have been replaced by more experienced operators from countries such as Germany. This highlights the need for local biogas training.

[18] Cardboard, paper, plastics, tetrapak, glass and metals are sorted for recycling.

5. General business case for biogas

From the case studies, it is clear that the financial viability of biogas facilities is highly site specific. However, this section presents a general business case for biogas for a number of scenarios, to highlight some of the key factors that determine biogas viability. Before presenting the scenarios, some general observations on the project costs for biogas facilities in the South African context is presented. It should be noted that the business case is only part of the picture in terms of overall project viability. Other elements include securing finance and obtaining regulatory approval, which are not covered in this document.

5.1. Project costs in the South African context

5.1.1.1. Structure of project capital expenditure

Investment costs for biogas projects consist largely of capital costs for the digesters, engines, feedstock supply systems, control systems, storage tanks, electricity and/or gas grid connections. Other major costs include project design, engineering and environmental services, legal fees, notary and land registration fees and banking charges. Figure 9 below shows typical relative cost contributions.

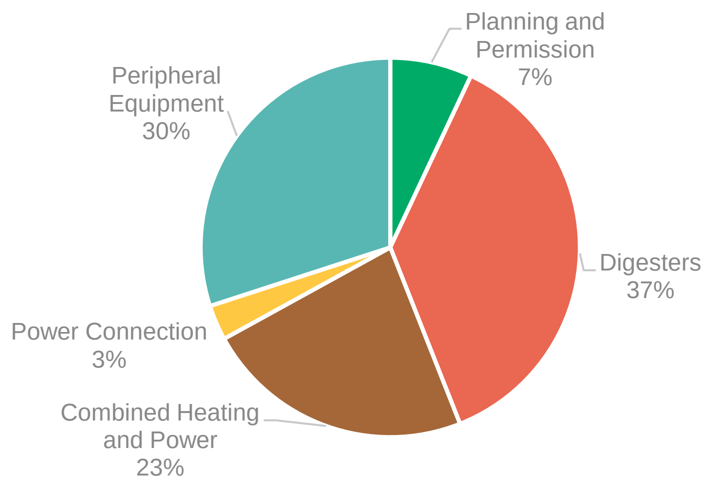

Figure 9: Typical project investment cost contributions

It is notable that digesters, CHP/engine and peripheral equipment costs dominate. To minimise these costs, various design measures can be taken. For example:

- Digester costs can be reduced by using lagoon digesters as opposed to concrete (stirred tank) digesters.
- Engine costs can be reduced by ensuring the correct engine choice for the required energy output. In other words, considering for what purpose the biogas will be used for (electricity, heat, or both) and picking the correct engine type19. Furthermore, plant capacity can be increased over time with the addition of engines during plant lifetime.[20].

[19] CHP, Otto, Pilot or Turbine

[20] However, this should be considered during plant design, to ensure other equipment (such as digesters, buffer tanks, electrical control system) is adequately designed to handle increased capacity.

5.1.2. Capital cost

From site visit and interview data, a costing graph for biogas installations (based on electrical capacity) was determined. This was then compared to South African literature data (from SABIA), as well as German literature data (from FNR). This analysis is presented in Figure 10 and Figure 11. These figures shows a degree of consistency between costs for the three data sources, but also some variability, which suggests that there may be many underlying factors to the capex (e.g. design of digester, type of energy infrastructure etc.).

