Biogas Industry in South Africa

An Assessment of the Skills Need and Estimation of the Job Potential

May 2016

Imprint

Published by the
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices Bonn and Eschborn, Germany

South African-German Energy Programme (SAGEN)
GIZ office
Hatfield Gardens, Block C, 1st Floor
333 Grosvenor Street
Hatfield, 0028
Pretoria, South Africa
T +27 12 423 5900
sagen@giz.de
Contacts: Sofja Giljova (sofja.giljova@giz.de)
Sayuri Chetty (sayuri.chetty@giz.de)
www.giz.de/southafrica

In cooperation with
Southern African Biogas Industry Association (SABIA)

Consultants
AltGen Consulting
The Boulevard Office Park, Block C, 3rd Floor
Searle Street
Woodstock, 7925
Cape Town, South Africa
T +27 21 880 2561
Contacts: Sarah Stands
Sean Gibson
Ann Potgieter
Hanna Schlegel
www.altgen.co

Design and layout
Twaai Design

Cover photo
Bronkhorstspruit Biogas Plant

Published in South Africa - May 2016

Biogas Industry in South Africa

An Assessment of the Skills Need and Estimation of the Job Potential

May 2016

Nomenclature, Definitions and Acronyms

Acronyms	Definition
AD	Anaerobic Digester
CHP	Combined Heat and Power
DEA	Department of Environmental Affairs
DoE	Department of Energy
DTI	Department of Trade and Industry
EF	Employment Factor
EPC	Engineering, Procurement and Construction
FIT	Feed-in Tariff
FTE	Full-time equivalent
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IBBK	International Biogas and Bioenergy Centre of Expertise
IO	Input-Output Model
kW	Kilowatts
LFG	Landfill Gas
LSM	Living Standards Measure
Ml	Mega litre
MSW	Municipal Solid Waste
MW	Megawatt
NDP	National Development Plan
NEM:WA	National Environmental Management: Waste Act

NEMA	National Environmental Management Act
NQF	National Qualifications Framework
O&M	Operation and Maintenance
OFO	Organising Framework for Occupations
PR	Public Relations
QCTO	Quality Council for Trades and Occupations
R&D	Research and Development
RDP	Reconstruction and Development Programme
RE	Renewable Energy
REIPPPP	Renewable Energy Independent Power Producer Procurement Program
SABIA	South African Biogas Industry Association
SAGEN	South African-German Energy Programme
SANEDI	South African National Energy Development Institute
SAPA	South African Poultry Association
SAPPO	South African Pork Producers' Organisation
SAQA	South African Qualifications Authority
SARETEC	South African Renewable Energy Technology Centre
SF	Skills Factor
TVET	Technical Vocational Education and Training
WWTW	Wastewater Treatment Works

Term	Definition
Agro-processing	Processing and transforming of raw and intermediate products/residues from agriculture, forestry and fisheries
Anaerobic	Without oxygen present
Biogas	Organic gaseous mixture comprising mostly of methane and carbon dioxide
Digestate	Post-digestion matter
Digester (bio-digester)	The container which seals the feedstock from oxygen, in which the digestion takes place and the biogas is captured
Digestion	Breaking down of large organic molecules by micro-organisms
Direct jobs	Jobs required for project activities
Early-adopters	People or companies that implemented the technology before an industry was established
Employment Factor (EF)	The number of jobs created per megawatt (MW) of power generated by the plant
Feedlot	The farm at which animals are fed to the desired weight for slaughter
Feedstock	The organic matter used in a bio-digester to generate biogas
Full-time Equivalent (FTE)	One person working full-time for one year is regarded as one FTE, based on a 160-hour work month
Indirect jobs	One person working full-time for one year is regarded as one FTE, based on a 160-hour work month
Landfill gas (LFG)	One person working full-time for one year is regarded as one FTE, based on a 160-hour work month
Municipal Solid Waste (MSW)	Garbage including organic matter collected from households, retail stores and commercial processes, typically sent to landfill
Organogram	Organisational chart to show relationships between jobs and positions in a project

Person-years	One person employed full-time for a period of one year (1 920 hours), comparable to one FTE job
Remuneration mechanism	A predefined tariff imposed on feeding energy into the national grid (feed-in tariff)
Silage	Crop and grass cuttings compacted in an air-tight container
Skill level	Relating to the qualifications and experience of a person performing a job
Skill level factor	The percentage contribution of each type of skill level for each project size and phase

Executive Summary

The South African Biogas industry has existed in a low-intensity state for an extended period of time, which is testament to its potential, and much of this potential is embodied in the number of jobs that a nascent biogas industry will create.

As of April 2016, there are about 1 700 people directly employed in the biogas industry, with 38 commercial projects in operation. Many more projects are in construction though, and it is thus self-evident that there exists an ever-expanding need for skilled operators in the industry. Further, at this point, there are no biogas unit standards and no NQF validated biogas-specific certifications. It is highly likely that all commercially deployed skilled biogas practitioners and professionals that have received training, would have been trained internationally on specific biogas knowledge.

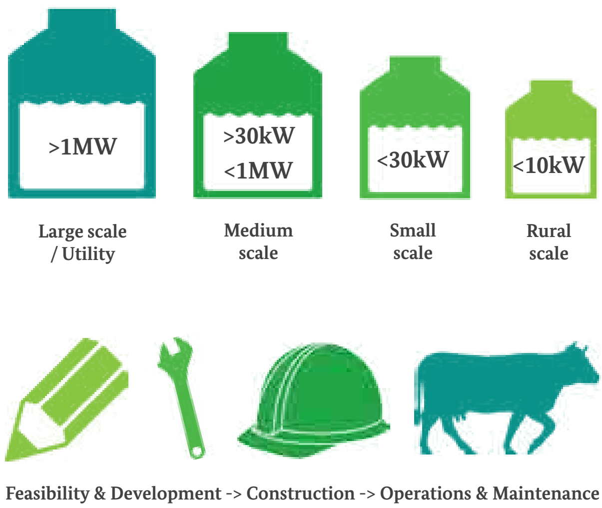
In order to attempt to estimate the ‘employment potential’ from biogas, this study has the following as a starting point:

- an investigation of the current and future capacity of the biogas industry,
- an interrogation of the current projects and their organograms, and
- an analysis of the number of projects that can be developed over time, as well as from the available feedstocks.

The form of the inquiry includes an eclectic mix of methods viz. defining the biogas market boundaries, collecting primary employment data as well as secondary data through stakeholder engagements in semi-structured informal interviews, biogas plant site visits, panel presentations for discussion and comments to the South African Biogas Industry Association (SABIA) network and further communication on progress and inputs via teleconferences and email conversations, as well as desktop investigations and analyses.

With regards to the interviews, of the 35+ stakeholders approached, only 17 were willing to participate in the study and contributed their data and project information. Of the stakeholders that did participate, all indicated that one of the biggest hindrances to biogas implementation currently is the policy and legislation. A further issue is the high capital cost and lack of remuneration mechanisms associated with <1MW electricity generation.

However, most developers are dedicated to opening up the industry through appropriate channels including public awareness, policy/legislation and government-associated changes; and should an enabling environment be fostered for the biogas industry, developers foresee a successful future with improved profit margins and smoother initiation processes.



An Excel based input-output model utilised aggregated stakeholder data to determine the employment factor for each type and phase of a biogas AD project i.e. large, medium, small and rural projects, through the phases of feasibility, development, construction, operation and maintenance. Developers indicated their expected project per 5-years pipeline, which enabled a baseline of project growth to be forecasted until the year 2030. The approximate FTE jobs per project phase and size over time was calculated, and the developer outputs for the meaningful job creation (operation phase) are shown in Table i.

Jobs currently in **operation phase** of biogas industry	270 FTE
Conservative job forecast to 2030	59 000 FTE
Optimistic job forecast to 2030	88 000 FTE

Table i: Model Outputs from Developer Pipeline estimates

The certification skills gap for biogas is set at 100%, whilst the experience skills gap remains under the spread of the current industry developers with skills taught in-house and through experience.

The initiation of courses through colleges and universities would open up the skills market in the biogas industry. Should the skills gap continue to expand in the way it is, the resultant skills market will be untrusted and developers would struggle to push their projects into the operation phase without the relevant skills at hand.

Given the prospective industry growth and associated potential jobs, a standardised qualification for biogas plant design, operation and maintenance is justified. Such a course could be supplemented with industry associations for hands-on, relevant information to further spread awareness and education. Closing the certification skills gap would open up the industry and market for skills in this area, with knock-on effects of increasing safety standards and quality of work and technology, as well as opening up the green biogas market to utilise South Africa's waste streams.

Contents

List of Figures

List of Tables

SECTION 1

Introduction

1 Introduction

1.1 BACKGROUND AND MOTIVATION

With the global movement towards a sustainable and just future, two of the most significant human derived obstacles to overcome are unsustainable waste management and access and supply of clean energy generation. These obstacles align with a number of the Sustainable Development Goals (SDG), recently endorsed by the United Nations in 2015 (see Figure 1 below). With the implementation of an Anaerobic Digester (AD), biogas is produced from organic waste, redirecting and utilising waste streams to generate renewable electricity and heat, or a clean gas fuel; the wide-scale implementation of which can significantly address a number, arguably all, of the newly formed and adopted SDGs.

Biogas is produced through the fermentation process of organic matter. Feedstocks originate from a wide range of outputted anthropogenic activities and industries including sewage, food waste and agriculture waste. Using simple technology, the organic matter is contained and an anaerobic biological process is initiated to produce methane rich gas which can then be utilised in situ; to be used directly or to produce heat and/or electricity as shown in Figure 2, thus negating the use of fossil fuels (The Biogas Association, 2013), diverting/converting current waste streams to resources, supplying an electricity and heat source to rural/off-grid locations and reducing high operating costs for industry, farmers, governments and ultimately the public. Once the organic matter has been digested, a second output is produced that is a nitrogen-rich digestate substance which is less odorous and contents less pathogen. This is pumped out of the digester and can then be used as a low grade fertiliser for crops.

Figure 1: Sustainable Development Goals (United Nations, 2015)

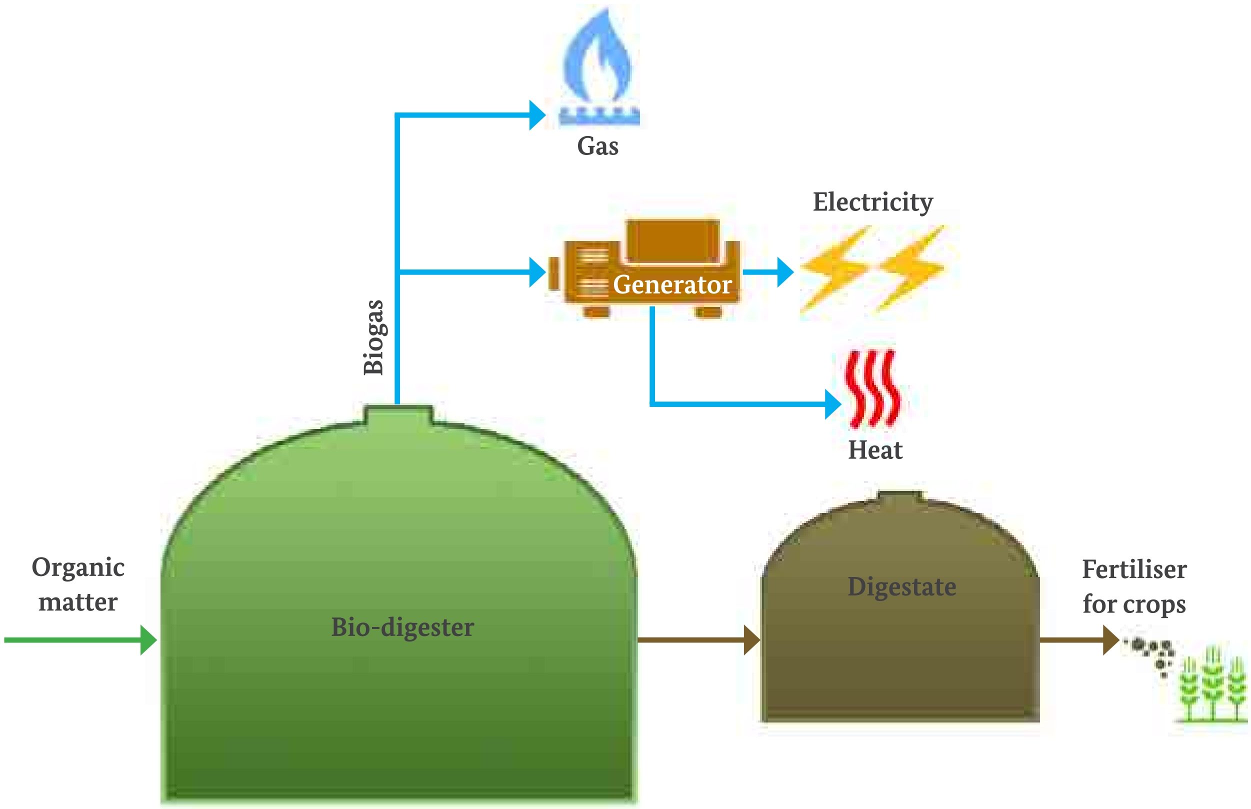


Figure 2: Biogas operation schematic

With the aim to eliminate income poverty and reduce inequality, the South African National Development Plan (NDP) Vision 2030 lists sustainable development as a 'critical action' to achieve these milestones (National Development Plan, 2013). Carbon emissions and the concurrent energy requirements are problems that all nations, developed and developing, are facing. With the launch of the Renewable Energy Independent Power Procurement Programme (REIPPPP) initiated in 2011, South Africa has a fast-developing utility-scale renewable energy industry. The REIPPPP has a current target of 10 000 GWh of renewable energy by 2030 (DoE, 2012), with 32 projects currently feeding about 1 500 MW into the grid at the close of 2015 (Boulle et al., 2015). Under the current iteration of the REIPPPP, 12.5 MW is allocated to biogas projects, yet at the time of writing, the MW allocation has not seen its full potential.

The NDP also speaks to waste and wastewater management, and that waste-to-landfill mechanisms need to be refined, improved and optimised in the face of a growing waste crisis: landfills are filling up (Ackroyd, 2014) and environmental concerns have resulted in strict definitions and legislation for waste treatment, as designated in the National Environmental Management: Waste Act (Act No. 59 of 2008), (NEM:WA, 2008).

The South African-German Energy Programme (SAGEN) initiated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is currently investigating the market development associated with implementing biogas projects in South Africa, in conjunction with the Department of Energy (DoE), the Southern African Biogas Industry Association (SABIA) and other stakeholders through the National Biogas Platform. A key aspect in developing a biogas market and understanding the latent potential of the industry is unpacking the specific skills needs and job potential of the biogas industry, specifically within the South African context, where 24.5% of the population are unemployed and only 13.5% of school leavers receive a tertiary qualification (StatsSA, 2014).

Some studies indicate that biogas may create 5 times more jobs (direct and indirect) than any of the other renewable energy technology (RET) per MW installed (IRENA, 2015). One of the reasons that biogas has not taken off in South Africa yet is due to the deficiency of human skills to design, implement and operate biogas plants safely and effectively (Greben and Oelofse, 2009). However, there are currently no comprehensive biogas specific job creation estimates or skills gap analyses for South Africa that have taken into consideration all the important factors (scale of plant, feedstock, lifespan of the project, etc.) that make biogas so unique in comparison to other renewable energy technologies.

1.2 OBJECTIVES

The aim of the study is to:

1. Provide a scoping report with conservative estimates for the potential of various employment opportunities specifically related to the biogas industry
2. Identify the employment prospects according to factors such as biogas plant size, feedstock, lifespan of the project and other relevant factors
3. Analyse skills needs and identify existing skills development in cooperation with the industry
4. Identify any limitations that may be applicable to the credibility of the results
5. Outline assumptions for the calculated estimates

The outcomes of the completed assessment shown schematically in Figure 3, will substantiate the development of the Department of Energy's National Framework, and assist in providing information for the key decision makers and relevant institutions to potentially develop accredited coursework material that may be integrated into existing qualifications or, to develop a specific qualification/training programmes relating to the biogas industry. Additionally, the results of the study should indicate which open doors are available for students interested in entering the renewable energy and biogas industry. By understanding the potential biogas market in South Africa, the relevant institutions and organisations can be better informed, enabling them to nurture local talent and develop a local skilled and semi-skilled labour force that is competent to work in this growing industry rather than having economic opportunities being outsourced to international skills.

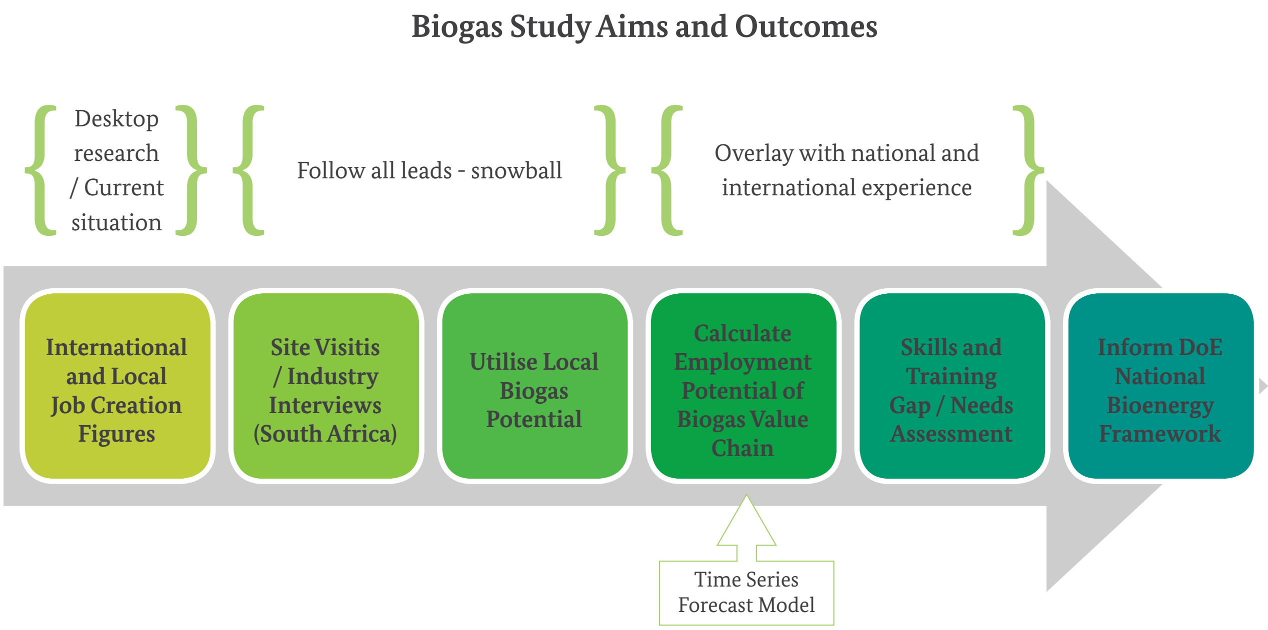


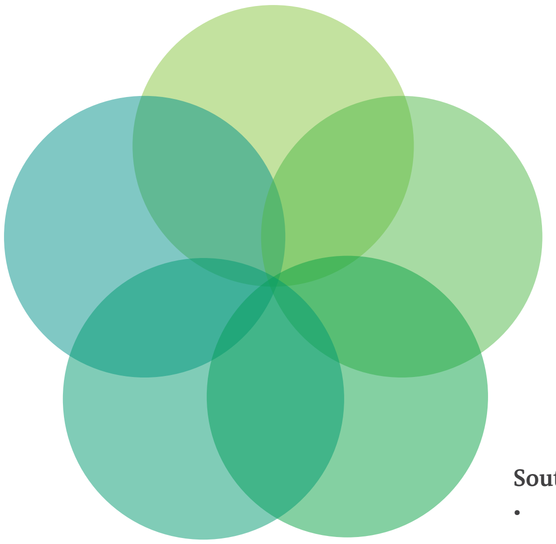
Figure 3: Biogas Study Aim and Outcomes

1.3 SCOPE

The study focuses on current and future direct job potential in the biogas industry specific to the South African context. The main focus includes reviewing anaerobic digestion with feedstocks most common in South Africa from agricultural waste, municipal solid waste, abattoir waste and wastewater treatment works (WWTW). The research boundaries overview for this study is visually demonstrated in Figure 4.

Study Boundaries

Primary Feedstocks
- Municipal Waste (WWTP, Solid)
- Commercial processes (food, abattoir, animal waste)



Quantifying Jobs
- Direct Jobs
- Based on Case Studies
- Unique Job and Skills Factor
- Individuals / Org charts

Biogas Potential
- Stakeholder information
- Available statistics

Assessing the Skills Gap
- Unique to South Africa
- Includes international courses / training currently used by developers

South African Value Chain
- Direct Jobs
- Semi-direct Jobs
- AD plant activities

- Does not include indirect jobs (multiplier can be utilised for a high level understanding)
- Biogas potential is one of the largest stumbling blocks to forecast job creation
- Primary focus on AD projects in the construction, commissioning or O&M phases

Figure 4: Study Boundaries and Research Overview

2 Terminology and Background Information

2.1 FEEDSTOCKS

Although all organic matter can be used to generate biogas, not all avenues of organic matter production are applicable to the South African biogas industry due to circumstances that particularly revolve around capital investment. Currently in South Africa, biogas is primarily utilised as a problem-solving mechanism to redirect solid and hazardous waste from landfills, gain economic benefits from on-site generation of electricity and to provide fuel (cooking, heating, lighting) and sanitation for rural households that do not have a grid connection. Internationally, many more feedstock avenues have been thoroughly utilised on a large scale through government-initiated programs (as explained in Section 2). Feedstocks considered in this study are limited by project feasibility, due to the industry being in its infancy.

As a reflection of the state of waste-to-energy industry internationally and in South Africa, the feedstocks in the scope of this study include sewage, food waste, manure, agricultural, commercial waste and municipal solid waste (MSW).

Two feedstocks not included in the study are landfill gas as a part of MSW (LFG/MSW), and energy crop sources. LFG/MSW is excluded for three reasons. Firstly, the technology is significantly different; secondly, there are not enough projects to include in an aggregate job intensity factor; and thirdly, LFG does not incorporate an additional standalone plant that requires careful management of the feedstock and rather contains the gas that is already being created on the landfill site. Although there are current LFG/MSW projects running in South Africa, such as the Marianhill landfill site in KwaZulu-Natal[1], their set up varies too considerably from the other feedstocks to be able to draw comparisons. This feedstock provides a future avenue for further research.

The second technology/feedstock not considered in this study is biomass from food crops or energy crops (crops grown for energy production purposes). South Africa is a water-scarce[2] developing nation with a significant number of people living off subsistence farming[3], living in poverty (56.8%) and experiencing hunger (13.4%) (StatsSA, 2014). Therefore, growing food crops such as carbohydrate-rich maize for energy/electricity production cannot be considered for South Africa as it is for developed nations such as the USA and Germany. Many arguments and considerations are taken into account in the food-energy debate of African countries, including the use of arable land, malnutrition statistics and sources of income. Thus for the purposes of this study, the inclusion of crops grown only for energy is not considered as a feedstock.

2.1.1 Agricultural Waste (vegetables, sugar cane and fruit)

For this study, agricultural waste or agro-industrial residues are used to refer specifically to crop and plantation wastes. Manure and abattoir wastes are so relevant in the South African industry that they warrant separate explanations.

A number of agricultural outputs, typically thought to be waste streams, are rather redirected and utilised as a resource for other farms, such as fruit pulp for livestock feed, and compost for fertiliser (Stakeholder Interviews, 2016). Agricultural waste streams currently being utilised in this way are thus unlikely to be redirected towards AD. The potential for AD implementation in South Africa therefore exists where agricultural waste is not currently redirected for another use and/or 'sold' for other purposes. The highest potential of AD implementation is on farms that could benefit from reducing their electricity and/or heat costs as well as costs associated with waste treatment, storage and transportation (for example, farms that

1 eThekwini Municipality, 2014. Project Summary Document: Durban Landfill-Gas to Electricity. [Online] Available at: https://www.iea.org/media/technologyplatform/workshops/southafricabioenergy2014/Sitevisit_Durban_LandillGas_to_Electricity_22_Nov.pdf [Accessed 29 02 2016].

2 South Africa receives only 450mm of rain, compared to the global average of 870mm (Department of Environmental Affairs and Tourism, 2011)

3 Statistics South Africa estimates that over 80% of agricultural households in South Africa are involved in subsistence and smallholder farming (StatsSA, 2013)

package or process products on site).

Sugarcane consists of 15% fibre, 15% sugar and the remaining amount water. Once the sugar water has been removed from the cane, the remaining fibre known as bagasse, is burnt in boilers to produce steam and electricity to be used on site (van der Merwe, 2014) and therefore an AD technology is not required nor is it a viable feedstock. However, other by-products from the sugar milling process such as wastewater and filter cake are rich in organics and are not currently utilised in South African mills, and may be considered a valuable feedstock for biogas generation (Magama, et al., 2015).

2.1.2 Manure (feedlots or dairy farms)

Manure waste being an agricultural by-product from feedlots, dairy farms and other livestock farms is used as an untreated fertiliser or stored in waste lagoons. Implementing anaerobic digestion on site could significantly improve the manure handling process and remove the threat for negative environmental impacts such as pathogen spread and nitrate accumulation in the water table. The electricity and heat produced could then be used onsite to reduce operational costs and grid-dependence (Baltic Deal, 2012). The resulting digested sludge is then used as a treated fertiliser directly on the farm or sold to commercial and domestic agricultural operations.

2.1.3 Abattoir Waste

In South Africa, abattoirs provide the most significant opportunity for anaerobic digester implementation due to restrictive laws on hazardous abattoir waste treatment and the direct benefit of the heat and electricity required for the abattoir's operational requirements (Stakeholder Interviews, 2016). NEM:WA (2008) restricts wastewater from abattoirs entering conventional wastewater treatment plants due to the large amounts of organics they contain (NEM:WA, 2015). Similarly, incinerating and sterilising the waste has also been restricted because of the risks of pathogen spread and other negative environmental impacts (Neethling, 2014). Treating, storing and transporting wastes to special landfills that accept hazardous materials adds another cost element to the abattoir.

2.1.4 Municipal Solid Waste (MSW)

Organic food waste that is separated at source from domestic, industrial and commercial waste streams is often used for composting on site or directed to landfills. Redirecting this waste into an AD has the potential to generate heat, electricity or fuel gasses. The digested sludge could then be used as a low grade fertiliser/ soil conditioner.

Commercial food and beverage production such as breweries, cheese factories and fruit and vegetable processing can use organic waste to generate heat and electricity onsite, similar to an abattoir. With less stringent waste laws for these waste streams, the majority are currently directed to landfill or used as feed for livestock (Stakeholder Interviews, 2016). The implementation of anaerobic digestion on such processes would decrease costs for electricity and heat requirements, costs associated with waste transporting waste to landfills and, from a bigger picture, contribute significantly to redirecting waste from landfills.

2.1.5 Sewage

Biogas created on wastewater treatment works (WWTW) can be used to generate electricity for the up- and down-stream processes of the plant: the organic matter contained in raw wastewater can contain up to ten times as much energy as is needed to treat it (National Association of Clean Water Agencies, 2012). Like all other biogas by-products, the spent sludge is odourless and rich in nitrates, and can be used as a fertiliser for agriculture farming. Conventional wastewater treatment processes include anaerobic digestion to treat the sludge in order to minimise the water content, decrease the pathogen load, and remove the odours –biogas technology retrofits/additions and infrastructure is easily implemented on such WWTW (GIZ & SALGA, 2015). Other WWTW that do not have the conventional digestion process in place would require a greater capital input to implement a biogas unit, and hence the feasibility of such WWTW would require evaluation of the anticipated economic benefits (GIZ & SALGA, 2015).