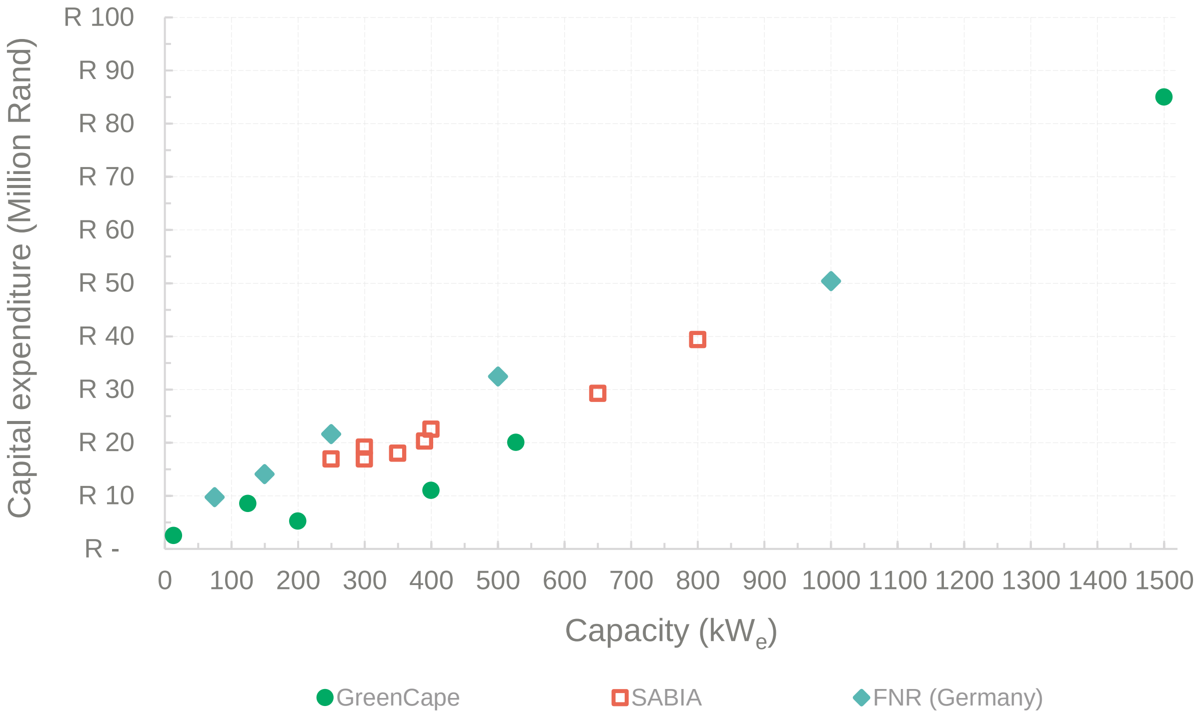

Figure 10: Biogas plant capital expenditure versus electrical capacity up to 1,500 kW$_e$[21]

[21] See Appendix for full figure (up to 5 MW)