Rural housing developments, schools and clinics that are not connected to a wastewater system could use anaerobic digestion to treat their sewage waste in order to generate electricity or gas fuel for cooking and heating with the additional benefit of removing potentially dangerous pathogens from entering the groundwater table (Stakeholder engagement, 2016).

2.1.6 Feedstock treatment and availability (location, continuity, and quality)

Unlike wind and solar renewable energy (RE) technologies, biogas requires a secondary resource (feedstock) as opposed to a primary resource (wind and sun). In order for biogas plants to be deemed viable, a consistent feedstock (a consistent material and quantity) is required over the 10-20 year project lifespan (NNFCC, 2016). For a biogas plant to run 24 hours a day, the associated feedstock must be available at all times as the digester needs to constantly and consistently be fed. Secondly, the removal of the digested sludge also requires regular management: the digestate mass is 90 to 95% of the feedstock, and if it is not removed regularly, the digester will malfunction (NNFCC, 2016).

The feedstock must also be relatively fresh for use in the anaerobic digester, as organic matter will naturally begin to decompose, decreasing the methane potential of the feedstock (NNFCC, 2016). Furthermore, the feedstock is required to have a certain water content, and leaving the feedstock outside for long periods of time results in drying out. Therefore, AD plants are generally equipped with special feedstock storage facilities to anticipate consistency.

The methane content of the biogas reflects the energy value. Different feedstocks, or substrates, generate differing amounts of methane in the biogas, depending on their organic content (F.M.o. Food, Agriculture & Consumer Protection, 2012). For example, maize and grass silage generate more methane per cubic meter of biogas than livestock manure, which still has a greater potential than human sewage waste.

2.2 TYPES OF JOBS

Jobs in relation to a particular industry are categorised into 'direct' and 'indirect' in order to ring-fence the job statistics and ensure consistency in estimates.

'Direct' jobs refer to jobs directly involved in project activities and include the development, implementation, construction, operation and management phases of projects (IRENA, 2013). 'Indirect' jobs are "indirectly" associated with the project activities but not directly, such as manufacturing, acquisition of materials and contracted support services such as legal and banking services (Steinberg, Porro & Goldberg, 2012). 'Induced' jobs are related to direct and indirect employees spending their money in support services such as accommodation, food and beverages (Rutovitz, 2010; Steinberg et al., 2012).

As the biogas industry in South Africa is in its infancy and there is little information available, we have used the data available from stakeholders and any jobs that could be quantified have been included in our calculations and job forecasts, resulting in a high-level conservative data estimate. External consultants have been excluded from the job counts in all cases where possible, however in the case of jobs concerned with environmental, legal and feasibility aspects that have been included by the developers in the development/feasibility project phase, these jobs have been included as direct even though traditionally they may be regarded as indirect.

Therefore, in future analyses of this topic, when more information is available, an in-depth evaluation of the boundaries between direct and indirect jobs can be performed in a biogas-specific context.

2.3 JOB METRICS

Quantifying jobs becomes more complicated when every individual does not hold a full-time role in a single position. This is especially relevant in the construction industry when individuals work a portion of the year, month or even week. Therefore, one must aggregate 'jobs' into a usable statistic/ratio. In forecast models (and in the REIPPPP), job and employment aggregates are measured in person-years as opposed to individual job head counts (Stands, Gibson & Moodley, 2014). One person-year refers to one person employed full-time for a period of one year, roughly 1 920 hours considering a 160-hour work month (Stands, et al., 2014). This compares to a Full-time Equivalent (FTE) value of one 'job'.

Due to the paucity of job related information and opportunities available from developers, this study will primarily focus on direct jobs associated with the biogas industry. Employment aggregates will be made in person-years of FTE's, as this has become the international norm for measuring quantifiable economic opportunity created when forecasting opportunities. In combination of a FTE and Employment Factor to aggregate and forecast jobs, industry consensus organograms will also be analysed for projects in different phases of construction implementation, to determine a unique Skills Factor, and to better understand the unique situation of the South African biogas industry and assist in identifying the potential and the skills gap. Each project phase must be analysed separately as the skills are unique to each one.

2.4 SKILLS AND ASSOCIATED PROJECT PHASES

Biogas projects are executed through a sequence of activities related to project phases, as well as supportive services as shown in Figure 5.

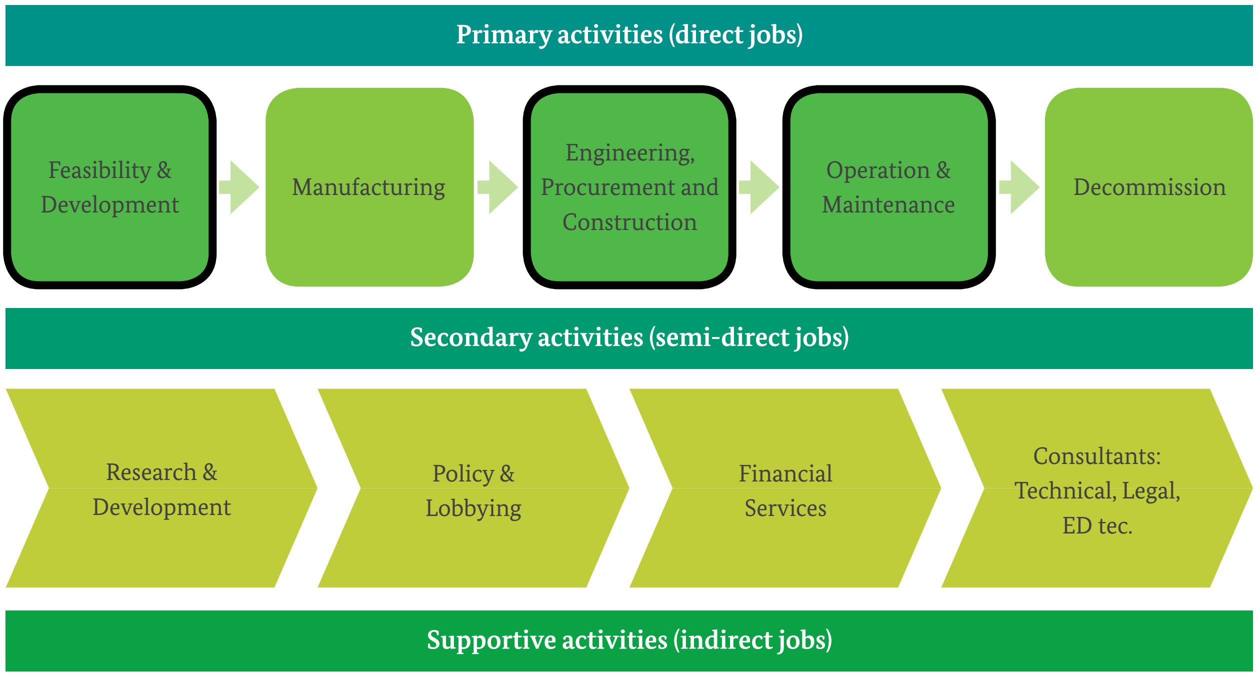


Figure 5: Activities, services and associated project phases in biogas projects

Highlighted above in the schematic, the focus for this study includes some project development, with a primary focus on the engineering, procurement and construction (EPC) activities as well as operation and maintenance (O&M) phase, emphasising the direct jobs associated with these segments.

One noteworthy comparison between biogas plants and RE such as wind and solar, is that most RE plants do not require the same intensity of feedstock (input) and digestate (output) handling activities, although requiring many more jobs in maintenance and operation (IRENA, 2016). Biogas, however, requires a feedstock preparation and supply as well as a digestate and gas management system, including the associated fertiliser handling. These activities are required for the running of the biogas plant and therefore are referred to and considered to be direct jobs in this study.

Jobs and skills associated with R&D, manufacturing and decommissioning are omitted for now, at least until a more formalised biogas industry evolves or the study is continued. Manufacturing is excluded from this study as the boundaries for the project and associated analysis were ring-fenced around employment related to plant activities. Manufacturing involves complex value-chain analysis and currently the source of the components depends greatly on the size of the digester.

While project size depends on the skill level of an AD, a variety of skills with diverse educational backgrounds are required for the roles encompassed in the different phases of the biogas value chain. For example, highly skilled biologists and biochemists are required to initiate the fermentation process and skilled managers and engineers, as well as semi-skilled civil labourers, are required for the construction and commissioning constituents of the project. Equally important are semi-skilled and unskilled farm labourers to manage the consistent feedstock supply and processing. Figure 6 depicts the various potential areas of direct employment through project phases the study is focussed on.

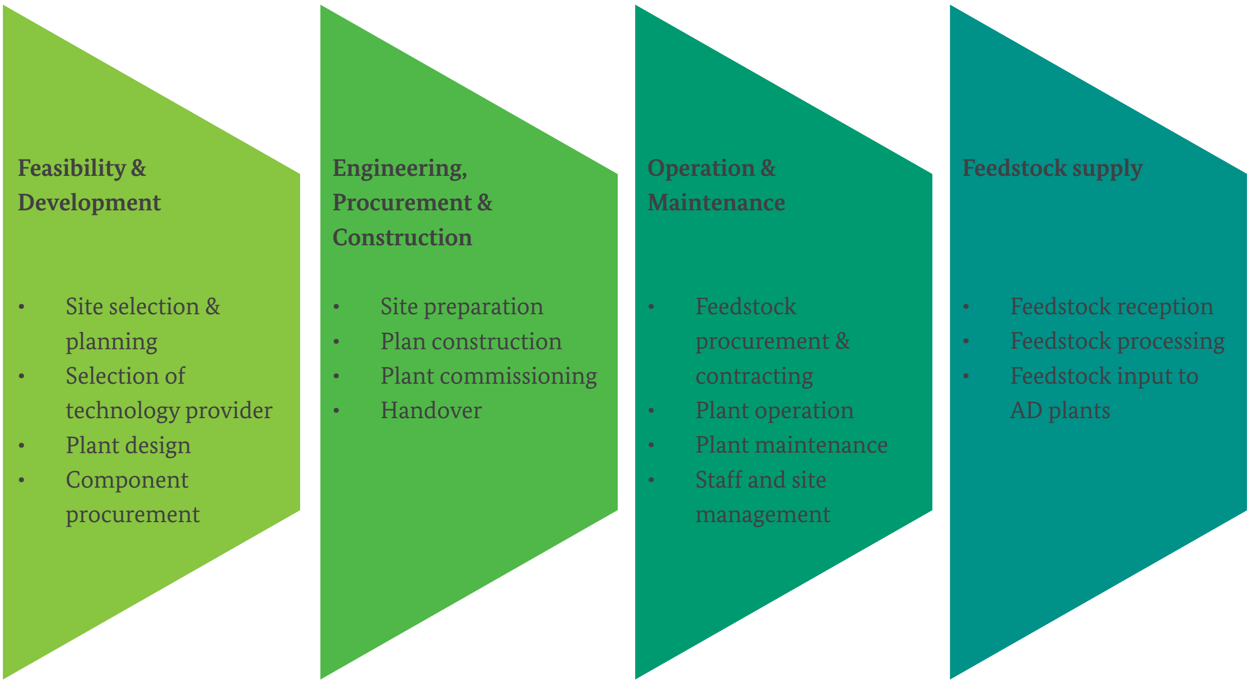


Figure 6: Potential areas of employment in biogas projects (adapted from McDermott, 2012)

The standardisation of skills within the biogas sector, coupled with an ideal associated qualification is difficult within an emerging market. The industry is relatively unregulated and therefore grows organically, including the regulation and skill development. That saying, it is the intention of the study to associate an ideal frame work for the understanding of the current skills landscape of the biogas industry in South Africa, and more importantly, the future of a more mature market.

Table 1 equivocates skill level to National Qualifications Framework (NQF) level, Paterson Grading and general occupation. The NQF designates levels for qualifications in South Africa. The Paterson Job Grading designates job grades according to freedom to act or make decisions within a role, regardless of salary (Paterson Grading, 2016). The Organising Framework for Occupations (OFO) links occupation title and skill set, and uses this information to identify skills needs along with the Quality Council for Trades and Occupations (QCTO). The South African frameworks and organisations are further explained in Appendix C and will be utilised as the bases for analysing the biogas skills gap.

Table 1: NQF equivalents and OFO groupings for each skill level (Paterson Grading, 2016)

<table>
<tr><th>NQF</th><th colspan="3">Skill level</th><th>Paterson Table</th><th>OFO Major Groupings</th></tr>
<tr><td rowspan="2">7-10</td><td rowspan="2">4</td><td rowspan="2">1st degrees, second and tertiary education leading to higher qualifications

Higher Education & Training</td><td rowspan="2">Highly Skilled</td><td>E/F</td><td>Top/Senior Managers</td></tr>
<tr><td>E/F</td><td>Professionals</td></tr>
<tr><td rowspan="2">6</td><td rowspan="2">3</td><td rowspan="2">First stages of tertiary education

Higher Education & Training/ Further Education & Training</td><td rowspan="2">Skilled</td><td>C/D/E</td><td>Managers</td></tr>
<tr><td>C/D/E</td><td>Technicians & Associate Professionals</td></tr>
<tr><td rowspan="4">3-5</td><td rowspan="4">2</td><td rowspan="4">Secondary level of education

Further Education & Training</td><td rowspan="4">Semi-skilled</td><td>B</td><td>Clerical & Support Workers</td></tr>
<tr><td>B</td><td>Services & Sales Workers</td></tr>
<tr><td>B</td><td>Skilled agriculture, forestry, fisheries, craft & related trades</td></tr>
<tr><td>B</td><td>Plant & machine operations & assemblers</td></tr>
<tr><td>1-2</td><td>1</td><td>Primary level of education

General/Basic Education & Training</td><td>Un-skilled</td><td>A</td><td>Elementary workers</td></tr>
</table>

3 General Study Methodology

The study uses a variety of methods to understand the current state of the South African biogas industry; to assess the current employment and associated skills; and thus to forecast the future employment potential and associated skills gap in five year increments until the year 2030. The two sections are separate from each other, the general study methodology is detailed in this Chapter, and the model methodology, established from stakeholder inputs, is provided in Section 3.

The information for the study was sourced from desktop research, stakeholder interviews and site visits, according to the schedule shown in Figure 7. SABIA guided the initial engagements with stakeholders, and desktop research uncovered more contacts.

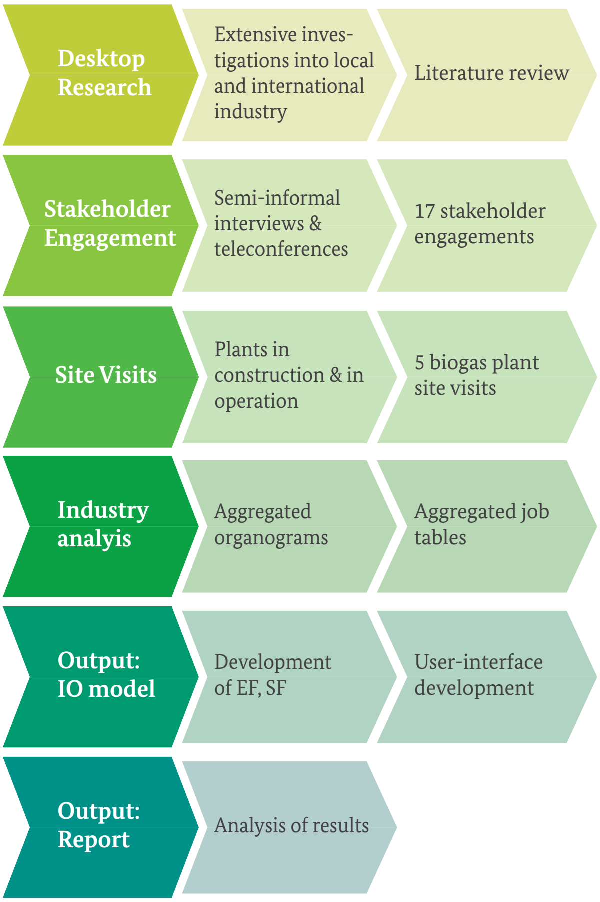


Figure 7: Details of study methodology employed for this study

Stakeholder engagement was the most relevant source of information for this study for two reasons. Firstly, biogas industries around the world are country-specific due to close associations with feedstocks, energy sources, output usage and private and public interest, therefore, the information available for international biogas industries is not directly comparable to the South African context. Secondly, the current awareness of biogas in South Africa has resulted in a few state-backed projects and majority private sector projects, with a consequential lack of transparency due to trade secrets and competitive advantages.

The stakeholder engagements for this study focussed on developers, owners, contractor workers, environmental assessment practitioners, government bodies and interested parties associated with the current biogas industry (listed in Appendix A). Interviews were conducted in both formal and informal settings, depending on the availability of the stakeholders and whether or not a site visit was included. Site visits were conducted for projects both in construction and in operation phases. The interviews were focussed around a questionnaire and organogram table (Appendix B) that covered the topics illustrated in Figure 8.

During the engagement period, stakeholders were often not inclined to divulge many project details due to trade secrets and competitive advantage in the field. A few declined any contact at all.

Figure 8: Questionnaire topics

SECTION 2

Study Outputs

4 Desktop Assessments / Literature Review

4.1 INTERNATIONAL PRECEDENTS

The international biogas scene varies widely due to differing policies and legislature, technology availability, feedstock utilisation, investment and cultural biases; and it is important to note this when drawing comparisons between countries in terms of assessing the potential and status of biogas generation. It is clear however that developed nations tend to have larger scale AD plants for commercial utilisation, agriculture, landfill gas and wastewater treatment; whereas developing nations tend to have smaller scale rural and household digesters. This is an indication of the priorities of the nation and the benefits to the end user; i.e. whether the AD application is for electricity production and/or mitigating waste streams, or intended to provide basics needs to households and thus improving the lives of individuals.

A number of developed and developing countries were investigated in the desktop assessment to map out the international biogas industry and provide context to the South African environment. To draw comparisons to this study the investigation considered jobs, skills and education as well as employment factors and installed capacity in each country, depending on the available information. It is noteworthy that job creation statistics vary widely with the source of information, and there is no global standardisation when defining or quantifying a singular job, thus resulting in country-specific norms.

4.1.1 Developing countries

4.1.1.1 Brazil

A high percentage of energy in Brazil is produced from renewable sources, most notably biomass and biofuels from sugar cane processing wastes (bagasse), which account for an estimated 845 000 direct and indirect jobs in the biofuels sector (IRENA, 2015). Specific jobs attributed to biogas was not found in Brazil-specific literature, and biogas production in Brazil seems insignificant in comparison to the number of jobs with only 22 biogas plants recorded to be connected to the national electricity grid in 2014, mostly attributing from landfill gas (REN21, 2015). [4]

The International Centre on Renewable Energy – Biogás CIBiogás Energias Renováveis - provides policies, education and promotion of the biogas industry in Latin America and the Caribbean. The not-for-profit organisation offers a 3-month Distance Learning course on biogas energy for students and professionals in the renewable energy sector (CIBiogás, 2016).

4.1.1.2 India

India has an estimated 4.75 million household bio-digesters, resulting in approximately 85 000 direct and indirect jobs (IRENA, 2015). Household digesters are common in India as approximately 68% of the population live in rural areas (The World Bank, 2015), where the primary economic activity is agriculture. The high accounts of job creation in the biogas industry in India is attributed to the loose definition of a job and absence of a Full-time Equivalent (FTE), where a job may count as one person feeding a household digester once per day, who would otherwise not have a daily job yet is not performing activities on the AD for the whole duration of the day i.e. 8 hours.

There are a number of biogas training centres and various qualifications offered in India, including the Biogas Development and Training Centre at the Kalinga Institute of Industrial Technology (KIIT University, 2009), and the Virendra Kumar Vijay Centre for Rural Development and Technology (Center for Rural Development and Technology IIT Delhi, 2009). There is also a 1-year vocational education course for a Biogas Energy Technician qualification (online distance learning) through the National Institute of Open Schooling (National Institute of Open Schooling, 2012).

4 The number of jobs in the biogas industry in Brazil could not be found in literature.

4.1.1.3 China

China was the highest investor in, and generator of, renewable energy world-wide in 2014 (IRENA, 2015). There are approximately 100 000 large-scale and 43 million rural household digesters in China, with 209 000 direct and indirect jobs in the biogas sector in 2014 (IRENA, 2015).

A global discrepancy of generalising and quantifying job/employment opportunities is highlighted here as an example of the variation of job statistics: although China has ten times the amount of household bio-digesters than India, it records only three times the amount of jobs in the entire industry than India. This inconsistency is attributed to different classifications and quantification boundaries of defining a job and/or employment opportunity, as well as inaccuracies in data collection. Another contributing factor to misaligned global job statistics is a result of the different organisational structures for implementing technology in rural areas: if China uses a centralised biogas institute as indicated below, fewer jobs may be created if one skilled person attends to many digesters in a day, perhaps even driving long distances to conduct site visits, rather than one unskilled or semi-skilled person who can attend to a fewer amount of ADs within walking distance; thereby inhibited by skills level and socio-economic factors such as having a driver's licence or access to a vehicle.

The Biogas Institute of the Ministry of Agriculture conducts training, research, and development of industrial standards for the growing biogas industry in China (BIOMA, 2013). BIOMA held a 7-week biogas training course in 2015 for English-speaking Africa countries, which was attended by participants from 12 African countries, including South Africa (BIOMA, 2015).

4.1.1.4 Kenya

The Kenya National Domestic Biogas Programme (KENDBIP I and II) under the African Biogas Partnership Programme (ABPP) and international organisations such as the Netherlands Development Organisation (SNV) Netherlands Development Organisation and Hivos has set objectives to assemble 27 500 rural bio-digesters by 2017[5]. Under this project, 366 Kenyans were given instruction in biogas masonry and 49 as field supervisors, as well as various other direct and indirect jobs (ABPP, 2010).

Private companies that implement biogas technology facilitate artisan training in Kenya and Uganda, with the aim that trained artisans can one day open their own companies in biogas construction and operation (ABPP, 2014). The ABPP also aims to empower women in the biogas industry as plant owners, and masons.

UK-based Tropical Power Energy Group has commissioned the first utility scale AD plant in Naivasha, Kenya. The Gorge Farm Energy Plant has a 2.2 MW capacity, and came online in 2015[6] (Tropical Power, 2016). The plant sells energy to the Kenya Power grid at 10 USD cents per kilowatt hour, using 50 000 tons of agriculture waste per year (Doya, 2015).

4.1.1.5 Tanzania

The Tanzania Domestic Biogas Programme, under SNV and Hivos, aims to implement 20 700 bio-digesters by 2017. The programme offers 10-day masonry training courses and aims to generate 840 human-years of direct employment (TDBP, 2016).

4.1.2 Developed countries

4.1.2.1 Germany

Germany has a total of 4 GW of total biogas power installed (Wagner, 2015), ranging from agricultural wastes to wastewater treatment plants. This makes up over 3.5% of the

5 SNV has indicated that the program has been successful and is on-going

6 An estimate of the jobs involved with this project could not be found, and the developers and industry partners were not inclined to meet with AltGen regarding this.

total electricity requirements of the country (Fachverband Biogas e. V., 2011), and generates approximately 47 000 direct and indirect jobs (IRENA, 2015).

The education and biogas training is quite advanced in Germany, including many diplomas, bachelor and master degrees in biochemistry; biochemical engineering and renewable energy cover biogas and anaerobic digestion; and further degrees in mechanical and electrical engineering. The level of education in the field has facilitated/led to Germany's success and position in the global biogas market: Germany is one of the top engineering exporters for biogas hardware, software and human capital, and is the largest exporter of biogas technology and generates over 10% of the German biogas industries turnover in foreign countries (Fachverband Biogas e. V., 2011). The International Biogas and Bioenergy Centre of expertise (IBBK) was founded in Germany and engages companies, experts and learning institutions in the biogas field. The IBBK hosts training events in South Africa, Europe and Malaysia (IBBK, 2016), offering 1 week to several day courses in international locations. Multiple private biogas technology companies and associated universities offer 2-5-day training courses in biogas technology and operation.

4.1.2.2 United Kingdom

117 operating anaerobic digesters recorded in the United Kingdom (UK) resulted in a reported 482 full time jobs for 2013 (WRAP, 2014). The UK biogas industry is growing, with more plants coming online each year. Various organisations and education centres in the UK hold biogas courses: IBBK, mentioned previously, holds conferences and training courses in the UK (IBBK, 2016) and Renewable Energy Association (REA) Biogas also holds training courses over 2-3 days and many more.

4.1.2.3 United States

The United States currently boasts 240 livestock farm AD's, 630 landfill gas projects and 1 200 wastewater treatment AD's (U.S.D.o. Energy, 2014). According to the Biogas Opportunities Roadmap for 2020, 11 000 additional livestock farm AD's could generate 18 000 permanent jobs[7] to run the digesters. The American Biogas Council oversee biogas training and education, where a multitude of private companies perform webinars and workshops (American Biogas Council, 2016).

4.1.3 Conclusion of International Precedents

Although the international biogas industry has set the precedents for upcoming biogas industries, the growth of the South African biogas industry will forge a unique path. Firstly, the South African industry is not focussed on rural and small-scale biogas as is conventional for developing countries, due to the growing middle-class and country-wide urbanisation. Therefore, standardised and government-funded rural biogas implementation such as that occurring in China and India is not applicable on as wide a scale in South Africa. The majority of South Africa has an established sewage system, waste-removal system and large, established commercial industries for food processing and agriculture. This provides opportunities for large- and utility scale biogas plants, but due to hindering laws and remuneration mechanisms, the capital required for implementation decreases the wide-scale execution of this type of AD, as is done in Europe, North America. The interest and awareness of biogas as a renewable energy source in South Africa is growing for a number of reasons: the formulation of industry associations, support from government bodies such as SANEDI key projects and effective PR, MW allocation in the REIPPPP, considerably fuelled by electricity price increases and operational cost reduction for agricultural, commercial and industrial uses. That being said, South Africa may look to international policies and legislation structures as a guideline for relevant points in streamlining the current legislative process.

Despite the South African industry forging a path between that of developed and developing countries, the technology, knowledge and benchmarks gained from international precedents are still relevant to be considered and noted in the formation of the SA standards, particularly with regards to the legislation and policy structures. Table 2 details the job statistics for a range of countries that can be found in literature. The entries for South Africa are from a study by Maia, et al. (2010), and are discussed more in-depth in Chapter 4.2.1: Previous research in South Africa.

7 The United States Department of Energy (2014) does not indicate which feedstocks would contribute to the permanent jobs, rather the range of feedstocks would all require differing amounts of jobs.

Table 2: Biogas job statistics from around the world

Country	Technology	Development[8]	Installation & new facilities (jobs/type)[9]	Paterson Table	OFO Major Groupings	Total	Source
Canada (I/O, 2009)	Biogas (CHP)		12/direct (includes export) 8/indirect	63/direct 41/indirect	0 (includes export)	75/direct 49/indirect	(IEA, 2012)
Denmark (I/O, 2009)	Biogas (CHP)		4/direct 3/indirect	40/direct 12/indirect	93/direct 72/indirect	137/direct 87/indirect	(IEA, 2012)
France (I/O, 2009)	Biogas (CHP)		192/direct 158/indirect	153/direct 42/indirect		345/direct 200/indirect	(IEA, 2012)
Germany (I/O, 2009)	Biogas (CHP)		8 345/direct 5 575/ indirect	4 104/direct 673/ indirect	9,142/ direct 3,395/ indirect	21 591/ direct 12 467/ indirect	(IEA, 2012)
South Africa (I/O, 2010)	Biogas (CHP)		60/direct	6/direct	100		(Maia, et al. 2011)
UK	AD	**320 - 579 FTE**	68 - 123 FTE	379 - 868 FTE	752 - 1 360 FTE	1,358-2,457 FTE	(McDermott, 2012)

4.2 SOUTH AFRICA: CURRENT STATUS OF BIOGAS INDUSTRY

South Africa's biogas industry encompasses a growing number of projects implemented primarily through private funding on agriculture and livestock farms, abattoirs, municipal wastewater treatment plants and rural/domestic households, further explained in Chapter 5.8: South African Case Studies.