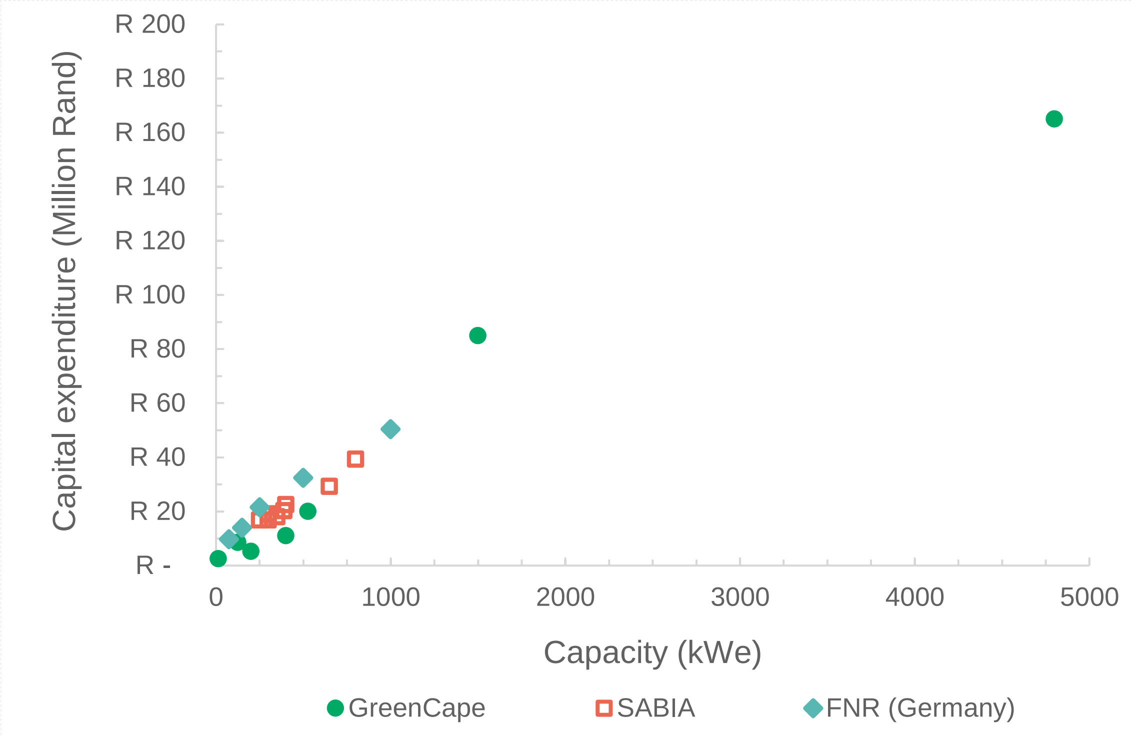

Figure 11: Biogas plant capital expenditure versus electrical capacity up to 5 MW$_e$

5.1.3. Operating costs in the South African context

Operating expenses for three biogas plants was obtained, with an average operating expense of R1,700 year^{-1} kWe^{-1} or R253/hour on average, although values varied significantly between the installations. Similarly, SABIA (2015) reported operating costs of R45/hour–R510/hour (more than an order of magnitude difference), with an average of R235/hour.

It should thus be noted that system size and design play a major factor in operating expenses. Systems generally become cheaper per unit energy output (i.e. R/kW) as they become larger, due to economies of scale. Furthermore, the digester type plays a role, with plug flow lagoon-type digesters generally being cheaper than conventional vertical continuous stirred tank reactor (CSTR) type digesters.

5.2. Scenario Analysis

5.2.1. Outline of scenarios

As scale is clearly a significant determinant of costs, two primary scenarios were considered, namely:

- Scenario A: a small-scale biogas installation (in a commercial context)
- Scenario B: a medium scale biogas (in an agri-processing context)

The contexts were selected on what has been observed to be likely or typical applications for biogas in the Western Cape.

5.2.2. Approach to assessment of financial feasibility

Financial viability was determined using a financial viability assessment tool (in Excel) developed specifically by GreenCape for biogas pre-feasibility assessments.

The input parameter to the tool are:
- Feedstock type
- Feedstock amount
- Electricity tariff
- Logistics (mass, distance)
- Gate fee
- Financial variables (inflation, loan/equity split, interest rate)

The outputs of the tool are:
- Capital cost
- Operating costs
- Electricity production
- Heat production
- Financial indicators (PBP, IRR, NPV, LCOE)

The tool contains a number of assumptions (all set as adjustable parameters). These include literature values for the energy yields of various feedstocks, feed to digestate ratios based on average values derived from literature and existing plants operating in the Western Cape. Capital and operating costs are based on the South African cost data presented in section 5.1. For CAPEX, a curve has been fitted to the industry data to enable estimation for different plant sizes. Lifespan of equipment has been based on literature data augmented by data gathered from project developers. Default (but adjustable) parameters are available for other costs and financial parameters in the SA context (e.g. tax rates, inflation, loan/equity split, interest rates) as well as the Western Cape context (e.g. gate fees, electricity tariffs, fuel costs).

5.2.3. Input assumptions

For each of the scenarios, the set of input assumptions were made (see details in scenario descriptions to follow). To determine the waste management costs the following assumptions were made:
- Logistics costs were determined according to the data gathered through the Western Cape Industrial Symbiosis (WISP)[22] and literature values. An average value of R15 ton^{-1} km^{-1} was used based on Strachan et al (2016), IBBK (2016), and WISP (2016).
- A number of landfill gate fees value were considered, based on chosen scenario conditions, such as plant location and waste type[23]. These figures were based on 2016 Western Cape landfill gate fees (see details in scenario descriptions to follow).

With regard to the financial parameters, a discount rate of 15% and expected rate of return of 15% was assumed. This is consistent with an assumption of funding from development finance institutions or multi-lateral organisations, as is typically the case for biogas facilities in the SA context currently.

[22] For more information see: greencape.co.za/wisp/
[23] General, Special/Hazardous

GreenCape

5.2.4. General business case for Scenario A: a small-scale, commercial biogas installation

This scenario is based on what might be expected for a commercial facility, such as a very large mall where food waste is separated, or a small central facility for a number of food waste generators such as restaurants, hotels and malls. The input parameters used in the financial viability assessment are presented in Table 8 below. The results of the viability assessment are presented in Table 9.

Table 8: Input assumptions for the viability assessment for Scenario A: a small-scale, commercial biogas installation

Parameter		Value used
Power output		25 kW
Annual electricity production		176 MWh/yr
Heat output		36 kW
Annual heat production		251 MWh/yr
Feedstock chosen		Food waste
Feed rate		1.3 ton/day
Capital cost		R5.9 million
Cash: debt ratio		100:0
Plant life		15 years
Power usage		100%
Heat usage		100%
Waste management costs/savings		1.3 ton/day at R395 per ton[24]
Power purchase price		**R1.10 per kWh**
Heating fuel displacement potential	Coal	-
	Diesel	R266 000 R/yr | 251 MWh/yr | 24 000 litres/yr
	Heavy Fuel Oil	-

Table 9: Results of the viability assessment for Scenario A: a small-scale, commercial biogas installation

Parameter	Calculated Value
IRR	**10%**
NPV	**-R1.3 million**
LCOE	R2.99/kWh

It is visible from the resultant IRR (10% i.e. <15%) and NPV (negative) that **the small-scale biogas system is not financially viable**. The scenario assumptions are relatively optimistic: considering the use of an energy-rich feedstock, 100% heat and energy usage, complete substitution of diesel (an expensive fuel) for heating, 100% landfill savings (considering relatively expensive City of Cape Town general waste gate fees) for feedstock diversion, as well as a 100% cash purchase (thus no interest repayment on a loan).

[24] Comparable to City of Cape Town General Waste landfill tariff, distance to landfill set to 10 km for logistics costs

If all other variables are left constant, but power purchase price (i.e. resulting in savings) increased to R1.47/kWh, a typical tariff for City of Cape Town commercial users[25], such as a mall, IRR increases to 12%, with NPV improving to -R830 000. **Even with optimistic conditions, the system is unlikely to be profitable, unless capital costs were significantly reduced.**

For a 25kW system such as that proposed here, an electricity saving of **~R2.20/kWh** is necessary for financial viability. In this case, it does not seem to make business sense to invest in biogas, which may explain the apparent lack of (commercial) small-scale installations in the Western Cape, despite a number of biogas project developers targeting this sector.

5.2.5. General business case for Scenario B: a medium size, red meat abattoir biogas installation

This scenario considers a system of 250 kW, a more common size for a commercial biogas installation. The feedstock considered is abattoir waste. Three cases were considered within Scenario B. These were:

- Case B1: No waste disposal cost;
- Case B2: High waste disposal cost; and
- Case B3: Lower waste disposal cost, lower electricity price and provision of on-site heat needs

5.2.5.1. Scenario B: Case B1

The input parameters used in the financial viability assessment for Case B1 are presented in Table 10. The results of the viability assessment are presented in Table 11.