Investigations into the available waste streams indicate that there is potential to implement many more anaerobic digesters nation-wide, particularly as a cost savings where waste can be diverted from landfills or reutilised as an energy or heat source (Barnard & Holzbaur, 2013). The benefits from biogas implementation specific to South Africa include reduction of waste entering over-capacitated landfills, generation of heat and electricity (whether for self-consumption or to a lesser extent to feed into the grid), gas production for commercial

8 'Development' refers to people in the field of design, feasibility and organisation of biogas plants

9 Includes feasibility, development and EPC for all entries except for that of the UK, where it refers only to EPC

or domestic use, growth of a potential fertiliser industry, growth of the green economy and local/regional job creation and skills development. With regards to household and rural digesters, this results in improved livelihoods with the use of gas for cooking, and providing heat and lighting that would not normally be available to rural communities (Stakeholder Interviews, 2016) (Appendix A).

4.2.1 Previous research in South Africa

A few published documents relating to biogas and anaerobic digestion in South Africa are chronologically listed in Table 11, Appendix C. It must be noted that this table is not comprehensive, and contains only publications and findings deemed relevant to this report.

Research completed in the biogas industry in South Africa commonly indicates that South Africa has had a slow uptake of anaerobic digestion both commercially and rurally compared to other developed and developing countries. This is attributed to intensive capital investment requirements, slow and hindering legal processes associated and a lack of government support.

Many of the studies reveal that there is biogas potential across various waste streams; for both rural and farm-scale digesters, van Rooy et al. (2013) speaks of the growing waste to energy industry in South Africa, which is further extrapolated by van der Merwe et al. (2014). De Lange and Nahman (2015) calculate the cost of wasted resources such as organic food waste over the food value chain in South Africa, clearly presenting opportunities to decrease a cost drain and utilise a viable resource. Stafford et al. (2013) as well as GIZ and SALGA (2015) have researched the biogas opportunities in WWTW in South Africa and found that it could present a useful sewage sludge treatment opportunity whilst generating electricity to feed into the plant, as a benefit. Lutge and Standish (2013) investigated the opportunities for biogas from farm animal waste, and found that although the technology would be beneficial, the costs associated may not justify the implementation (at that time). Smith, Goebel and Blignaut (2013) indicate that social upliftment opportunities may result from implementing biogas projects specifically in rural locations. A few of these opportunities may benefit women in particular, decreasing the time spent collecting fire wood or making charcoal and cooking in dangerous fumes, thus improving quality of life from a time and health perspective (Musyoki and Tinarwo, 2015).

Previous investigations into the potential job creation of biogas in South Africa are found primarily in two studies, AGAMA (2003) and Maia et al. (2011), yet neither of these studies provide employment factors or results that can be utilised in this study, as first and foremost, they are both outdated and many changes to the industry have occurred since these studies were published. Agama's findings were based on European capacity forecasts which are not applicable in the South African context, and the research was primarily focused on landfill gas rather than anaerobic digesters. Research performed by Maia et al. (2011) allocated different waste streams to the waste-to-energy technology found to best correlate to them at the time, assuming that there is no cross-over of waste streams between technologies. Technologies such as LFG, AD and pyrolysis/gasification were analysed independently, and therefore did not take into account any potential addition of feedstocks from sources that were not allocated specifically to AD biogas.

Due to the lack of detailed project and employment information such as designation of project sizes, duration of project phases, job titles and skill levels in previous reports and studies, this study has not utilised the outputs of these previous resources in quantifying the potential job creation methodology. Without robust information, the need to conduct primary research and to develop a unique employment factor and skills factor exclusive to the South African biogas AD technology via local case studies is substantiated; a method that was not possible a few years ago with the lack of installed AD plants.

4.2.2 Current policies and frameworks

Renewable energy applications and the green economy in South Africa are widely supported by various policies and frameworks, the most relevant and latest of which are listed in Table 12 (Appendix C). The most important legislation documents framing the biogas industry include the National Environmental Waste Management Act (NEM:WA, 2008), Air Quality Act (NEM:AQA, 2004), and the Gas Act (NERSA, 2001) (Stakeholder 10, 2016); however, because the industry is still in its infancy, it lacks specific biogas policy preventing the full potential of biogas implementation. With no defined legislation that can be applied specifically to the biogas industry, a number of overlaps occur when obtaining permission to develop a biogas project. This is further explained in Chapter 5: Stakeholder Engagement.

While the lack of standardisation in the legislative environment presents an opportunity for the industry to shape the future, the absence of regulation and what most argue as 'over-regulation' in some cases (specifically licensing), disables the potential of a biogas rich future in South Africa. SABIA in collaboration with GIZ, the DEA, the DoE and other National Government Departments are working closely to align the industry requirements and create standards that satisfy both the public and private sector.

4.3 SOUTH AFRICAN FRAMEWORK FOR SKILLS DEVELOPMENT AND TRAINING INSTITUTIONS

4.3.1 Framework for Skills Development

The absence of human resources skilled in the application of biogas technologies (design, implementation, and operation) and the shortage of knowledge of the job creation and skills development potential of the biogas industry are skills gap factors impeding the growth of the industry in South Africa (Schneider, 2015). This skills gap is not unique to the biogas industry, and is a common theme throughout the energy, engineering and RE industry; compounded with the current national skills gap and substantiated in the national scarce skills list. This skills gap is discussed at length in the study conducted by Stands, et al. (2014), and is further elaborated in Chapter 9: Skills Gap Analysis.

With any developing industry, associated skills and education platforms are developed for standardisation. Established, formalised skills platforms allow for quality control and reduce the risks associated with developing a project, such as employing labour that is not as skilled as they claim. Skills and qualifications identification, development and training is required to follow procedures and policies set out in a number of organisations and frameworks according to South African legislature. Each authority or framework listed in Table 3 is required to participate in the skills development sector, as per the description.

Table 3: South African Frameworks and Policies associated with Skills Development (Stands, et al., 2014, van der Merwe, 2014, GIZ & SALGA, 2015)

Framework/ Policy	Function
National Qualifications Framework (NQF)	• Sets boundaries, principles and guidelines to provide a base and structure for the qualifications system • The system allows for national recognition of learner achievements, and ease of understanding of learner qualifications and knowledge (SAQA, 2015)
Organising Framework for Occupations (OFO)	• Links occupations to specific skills and identifies training needs • Provides a skills based classification system in a SA context in terms of skill level and specialisation as attributes of a job • Allows a parallel to be found within the NQF (D.o. Higher Education & Training, 2013)
South African Qualifications Authority (SAQA)	• Oversees the development and implementation of the NQF, in terms of regulations specified in the National Qualifications Framework Act (No. 67 of 2008) (SAQA, 2016)
Quality Council for Trades and Occupations (QCTO)	• Develops occupational qualifications according to the OFO in order to meet industry needs • Figure 9 contains an excerpt from the QCTO application process that details the information required when applying for registration of a qualification (QCTO, 2014)
Energy and Water Services Sector Education and Training Authority (EWSETA)	• Responsible for coordinating, facilitating and providing quality assurance for sector reliant skills development programmes for stakeholders and managing skills through the National Skills Development Strategy (III), all associated with the water and energy sectors • Implements skills plans by establishing learning programmes, approving Working Skills Plans and Annual Training Reports • Allocation of grants to employers, education and training providers and workers as well as education monitoring and training in the sector falls under EWSETA • Facilitates learnerships with employers in terms of workplaces and supporting creators of material (EWSETA, 2013)

Figure 9 provides a summary of the Occupation Qualification application requirements for a newly established qualification, substantiated by the needs of industry standards. As the purpose of this study is to define the skills gap of the industry, which may then be used as the departure point of a formal biogas skills market, the relevant points in Figure 9 must be considered in all analyses to enable ease of progress should a qualification be established. This is further discussed in Chapter 9: Skills Gap Analysis.

RELEVANT QCTO OCCUPATIONAL QUALIFICATION APPLICATION POINTS

1. Occupation that the qualification will relate to and OFO code: The occupation that the qualification will relate too, requires the insertion of an occupational title. An occupational title must always fit into the sentence 'I am a ....' i.e. it does not reflect a field of study and cannot end with '..ing'. This title need not be reflected on the OFO (Organising Framework for Occupations). It may be a specialisation as entry into or as an addition to an actual occupation on the OFO.

2. The OFO code is the 6 digit occupational code of the related occupation on the OFO. The related occupation that the qualification is aimed to address must be identified prior to the completion of the application form. If unsure of the OFO code to be used, the SETA to whom skills levies are paid or the SETA whose sector most likely would employ the larger amount of people in the relevant occupation can be contacted for assistance. QCTO qualification development staff might also be in a position to advice on the appropriate SETA or occupation.

3. Provide a short description on why this qualification is needed (rationale):

   This must include a description of:

   - The specific needs that the qualification will meet in the sector for which it is to be developed. Where relevant, professional body needs can also be reflected.
   - The benefits it will have for society and the economy.
   - The range of typical learners and the areas in which they will be able to find employment.
   - Where applicable, the learning pathway where the qualification will reside, i.e. if it will be an entry into a specific occupation or a further specialisation (an addition to a specific occupation) to allow for career progression.

4. Professional bodies, associations or organizations that are involved in this occupation: All professional bodies, associations or organizations operational in the field of the occupation and where relevant, the specialisation, must be listed.

5. Employee and employer organizations that are involved in this occupation: All employee and employer organizations operational in the field of the occupation and/or specialisation must be listed. This also includes major employers who will employ large numbers of learners.

6. Current qualifications, and trades that will be affected by the qualification: Information must be provided on current qualifications and trades that will be affected and/or replaced by the development of the qualification. The information required only relates to qualifications under the auspices of the QCTO and thus include qualifications previously allocated to ETQAs for quality assurance purposes.

Figure 9: Application details for QCTO (QCTO, 2014)

4.3.2 Current Training institutions/programmes in South Africa

There are many institutions in South Africa that focus on research, training and development of RE. Currently, these institutions focus on solar and wind power research, with a few individual researchers investigating bio-energy. Many university and technical courses that involve chemical processes, microbiology and agriculture methods cover anaerobic digestion science and technology, such as chemical engineering and biology. Those with biogas-specific research are listed in Table 4, along with a number of training opportunities advertised by private companies.

South Africa demonstrates a formalised skills development framework and all the avenues to standardize biogas training and qualifications. However, as the industry is new and growing, formalisation has not yet been completed due to lack of necessity. The courses listed in Table 4, although in some cases provide formal education, do not currently meet the growing needs of standardised and accredited training for operators in South Africa. In comparison to established industries in countries such as Germany and the UK, South Africa is still much further behind in terms of certifications and training. This report therefore will be in researching the potential and need for such training and certification avenues, and these are further explored in the coming chapters, most notably in Chapter 9: Skills Gap Analysis.

Table 4: Institutes and programmes in South Africa in the renewable energy and biogas industries

Framework/ Policy	University affiliation	Programmes offered	Link
South African Renewable Energy Technology Centre (SARETEC)	Cape Peninsula University of Technology	Short courses and formal training courses	http://www.saretec.co.za/
Sustainability Institute	University of Stellenbosch	Postgraduate programmes, short courses	http://www.sustainabilityinstitute.net/
Centre for Renewable Energy and Sustainability Studies (CRSES)	University of Stellenbosch	Postgraduate programmes, short courses, workshops, lectures	http://www.crses.sun.ac.za/index
Centre for Energy Research	Nelson Mandela Metropolitan University	Postgraduate programmes, short courses	http://energy.nmmu.ac.za/
Environmental and Process Systems Engineering	University of Cape Town	Postgraduate programmes	http://epse.uct.ac.za/
Energy Research Centre	University of Cape Town	Postgraduate programmes	http://www.erc.uct.ac.za/
Risk and Vulnerability Science Centre	University of Fort Hare	Postgraduate programmes	http://ufh.ac.za/centres/rvsc/introduction
Dicla Training Centre		Sustainable agriculture practices	http://www.diclatraining.com/training_courses/index.asp
Renewable Energy Solutions		1-day biogas training courses offered	http://renen.co.za/products/#BioGas
Internationales Biogas und Bioenergie Kompetenzzentrum (IBBK)		Biogas Training Seminar and Study Tour	http://www.biogas-training.co.za/

10 Dr Sampson Mamphweli is a Senior Researcher at the University of Fort Hare (UFH, 2016), his fields of interest include renewable energy generation from biomass and biogas. He has authored numerous papers and performed presentations on this field and associated industry and is currently involved with rural AD project implementation and the training of associated masons and operators.

11 IBBK holds short courses in various countries with growing biogas industries. The last short term course was held in January 2016 covering theory, designing and application of biogas plants (IBBK, 2016).

5 Stakeholder Engagement

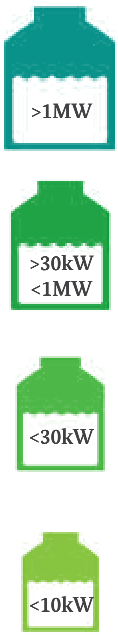
Stakeholder engagements and informal semi-structured interviews were utilised to define the biogas industry specific to the current South African industry and include broad aspects such as plant sizes and capacity, to more detailed aspects of developer anticipated pipeline of projects per year going forward. Industry organograms were collated and aggregated from data collected from stakeholders, which included an analysis of current and ideal skills associated with all phases of the biogas technology. Stakeholders gave input on their perceived challenges and benefits of the South African biogas industry, which were implemented into the definitions and scope for the biogas potential and model scenarios.

5.1 PLANT SIZES (CAPACITY)

Biogas plant sizes are not conventionally generalised in South Africa or internationally, due to the wide variety of effecting factors, and stakeholder opinion is not uniform on this point. Biogas plant capacity is dependent on the output desired (gas, electricity generation, heat), the availability of feedstock and financial structuring. Some developers designate their plant sizes in terms of volume of digester, some on input tonnage and type of feedstock, whilst others designate the output capacity in terms of electricity or gas volume linked to engine size or hours of gas use.