[25] Small Power User - High Consumption (>1 000 kWh/month) plan

Table 10: Input assumptions for viability assessment for Scenario B, a medium size, red meat abattoir biogas installation: Case B1

Parameter		Model value used
Power output		250 kW
Annual electricity production		1.76 MWh/yr
Heat output		360 kW
Annual heat production		2.51 MWh/yr
Feedstock chosen		Red meat abattoir waste Composition[26]: 75% manure, 12.5% blood, 12.5% animal tissue
Feed rate		52 ton/day[27]
Capital cost		R13.7 million
Cash: debt ratio		20:80 at 18% interest
Plant life		15 years
Power usage		100%
Heat usage		100%
Waste management costs/savings		None[28]
Power purchase price		**R1.00 per kWh[29]**
Heating fuel displacement potential	Coal	R540 000/yr = 2 500 MWh/yr = 360 ton/yr
	Diesel	-
	Heavy Fuel Oil	-

Table 11: Results of viability assessment for Scenario B, a medium size, red meat abattoir biogas installation: Case B1

Parameter	Calculated Value
IRR	**11%**
NPV	**-R2.7 million**
LCOE	R2.21/kWh

It is visible from the **resultant IRR (11% i**.e. <15%) and **NPV (-R2.7 million)** that the above conservative case (Case B1), for Scenario B (a commercial scale 250 kW system), is **not viable**.

The above scenario parameters, namely:

- free waste disposal on farmland (or cheap landfilling in rural municipalities)
- a power purchase price (i.e. savings) of R1.00/kWh, comparable to Eskom's Ruraflex tariff scheme
- use of a low-cost thermal energy source, such as coal

[26] Typical waste composition based on abattoir site visits
[27] ~1 000 Livestock Units per day
[28] Assuming the abattoir is located on/near a farm which can be used for (free/very low cost) land disposal of waste
[29] Comparable to Eskom Ruraflex tariff package

are generally representative of high-throughput, rural abattoirs in the Western Cape. Biogas installations for these types of waste producers were typically rare in the past, but, due to changing economic and legislative conditions, are expected to become more common. These changes include which landfills are allowed to receive / dispose of abattoir waste. This pertains to the National Norms and Standards for Disposal of Waste to Landfill that regulates the minimum requirements for the construction of landfills and the types of waste can be disposed at specific landfills that came into effect in 2016. This change in legislation can increase waste management costs substantially for two primary reasons: logistics costs (waste needs to be transported further to be disposed at an appropriate landfill), and disposal fees (gate fees are generally higher at more engineered sanitary landfills).

To examine the financial viability of biogas facilities taking into account the more likely costs of waste disposal and also other energy use profiles and costs, a number of alternative scenarios with different input parameters were considered (Case B2 and B3). These scenario cases are presented in Table 12 below. In addition, to examine the effect of scale, a number of scenarios considering the profitability of a 125 kW installation were also analysed for all three cases. Overall, these results emphasise the significance of scale.

Table 12: Results of the all the viability assessments for Scenario B: a medium size, red meat abattoir biogas installation

Size (kW)	Scenario B		IRR	NPV	Required size for viability[30]
250	Case B1	R1.00/kWh Free disposal 100% electrical and thermal (coal) usage	11%	-R2.7 million	**>575 kW**
125			7%	-3.9 million	
250	Case B2	R1.00/kWh R500/ton gate fee + 30km logistics 100% electrical and thermal (coal) usage	46%	R28 million	**>40 kW**
125			34%	R11 million	
250	Case B3	R0.80/kWh R200/ton gate fee + 10km logistics 100% electrical, 50% thermal (coal) usage	20%	R4 million	**>140 kW**
125			14%	-R0.47 million	

5.2.5.2. Scenario B: Case B2

The Scenario B: Case B2 considers landfilling of the hazardous portion of abattoir waste (blood, innards, condemned carcasses), which generally accounts for about 25% of a typical abattoir waste stream, at a hazardous waste disposal facility. A landfill gate fee of **R500/ton**[31] and **transport distance of 30 km** was assumed. With all other variables are left constant, **IRR**

[30] NPV > 0, IRR > 15%

[31] Comparable to Special/Hazardous waste gate fees outside the City of Cape Town

increases to 46%, with **NPV improving to R28 million**. This type of scenario, where there is a cost to disposal, is very robust to changes in scenario conditions, as waste management costs become dominant.