Furthermore, due to a lack of remuneration mechanisms for excess electricity and an overarching policy or framework for wheeling agreements that enable the non-linear transmission of electricity in South Africa, some biogas plants that produce excess electricity have decreased their production capacity to supply only what (electricity, heat and gas) can be utilised on site (Stakeholder Interviews, 2016).

For the purposes of this study, biogas plant sizes were designated into the following categories: small, medium (commercial) and large/utility for ease of comparisons between different biogas projects and activities specific to South Africa, as shown in Figure 10. An analysis of SABIA's working group activity, active rural AD installers, and



Large scale

- Self-consumption & fed into the grid e.g. abattoir, feedlot, agricultural processing
- Case studies / Developers: Bronkhorstspruit - B2W, Uilenkraal - CAE & Morgan Springs - BiogasSA
- 15-150 Tons of MSW/manure/abattoir/WWTW (Typical feedstock)

Medium scale

- Self-consumption (with possibility to feed into grid) e.g. restaurants, schools, farms
- Case studies / Developers: Jan Kempdorp - Ibert, WEC
- 2-15 Tons of MSW / manure / agricultural / abattoir / sewage (Typical feedstock)

Small scale

- Self-consumption e.g. household
- Case studies / Developers: Waste to Energy Programme - SANEDI, Agama & BiogasSA
- 0,1-2 Tons of MSW / manure / sewage (Typical feedstock)

Rural

- Self-consumption e.g. household with 2 cows
- Off grid, rural communities and individual households
- <1 Tons of MSW / manure / sewage (Typical feedstock)

Figure 10: Project size designations and typical feedstocks (using tons as a generalisation unit) (sourced from Stakeholder Interviews, 2016; AltGen Consulting, 2016)

current project sizes indicated that a fourth project size is required that includes only rural biogas AD's, due to the large potential of implementing biogas projects widely in rural areas of South Africa and the different skills level requirements and job creation potential. As opposed to self-funded early-adopters of small and household AD's (such as game farms and sustainability advocates), rural bio-digesters are often government-implemented and subsidised. Rural populations in South Africa have a basic need of electrification, fuel sources and sanitation: many areas are too remote to be connected to the grid, and have not received service delivery. In order to address the socio-economic needs of the country and contribute to the National Development Plan (DoE, 2012), rural biogas projects are increasingly being funded and/or subsidised by governmental organisations (Refer to Chapter 5.8).

5.2 BIOGAS POTENTIAL: DEVELOPER PIPELINE ESTIMATES

Stakeholders were asked to estimate the number of projects they expected to initiate in the next 5 years, per project size. These results are summarised in Figure 11. The developer pipeline estimates are noted as conservative assumptions, as they reflect the current environment that the biogas industry is growing in. Therefore, these estimates are used in the conservative scenario of the model, as described in Section 7.2.

5.3 INDUSTRY CONSENSUS ORGANOGRAMS, BIOGAS JOBS & SKILLS VALUE CHAIN

Initial trends can be identified based on the preliminary outputs from projects currently in operation. With respect to rural and small scale projects, a single, highly skilled individual is capable of fulfilling many roles that are distributed between many different people in larger projects. For a period of a few days during construction of the AD, 1 – 3 unskilled labourers (or preferably a few skilled with previous building experience) are brought on board and receive basic construction training with regards to installation. Many developers working in the rural field have a long term goal to train up a local entity to operate

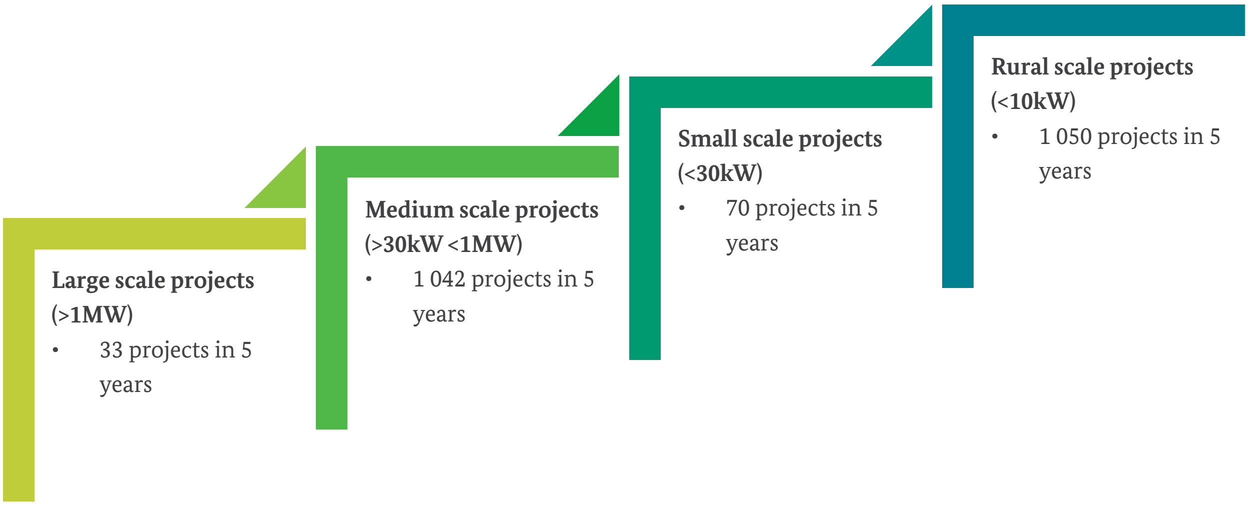


Figure 11: Sum of developer estimates of projects per year

and troubleshoot the digesters in the area (Stakeholder Interviews, 2016).

Medium and large scale projects often involve a team of highly skilled individuals in the development phase, with a few international skills brought in for particular roles that require specialised/technical experience. With regards to medium and large scale projects, comparisons can clearly be made, with strong initial similarities having been identified. For both sizes, the development phase is dominated by highly skilled individuals with key skills such as AD design, normally gained through international training and hands on experience. This is often due to the highly specialised equipment (such as engines and control systems) being obtained from Europe, requiring experienced individuals to provide guidance and training on the system.

The construction phase brings with it the need for more generalist skills found within the skilled, semi-skilled and unskilled levels. The fundamental skills required during construction include civil, mechanical and electrical engineers, technicians and installers. The unskilled and semi-skilled work force can be used from within the general construction industry and are not specific to AD. Only a small number of skilled and highly skilled individuals are required to oversee the general operations for both project sizes.

The team sizes drop significantly after construction and can vary from one to nine individuals for operations and maintenance. During this time, the highly skilled individuals play a more crucial role as they are largely, and often solely responsible for troubleshooting and ensuring the smooth operations of the plant. Although team dynamics can vary, the standard at present includes a small number of unskilled labourers involved in feedstock supply and one or two semi-skilled individuals responsible for monitoring the quality of the feedstock.

Please refer to the organograms in Appendix E for more detailed information regarding each phase and project size.

5.4 LOCAL CONTENT

Personal interviews and site visits during the course of this study further substantiated that most of the civil components to construct the AD can be easily found and sourced within South Africa, and as a result of the slow up-take of AD implementation, neither new manufacturing facilities nor new jobs were created at this time. This is especially true of rural and small scale AD's, with simple designs and technology, and a desire to keep overall capital costs low. For larger AD's, a few key items are sourced internationally. These items often include the dome, transformer, control panel and in some cases the engine and technical safety/monitoring equipment (Stakeholder Interviews, 2016).

5.5 SKILLS QUALIFICATION REQUIREMENTS FOR ORGANOGRAMS

The majority of stakeholders who engaged with the questionnaire indicated that their highly skilled employees involved in the design, feasibility and operation of the projects are trained in international courses. The skilled, semi-skilled and unskilled team members are trained on the job by the highly skilled members, through hands on experience on the plant.

A recurring theme in the biogas industry from both the technological and qualifications perspective is that Germany is the leader in technology and training in biogas. Experience is a highly regarded skill in the biogas industry, as most information gained internationally is not applicable in a South African context due to differences in technology applications, end-use of products, feedstock availability and preparation requirements as well as the legal environment.

5.6 SPECIFIC CHALLENGES FOR SOUTH AFRICAN BIOGAS INDUSTRY: INHIBITERS AND ENABLERS

The interview and questionnaire results from stakeholders and key players revealed a variety of obstacles inhibiting the expansion of the biogas industry, as well as a few enablers that currently have or may have a positive effect on the success of the industry. Table 5 gives an overview of the inhibitors and enablers, as well as a few potential enablers and solutions to the inhibiting problems.

Inhibiters of the biogas industry worth highlighting were those repeated during several Stakeholder interviews, which consist of the lack of remuneration mechanisms to feed excess power into the grid, as well as the associated costs (wheeling costs and land servitude costs) to transport power using the national/municipal grid(s) to locations off site. The result is a decrease of interest from developers

Table 5: Inhibitors and enablers of the South African biogas industry (Stakeholder Interviews, 2016)

Inhibiting factors	Current enablers	Potential enablers
Lack of awareness, public, private and government	SABIA, stakeholders and industry reflection in media	Policy changes to increase use of gas capturing AD on WWTW
Low electricity prices (make biogas more unviable)	Increasing Eskom tariffs	Subsidies/tax redemption for AD implementation
Tight margins, unable to pay qualified plant operators; lack of training and education around biogas	A few training courses provided in the country	Formalise biogas training and provide training for the 'less expensive' skilled or semi-skilled employees; further health and safety training can be aligned with the gas and natural gas industry
The cost and time taken to fulfil the current environmental licensing requirements (full EIA required for all plants that produce methane)	SABIA aligning Biogas policy/ licensing with current standards/ policy	Further streamlined EIA process – less licences for lower output
Legislative requirements are quite divided and unclear		Central base to refer to for legisla-tion
No market for surplus energy generation <1MW		Remuneration mechanism for surplus energy <1MW
Abattoirs can only be financially viable at scale for self-consumption (reducing waste, heat and electricity costs), i.e. 200 cattle per day, 1000 sheep, more than 100,000 chickens	Waste laws (NEM:WA) preventing abattoir wastes to be treated with municipal wastewater or sent to unspecialised landfills	Increased waste treatment restrictions/costs
Feedlot unviable below 20,000 cattle	Utilising other waste streams in the area (food, commercial, etc.)	
Farmers are high risk for banks to lend money for biogas implementation	Increasing operational costs for agricultural processes	Financial support/lender schemes for biogas AD implementation
Long (10year+) payback period too long for farmers to invest directly	Increasing operational costs for agricultural processes; more ADs proven in the country = more faith in technology	More streamlined process will require less capital investment; service and maintenance agreements for AD technology implementation (pay for only what they use)

looking to implement large scale projects, as exemplified in Figure 12. Furthermore, the implementation of biogas projects is heavily over-regulated and requires a minimum of three licences in the Environmental Impact Assessment process for any project that requires one ton or more input of organic waste, or 500 kg or more of hazardous waste (which may include sewage waste and abattoir waste) (Stakeholder Interviews, 2016).

'...in the case of consistent generation and availability (biomass and biogas), matching the capacity to generate with the ability to utilise, always seems to leave you at a dark fork in a dust road where you have to either scale down the project and consequently increase your cost per MW, or dump the extra power on the grid for a revenue that hardly pays for the extra equipment. For instance, in one of our current projects, although our capacity is utilised during the week, once Saturday rolls around and operations run with a skeleton crew while the rugby is on we end up with a serious amount of spare energy. Sure we can use the heat for feedstock or digestate drying, we could sell it to the grid or even wheel it to a second customer but the cost of this process and the additional hoops that municipalities or Eskom hold for us to jump through make it end up as a real waste of some great and clean energy.'

– Ennovation, 2016

Figure 12: Quote on biogas industry from Ennovation (2016)[12]

A few of the stakeholders and potential beneficiaries are losing faith in the biogas industry due to poor technology performance: technology that is designed abroad does not necessarily work well in South Africa as the feedstock is collected, handled and treated in a different manner. Furthermore, international biogas developers that are re-investing in the market tend to keep local involvement, job creation and skills transfer at a minimum; managing the plants remotely and sending in foreign technicians and technology providers when the need arises. The majority of implemented biogas projects have been largely influenced by international companies due to lack of local funding in terms of government support, shortage of local technology due to a gap in the skills market for biogas designers and associated technicians to maintain and operate the plants.

Internationally, biogas and anaerobic digestion is well known from a scientific, technical, human capital and skills resource stand point. A wide range of technology is available and adaptable to almost any type and quantity feedstock source. As the developing world starts to bring renewable energy into the spotlight, this information is spreading to South Africa. However, at present there is a large gap in understanding how biogas projects work as well as comprehension the perceived risks and associated benefits. This has led to a negative perception of the technology among lower Living Standards Measure (LSM) groups, which in turn makes municipalities doubt the potential for rural or commercial scale anaerobic digesters in rural areas across South Africa, despite the potential for numerous social, economic and environmental benefits (Stakeholder Interviews, 2016).

5.7 POTENTIAL BENEFITS FOR SOUTH AFRICAN BIOGAS INDUSTRY

The benefits of implementing biogas technology are wide-ranging, covering a number of aspects and problems South Africa is facing at present. The potential benefits are summarised in Figure 13.

12 Source: Ennovation, 2016 [Online]. Available at: http://www.ennovation.co.za/storage-the-missing-link-in-renewable-energy/ [Accessed 16 02 2016]

Socio economic

- Electricity, heat and fuel for rural areas
- Waste management, sewage and sanitation for rural areas
- Gas fuel: cleaner than other gas fuels or charcoal
- Less labour intensive energy collection than charcoal preparation, especially for women and children in rural areas who usually spend long hours collecting the wood for burning

Wide-reaching employment opportunities

- Feedstock treatment, preparation and transport
- Fertiliser preparation and transport

Supplementary industry

- Manufacturing biogas-specific domestic appliances for rural or household biogas use

Environmental

- On-site sewage treatment for rural areas that are not connected to a municipal wastewater grid
- Improvement of municipal wastewater treatment works (WWTW) sludge digestion and management
- Treatment of abattoir waste and other hazardous wastes (condemned materials that cannot be treated in WWTW or sent to landfill)
- MSW redirection from landfills
- Less deforestation and burning for charcoal fuel in rural areas
- Fertiliser produced from AD digestate can replace synthetic fertilisers made from fossil-fuel derived chemicals

Electricity

- No grid connection required for far-out rural areas that would be an expensive infrastructure process
- Lower electricity costs for abattoirs/agricultural farms/commercial plants/WWTW using biogas electricity/heat on site
- Rising electricity costs indicate that biogas electricity could provide a more economic supply within 5 years

Figure 13: Potential benefits of implementing biogas technology in South Africa (Stakeholder interviews, 2016)

5.8 SOUTH AFRICAN CASE STUDIES

Table 13 in Appendix D details a list of known biogas projects in advanced stages of construction and operation in South Africa as of April 2016, including a number of rural and household scale biogas projects from specific developers. SABIA are currently developing a project map of biogas projects around South Africa, although specific details are not yet available (SABIA, 2016). To the best of our knowledge, there are approximately 38 projects in total (rural projects may contain multiple digesters) in the feasibility and development phase, construction or operation[13]. This is taken as a conservative figure, as a number of developers chose not to engage with AltGen Consulting and the study.

13 Many more rural and household projects may exist that are not included in Table 13 due to lack of information and developer participation. Table 13 is not considered exhaustive, rather was a collaborative assessment from various stakeholders.

Three large, three medium and three small/rural scale projects were investigated for the model base-line aggregation, and seven large and medium scale projects were investigated as case studies. The projects were chosen on the level of developer participation and available information. While interviews were conducted with Landfill Gas project owners, they are excluded from the aggregated dataset. This is due to the technology being vastly different in comparison to the other types of feedstocks, and would therefore require a separate employment ratio to estimate the employment and skills factor from that sub-sector.

Many commercial processes projects were omitted from this list, as they use current/employed staff on the site for general labour and maintenance tasks, although these mechanisms are included in both Appendix E: Industry Organograms and Chapter 9: Skills Gap Analysis. That saying, as discussed in Chapter 11: Recommendations and further studies, quantifying the current number of commercial farms that could benefit from certification and training is an avenue of research that would be useful to determine the immediate need for biogas certification. Other case studies were omitted due to lack of correspondence and feedback from the developer or stakeholder involved. Although the number of projects utilised as case studies in this report is limited, the quantitative and qualitative conclusions of this study are not solely based around the Case Studies. Rather they form part of the many layers of information from literature and experts within the field and have been verified in all cases possible with reputable stakeholders.

Each case study below gives an overview of the technology, what made the project feasible and an outline of the associated skills and employment opportunities presented. The job numbers and specific employment factors for the case studies below are not given in the report as they are classified information. Rather, where project information was available, these figures have been combined and aggregated for use in the model.

5.8.1 Bronkhorstspruit Biogas Project (4.6MW) – Bio2Watt

The Bronkhorstspruit Biogas Project is the first commercially operational biogas project in South Africa, developed by Bio2Watt. Bio2Watt, a South African waste-to-energy company, responsible for developing, building, owning and operating the project; entered operations in October 2015 (Bio2Watt, 2014).

The project is located on the Beefcorp feedlots in Bronkhorstspruit, a small town about 50kms east of Pretoria in the Tshwane Metropolitan area. This site was feasible for the development of a biogas plant due to the proximity to crucial components including a readily available supply of feedstock, adequate water and grid access (Bio2Watt, 2014). The plant utilises roughly 120 000 tonnes of feedstock a year, the bulk being manure with additional supplements from the abattoir along with food wastes (Sean Thomas, 2015).

The Bronkhorstspruit plant has a generating capacity of 4.6MW and an initial life cycle of 20 years. It serves as an independent commercial entity, supplying electricity via a wheeling agreement (the first of its kind in South Africa) via

Figure 14: Bronkhorstspruit Biogas Plant (Makwana, 2015)

the city of Tshwane Metropolitan to the BMW Rosslyn Plant roughly 60kms from the site. The biogas plant supplies roughly 25-30% of BMW's electricity demand (Carr, 2015).

Sean Thomas, the MD of Bio2Watt, led the early stage development of the project with assistance from international and national specialists including Design Engineers, Feedstock Testing Technicians as well as Technical and Environmental Consultants. The development phase took roughly 7 years with construction commencing in July 2014 and commissioning in April 2015 (Sean Thomas, 2015).

Bosch Projects, in conjunction with ComBigaS (Danish Biogas Technology Partner), were responsible for the design, manufacture, supply and installation of the project (Carr, 2015); with Bosch Projects primarily responsible for managing and overseeing the 18-month construction process (Sean Thomas, 2016). The construction team consisted of 110 individuals roughly divided between three major disciplines (civil, electrical and mechanical), all of whom were on site for 4 or more months at a time, depending on their job requirements. The current operations and maintenance (O&M) team consists of 7 individuals, including a Plant Manager, 3 Monitoring Technicians and 3 Feedstock Supply Technicians. There are also 3 security staff on site (see Industry Consensus Aggregated Biogas Organograms in Appendix E).

The total project costs amount to R150m, consisting of R36m equity, R16m Department of Trade and Industry (DTI) grant and R98m loan from the IDC (Industrial Development Corporation). The project is structured as a limited recourse finance transaction with Norfund, the EPC contractor, two impact funds and Bio2Watt serving as equity investors (Sean Thomas, 2015). Roughly 50% of the materials sourced for the project were local with some key components having been imported from Europe.

A major problem encountered during the development of the project was the tedious steps in order to comply with rigid environmental legislation that needed to be undertaken before construction could commence. These processes took approximately 7 years and were extremely costly (R8million in legal costs) (*Ibid.*). The project has however, been successful which can be attributed to several factors including; proximity and availability of feedstock, utilisation of a wheeling agreement, grid access and most importantly, the support and buy in from various stakeholders including the client - BMW - who was willing to pay a premium for the electricity as it aligns with the sustainability plan to use energy from cleaner sources (BMW Group, 2015).

5.8.2 Uilenkraal Biogas Project (500 kW) – Cape Advanced Engineering (CAE)

Cape Advanced Engineering (CAE) is a South African company involved in the development, design, construction and management of biogas projects in Southern Africa. A key project is the Uilenkraal biogas plant located on a private dairy farm near Darling in the Western Cape. Planning began in 2008 with the assistance and close cooperation of the farmer and project owners Willem and Paul Basson. CAE was responsible for developing, building and operating the project with construction commencing in 2013 and the first biogas being produced in August 2014.

Figure 15:
Uilenkraal Biogas Plant
(Construction Review, 2015)

The farm consists of roughly 1 200 lactating cows housed in undercover units with an automatic mechanised pushing apparatus. The feedstock (manure, urine and wastewater slurry), is collected three times a day and is pushed into a channel. Contributing to over 70% of the feedstock, the manure then flows into a central collector, along with the additional feedstock sourced from near-by organic waste streams from the farm, and is pumped into the bio-digester (Claassen, 2015).

The Uilenkraal biogas plant is one of the first large scale biogas projects in South Africa to have a local content in the upper region of 80-90%, as a result of key components (the bio-digester, gas engines and CHP generators (2 x 250kVA) being locally sourced and manufactured). By way of example, the two generators were designed and manufactured by CAE (Taylor, 2015).

The total project cost amounted to R13 million which was solely funded by the farmers, yet the results have not had positive returns. The plant is currently meeting 95% of the farms electricity demand (200kWh's daily) supplying power to the farm's dairy, animal-feed milling and crop irrigation activities. According to the farmer, Willem Basson, the electricity generated from the biogas has decreased the farm's monthly electricity bill from R110 000 down to R12 000 (Claassen, 2015).

Although the plant is connected to the grid, current legislation does not permit feeding the surplus electricity back into the grid.

There are several factors which have led to the success of the Uilenkraal project, including the high self-consumptive requirement of the farm and the strong buy in from the farmers. Additionally, the farmers have ownership of the project which has also allowed for the sharing of overhead costs and available skills (managing feedstock and basic trouble shooting). An additional feasibility component is noted with the manner in which the cattle are housed: collecting manure from open fields requires many workers, and hard labour. At Uilenkraal the cattle are housed in high roof open barns where the manure is collected mechanically in a continuous stream. A high quality fertiliser from the digestate material is produced, which is used on the farm, further reducing input costs to the farmer. It is also sold to neighbouring farmers as an additional economic resource.

Due to the high level of mechanised components of this project, very few jobs are created, and where possible. The plant and the farmer utilise farm hands as human resources. Three technical plant managers are employed on shifts to manage the safety, daily troubleshooting and O&M of the plant- often managing plant performance remotely. Feedstock management is primarily managed by the farmer.

5.8.3 Elgin Fruit Juice Biogas Project (500 kW)

Elgin Fruit Juices is located in the Overberg district municipality roughly 70kms from Cape Town CBD in the Western Cape. The company owns and operates an onsite anaerobic digester which has an installed capacity of 526kW of electricity for own consumption during the operating season i.e. for 6 months from January to June. The heat produced

Figure 16:
Elgin Fruit Juice Biogas Plant
(Energy, 2015)

Figure 17:
Northern Waste Water Treatment Works
(Scholtz, 2013)

from the anaerobic digester is also used, creating steam for some of the key juice processes which includes drying.

The anaerobic digester is fed with the by-products (pomace and waste fruit) of the juice extraction process for which damaged or sub-standard fruit pulp is used. The anaerobic digester is also fed cow manure from the Groenland Meat Traders (1-2tonnes per day) as well as chicken litter from Elgin Free Range (<1 ton per week) (Mostert, 2015).

The digester was designed and constructed locally with specialised equipment from Europe. The concrete tank was designed and constructed by BAU Afrika, a local civil engineering consultancy (BAU-Afrika, n.d.). The project entered construction in January 2013 and reached completion and commission in December 2013, and came into operation in May 2014. It has a local content spend greater than 50% and was funded exclusively by private equity (Mostert, 2015).

There is currently one highly-skilled employee responsible for overseeing the management of the anaerobic digester as well as 4 semi-skilled full time staff and 2 – 4 unskilled part time workers (*Ibid.*).

The key success of this project can be attributed to the readily available feedstock, proximity to additional waste sources, the high on site electricity demand and the ability to utilise the heat produced.

5.8.4 Northern Wastewater Treatment Works Biogas Project (1.2 MW) – WEC Projects

The Northern Waste Water Treatment Works (NWWTW) serves as Johannesburg's largest treatment works, dealing with roughly 430million litres of sewage daily. It is also the site of the Joburg Water's first waste to energy biogas plant; developed following the refurbishment of three of the existing digesters at the Works (Naidoo, 2013).

NWWTW appointed Zitholele Consulting (a specialist consulting service provider in the areas of Engineering, Environmental and Waste Management) in conjunction with Golder Associates (a global consultancy advising on environmental, social, and financial aspects) and WSP Industrial (engineering and design consultancy), to develop, design and implement a biogas project at the NWWTW's (Scholtz, 2013). WEC Projects were awarded the tender to design, build and operate the project under the ownership of Johannesburg Water, and have committed to a 7-year O&M agreement (WEC Projects, 2016).

With an installed capacity of 1.1MW (3 x 376kW engines), providing roughly 10 - 15%[14] of the Works electricity demand (Odendaal, 2013), the design and construction of the project was completed within 12months with the project entering operations in August 2012. Once the remaining pre-existing digesters have been upgraded, 3 more engines can be put in place and the plant will produce

14 Electricity demand varies according to peak sewage hours (Electric Power Research Institute, 2013)

Figure 18:
Morgan Springs Biogas Plant
(BiogasSA, 2015)

up to 4.5MW's, providing more than 50% of the NWWTW's electricity needs (WEC Projects, 2016).

The success of this project can be largely attributed to the readily available, continuous waste stream as well as the pre-existence of the digesters at the Works which meant that no EIA was required.

5.8.5 Morgan Springs Biogas Project (400 kW) - BiogasSA

BiogasSA recently completed its first commercial turnkey biogas plant at the Morgan Abattoir in Springs, Gauteng. The plant has an installed capacity of 0.4MW, generating approximately 50% of the abattoir's own electricity needs as well as 90% of the abattoir's heat/warm water needs used for cleaning and sterilisation processes (BiogasSA, 2015). The digester will be largely run on abattoir wastes which includes paunch manure (stomach contents), manure, blood and guts.

The plant was designed and developed by BiogasSA, with development taking roughly two years. WEC projects have served as the EPC with construction beginning in 2015, taking roughly 16 months. The plant is currently in commissioning and once operational (2016), iBert will be responsible for operations and maintenance. The plant has a local content of roughly 35% with a total project spend of over R20 million (Stakeholder Interviews, 2016).

Part of the success of this project can be attributed to the readily available, continuous waste stream as well as the high electricity demand of the abattoir and its ability to utilize the heat produced by the system.

5.8.6 Jan Kempdorp Abattoir Biogas Project (135 kW) – iBert

iBert is a South African based company formed by collaboration between Bio4gas Express Reactor Technology Company (Bert), an Austrian based company, and Otto Hager, a South African energy specialist. iBert are active in the medium scale biogas sector with projects primarily based on abattoirs. They use their own technology, BERT reactor/digester, which has been specially designed for smaller to medium scale biogas projects (iBert, 2016).

iBert was responsible for the development, design, construction and operation of the Jan Kempdorp Biogas Plant located on an abattoir in the Northern Cape. The plant runs completely on abattoir waste which includes animal manure and slaughter waste. The digester utilises roughly 2020 tonnes of abattoir waste per year and has an installed capacity of 135kW, generating 650kWh/day (iBert, 2015).

The project cost amounted to R6 million which can be recovered within 4-5years of operational commencement (SABIA, 2013).

The success of this project can largely be attributed to the readily available, continuous waste source as well as the abattoir's need to dispose of condemned waste in a safe manner. Furthermore, the high electricity demand of the facility and its ability to utilise the heat produced by the biogas plant in abattoir processes add to the success of the project.