5.2.5.3. Scenario B: Case B3

Even for Case B3, with lower disposal costs (**R200/ton and transport distance of 10km)**, a power purchase price (i.e. electricity savings) of only **R0.80/kWh**, and **50% heat usage,** Scenario B is favourable, resulting in an **IRR of 20% IRR** and **NPV of R4 million**. Interestingly, however, downsizing this facility to 125 kW (26 ton/day feedstock) would not be financially viable, resulting in an IRR of 14% and NPV of –R470,000.

In order to examine the role of economies of scale and effect of scenario parameters, a sensitivity analyses was done on Case B1 (no waste disposal cost), B2 (high waste disposal cost) and B3 (lower waste disposal cost, electricity tariff and heat utilisation). The results are depicted in Figure 12.

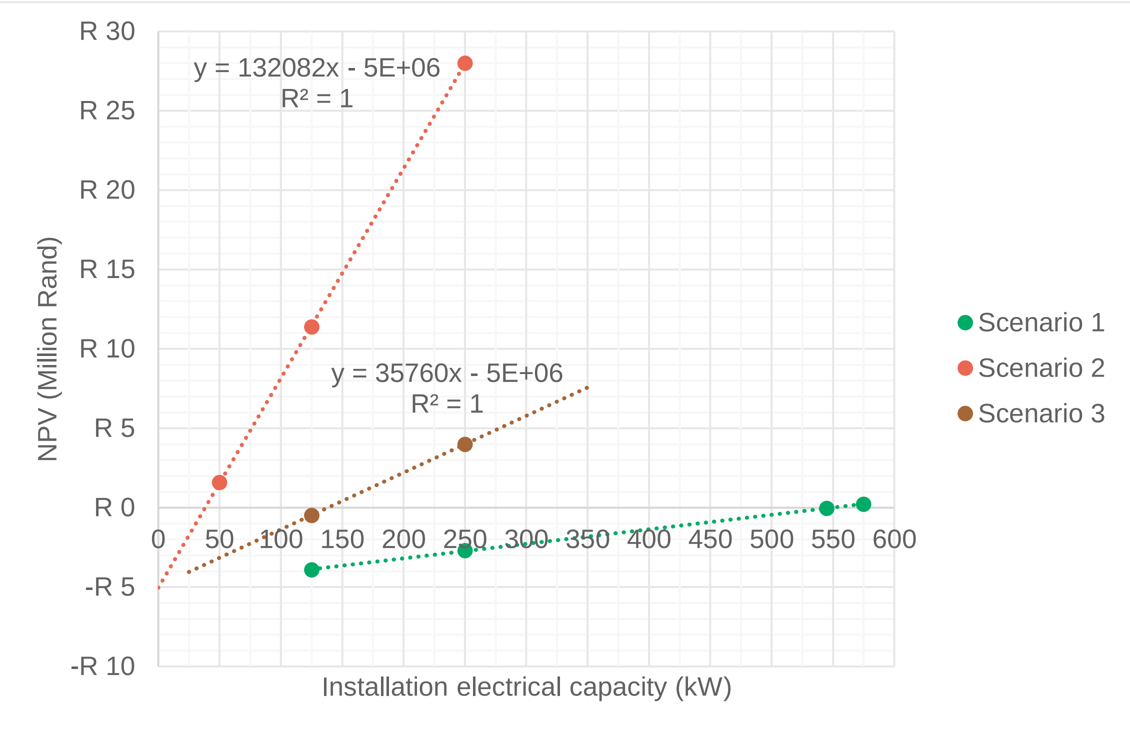

Figure 12: NPV vs electrical capacity for red meat abattoir biogas installation scenarios

As is evident from the above sensitivity analyses, waste management costs (gate fees, logistics costs) play a key role in determining the viability of a biogas installation. This suggests that **waste management costs could be a stronger driver for biogas installations in South Africa than energy savings**, due to the relatively low energy costs in South Africa.[32]

[32] Electricity prices in Europe are typically twice as much as South African prices.

6. Conclusions

6.1. Insights from case studies

- **Failure of projects has primarily been due to unfavourable cost-benefit ratio**, often as a result of insufficient scale, and particularly when electricity generation was not utilised, or could not be utilised as envisioned e.g. fed onto the grid.

- **The successful business cases are driven by a variety of models regarding feedstock, utilisation of energy for heat and electricity and off-take of products.** However, the success factors they have in common include:
  - **Energy savings:** Energy generated from the biogas was used on-site, often to offset own-use or for use within a small radius of production (e.g. by neighbours). This resulted in electricity and/or heat cost savings by reducing (Eskom) electricity purchases and/or substitution of diesel. These are significant for milling and dairy operations.
  - **Waste management savings:** Cost savings that could be accrued from the avoidance of landfill gate fees.
  - **Robust system with flexible feedstock:** Acceptance of mixed waste, including source separated Municipal Solid Waste (MSW).
  - **Revenue from multiple source.** Examples include:
    - Revenue from being a centralised waste management solution for other organic waste producers in the region.
    - Revenue from electricity and heat generation to neighbours with high energy needs, e.g. dairy processing.
    - Value-add to products, e.g. production of upgraded biogas (bio-methane) and liquefied carbon dioxide.
    - Production of other multiple products with established markets, i.e. recyclables extracted from MSW, digestate as an organic compost, digestate fibre solids as animal bedding (as an alternative to sand), and refuse derived fuel from the resultant waste.

- **Common challenges** were:
  - **Waste collection and separation:** Requirements to separate waste at source were often difficult to implement and costly in terms of additional labour and/or infrastructure. Waste aggregation is often a key factor required to secure economies of scale sufficient for collection costs.
  - **Lignocellulosic contaminants:** Crusting, the formation of a thick, solid layer on the surface of the digester, has been caused by straw from animal bedding entering the digester.

- **Grid feed in**: One of the challenges encountered is the embedded generation regulations preventing feeding of excess electricity to the grid. Wheeling to a third-party off-taker is possible, but has been cited as a challenge.[33]
- **Odour**: Odour complaints resulting from stockpiled organic waste.
- **Digestate management**: Difficulty in finding offtakers for digestate and mechanisms needed to concentrate the digestate and reduce the volume of product (links to lower logistic and handling costs).
- **Skills and training**: Insufficient knowledge and training resulted in several costly process issues.

6.2. Insights from the viability assessments

- **Scale and waste management costs play a key role in determining the viability of a biogas installation.** (The extent of on-site energy use may also be a significant determinant, but has not been explicitly examined).

- **Small-scale commercial biogas facilities (<50 kWe) do not appear to be financially viable under current landfill disposal costs and energy costs** (even assuming favourable conditions for financing and on-site energy use). These systems may be viable should waste disposal costs and energy costs increase substantially. (In the case considered, grid electricity cost would need to be greater than R2.20 KWh).

- **Medium size biogas facilities at abattoirs (>50 kW$_e$; <1MW) can be financially viable at the middle to higher end of the scale and when waste management costs (gate fees, logistics costs) are high (assuming current energy prices and high full utilisation of energy on-site.)**

- **Waste management costs could be a stronger driver for biogas installations in South Africa than energy savings**, due to the relatively low energy costs in South Africa

6.3. Overall conclusion

Financial viability of biogas facilities is highly site specific and generally, the business case is only strong under particular conditions. Those situations with larger volumes of organic waste (either on-site or by acting as a waste service provider), higher waste disposal costs, higher energy use on-site or in close proximity and ability to derive income from various sources (accepting different waste streams and selling multiple buy-products) are most likely to be financially viable.

[33] Note that this landscape is currently changing and the business case for small and medium-sized biogas facilities may well improve. The DoE officially announced that it would allow small-scale electricity generators (<1MW) to operate without having to obtain a generation licence from NERSA. However, these generators would still need to be registered with the National Regulator. However, it may take time before processes are in place to allow such registration. More information on the current status with regard to feeding-in to the Eskom grid and municipal grids in the Western Cape, as well as on wheeling, can be obtained from GreenCape's energy team (info@greencape.co.za)

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