Figure 19:
Jan Kempdorp Biogas Plant
(iBert, 2015)

5.8.7 New Horizons Waste-to-Energy Facility (4 MW) - Clean Energy Africa

Clean Energy Africa (CEA) and Wastemart have developed a large-scale biogas plant in Athlone, Cape Town, due to be commissioned in November 2016. Wastemart, as waste collectors and separators, will run a zero-waste-to-landfill operation: collecting, separating and utilising the waste collected from various retail stores. The glass, plastic and paper will be separated for various recycling streams, whilst the majority of the waste, (organic matter) will be routed to two large bio-digesters (Stakeholder Interviews, 2016). The plant will utilise approximately 400 tonnes of MSW per day, and generate about 1 500 cm^3 gas *(Ibid.)*.

5.8.8 Rural/Small scale

Many developers see that significant biogas potential lies within the rural sector as many communities are still without access to electricity, and even those with electricity find cooking expensive and would prefer to use an alternative fuel source. Households with sufficient waste or number of livestock are able to implement bio-digesters to provide an alternative energy source for thermal needs. There are several developers and governmental programmes working to implement biogas projects within the rural sector.

The South African National Energy Development

Figure 20:
Wastemart waste removal vans
(WasteMart waste management services, 2016)

Institute (SANEDI) is currently responsible for managing and rolling out the Working for Energy Programme[15], a renewable energy initiative focused on providing thermal energy and improving the quality of life for people in rural communities. They are currently involved in three initiatives, which include the Melani Village Biogas Expansion Project as well as the Illembe District and Mpufuneko Biogas Projects (SANEDI, 2015).

The lllembe District Biogas Project in KwaZulu-Natal consists of 26 operational digesters. Khanyisa Projects, a renewable energy developer, was responsible for training a number of local builders to construct the 26 six cubic meter digesters (Khanyisa Projects, 2016). The Mpfuneko Biogas Project in Limpopo which is currently underway, will involve the installation of 55 digesters. The Melani Village Biogas Project in the Eastern Cape has been developed in conjunction with the University of Fort Hare, with an aim of installing 110 digesters.

A number of developers are active in the rural/small scale sector including BiogasPro Agama and BiogasSA. BiogsaPro Agama has installed 320 units to date for various clients including include, bush camps, wine and game farms, rural households and schools. Their projects are predominantly located in the Western Cape with a few in the Eastern Cape and Kwa-Zulu Natal. They install a variety of digester models and sizes depending on the requirements of the client and feedstock availability. The smaller units take 2-3 days to construct and are able to process 5kgs – 20kgs of waste a day. Total project costs are on average in the region of R32 500, with an installation cost of R20 000 as well as R5 000 for the necessary connections (Ayres, 2016).

15 A bid was recently closed that involved the strategy for nationally implementing the WfE programme, which will contribute to more rural biogas projects.

6 Biogas Potential in South Africa

In order to investigate the job creation and skills development potential of Biogas in South Africa, we need to make some estimates and assumptions about what the future of biogas in South Africa may look like. Since biogas can potentially utilise all organic matter waste streams, determining the *theoretical potential* requires an analysis of the types and quantities of these waste streams in South Africa. The *actual potential* requires broader consideration, taking into account general awareness of biogas; factors contributing to the demand for alternative sources of fuel, electricity and heat; and legislative requirements for waste handling and gas usage. These considerations are detailed in the *model scenarios*, further explained in Section 3. This Chapter designates *theoretical potential* according to stakeholder information and statistical research, and makes various assumptions where necessary to draw up an *actual potential* value for use in the model.

It has to be stressed that this is an assumptive figure, and the majority of statistics have been subjected to a 50% viability assumption. This is to encompass the idea that logistical, economical and 'acceptance' issues may prohibit certain farms, households, schools and other entities from implementing biogas plants. There is a myriad of influences on biogas potential, not the least of which include the legislative and policy environment, general climatic conditions (being reliant on bio-feedstock means ultimately also being reliant on a favourable climate), education, training, as well as the de-stigmatisation of the use of waste streams in general.

6.1 RURAL HOUSEHOLDS, SCHOOLS AND CLINICS

6.1.1 Households and Agricultural Households

Currently, 35% of South Africa's population lives in rural areas (Statistics South Africa, 2009). The Integrated National Electrification Programme (INEP) for 2016/17 (DoE, 2015) provides policies and guidelines for unproclaimed areas, farm-houses and non-grid households. The policy states that the national utility does not currently recover the costs associated with supplying electricity to far-lying communities and predicts that providing grid electricity to these areas is not likely to be economical or sustainable, and off-grid energy alternatives must be considered (DoE, 2012).

The General Household Survey performed in 2014 by Statistics South Africa (StatsSA, 2014) benchmarked approximately 15.6 million[16] households[17] across South Africa. The Survey reports that an estimated 85.4% of households in South Africa have access to electricity, thus by deduction, at least two (2) million households do not have access to the national grid. These households are generally located in rural areas which are difficult to connect to the grid and therefore use alternative fuel sources for energy requirements. Although the majority of households are electrified, electricity is expensive and many households prefer to utilise a more economical fuel source for cooking needs. 441 000 households make use of solid fuels such as charcoal and wood for cooking and heating, whether they are electrified or not (StatsSA, 2009).

About 5.6 million households do not have a municipal refuse removal system in place and over 3 million households live in conditions of poor sanitation below the standard allocated to the Reconstruction and Development Programme (RDP) (StatsSA, 2014).

Although a 4-person household sewage and organic waste alone would not be sufficient to run an AD (Stakeholder Interviews, 2016), 2 or more households may feed a shared AD, and share the resulting biogas cooking hours. However, supplementing the AD with manure from livestock would make a single household AD viable. For the purposes of this study, only agricultural households have been investigated for potential AD's.

16 All numbers given in the survey are estimates of a total population of 53.7 million people

17 Rural households average 4.5 persons and urban households average 3.4 persons (StatsSA, 2014)

The 2011 Census, conducted by StatsSA investigated 14.5 million households, and of these almost 20% are listed as agricultural households (StatsSA, 2011). The average number of cattle, sheep, pigs and goats per agricultural household in South Africa is distributed as shown in Figure 21. This data is extrapolated to the total population of South Africa as listed in the General Household Survey of 2014 for ease of comparison and the estimated household livestock statistics are shown in Figure 22.

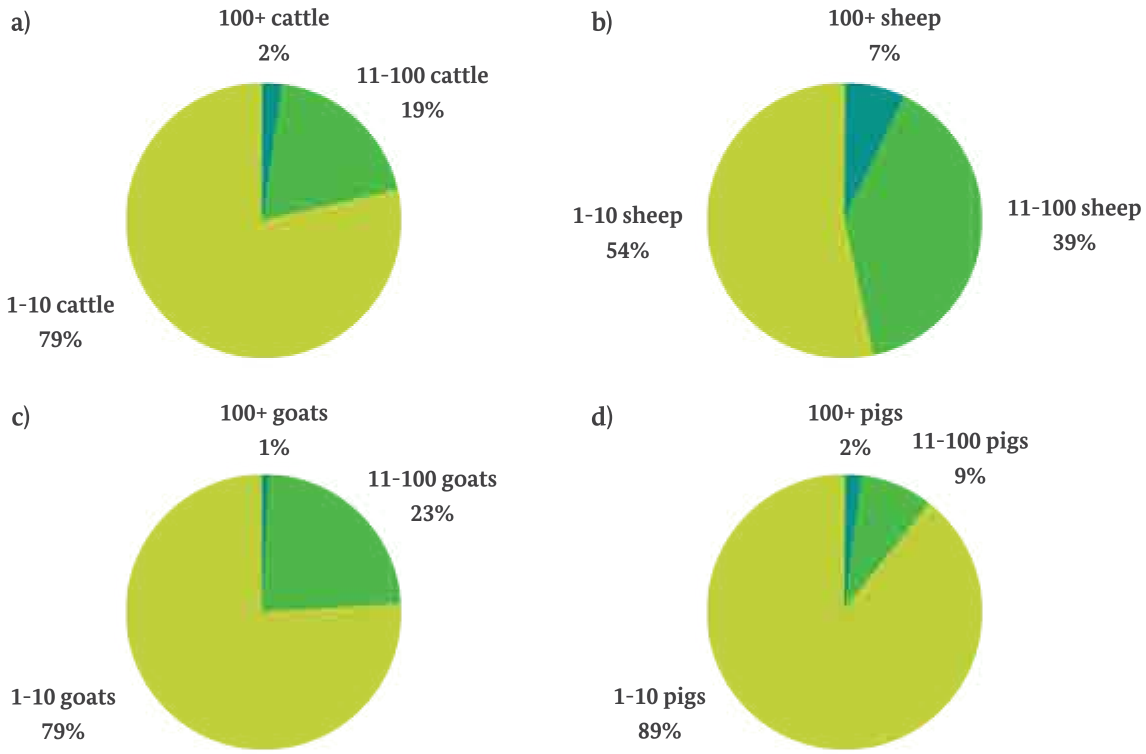


Figure 21: Distribution of percentage of agricultural households owning livestock: a) cattle, b) sheep, c) goats, d) pigs (StatsSA, 2011)

At the time of the census, less than 1% of agricultural households generated gas for cooking from the animal dung on their farms (StatsSA, 2011). This number has possibly increased slightly due to a growing number of developers in the rural-scale AD range, and greater interest from government-associated programs to electrify rural areas with renewable energy (such as the SANEDI Working for Energy Programme).

In order for a rural AD to be viable, the household for which it is implemented must have 2 or more cows (Stakeholder Interviews, 2016). Other traditional domestic animals do not excrete as much dung mass as cattle and the organic richness of manure types varies (F.M.o. Food, Agriculture & Consumer Protection, 2012), and since information on other animal types required to feed an AD is not readily accessible they are therefore not analysed in the study.

For the purposes of this study, an estimation of 50% of agricultural households have been assumed viable for AD.

6.1.2 Schools

Rural schools provide an opportunity for 'closed-loop' sustainable systems: food and sewage waste can be used as feedstock for an AD, and the resulting biogas can then be used for cooking, heating and electrification. Further to this, the fertiliser produced in the AD can be used on fruit and vegetable gardens, providing food for children and staff as well as an opportunity for learners to be educated about self-reliance, natural systems, plant growth and renewable energy.

According to the Department of Basic Education, there are 12 466 rural and 13 361 urban and metropolitan schools. All schools have waste streams of sewage and organic waste from feeding schemes, hostel kitchens and tuck shops that provide a feedstock for potential AD's. Most urban schools are connected to municipal sewage waste systems, which decreases the economic justification for an AD, and therefore the emphasis of this section is on rural schools, where AD's can solve more than one problem: lack of energy, poor sanitation and an added benefit of generating organic fertiliser that allows for the implementation of a food garden onsite. The Department of Basic Education (2011)[18] found that 700 rural schools did not have appropriate toilet and sanitation facilities[19]. An AD would significantly increase sanitation at any facility provided it is correctly utilised and accurately managed, and in this respect it would be imperative that the department of education retains service providers on long term operations and maintenance contracts to ensure effective and appropriate management and maintenance of the AD's.

An assumption is made that approximately 50% of rural schools are viable for AD.

6.1.3 Clinics

Another consideration for rural bio-digester implementation is for clinics in far-lying areas. Since there is a discrepancy in the definition and use of 'rural' in the national health system (which is allocated by district), no analysis has been done so far to clearly distinguish urban and rural areas (Health Systems Trust, 2015). Table 15 in Appendix F indicates the data attributed by the types of clinics nation-wide, by the National Health Care Facilities Baseline Audit performed by the Department of Health and the Health Systems Trust in 2012 and 2013 (Health Systems Trust & Department of Health, 2013). As in the previous sections, an assumption is made that approximately 50% of rural clinics are viable for AD.

In conclusion, the overview of statistics referring to rural households, schools and clinics are shown in Figure 22.

Rural houses: livestock

- 3.1 million agircultural households
  - *2.5 million households with 1-10 cattle*
  - *1.7 million households with 1-10 sheep*
  - *2.4 million households with 1-10 goats*
  - *2.8 million households with 1-10 pigs*

Rural schools

- 13 361 urban/metropolitan schools
- 12 466 rural schools
  - *700 rural schools without sanitation facilities*

Rural clinics

- 125 satellite clinics
- 3 074 clinics
- 44 community day centres
- 238 community health centres

TOTAL POTENTIAL

- **7 974 small scale AD's (<30 kW) [schools and clinics]**
- **1.55 million agricultural household AD's (<10 kW)**

Figure 22: Summary of statistics relating to rural houses, schools and clinics and conservative potential projects (Department of Agriculture, Forestry and Fisheries, 2015; Health Systems Trust & Department of Health, 2013 & Department of Basic Education, 2011)

18 Department of Basic Education, 2011. Action Plan to 2014: Towards the Realisation of Schooling 2025. [Online]. Available at: http://www.education.gov.za/LinkClick.aspx?fileticket=XZGwrpV9gek%3d&tabid=418&mid=1211 [Accessed 07 03 2016].

19 A lack of sanitation was found to directly influence the attendance at these schools, especially for girls at menstruation age.

6.2 AGRICULTURE (CROPS, VEGETABLES AND FRUIT WASTE)

As with the feedstock consideration (Chapter 2.1), agriculture refers only to crops and plants due to the significant potential associated with manure waste streams – thus justifying manure waste potential to be considered as a separate Chapter (Chapter 6.3).

South Africa has over 100 million hectares of farmland distributed around the provinces (Department of Agriculture, Forestry and Fisheries, 2015), used for grazing, forestry, crops and plantations - just under 900 million tons of crops are produced annually. Of all agricultural produce (including meat, milk and seafood), 10 million tons per annum is wasted, and 50% of this wastage occurs during agricultural production and post-harvest handling and storage (Nahman & de Lange, 2013) before the products reach the processing and packaging phase (see Figure 26).

Agricultural waste provides a potential feedstock for anaerobic digestion, however these streams are cannot be considered in the potential feedstocks of the model without further investigation. Firstly, ring-fencing the waste stream for feasible AD project feedstocks is quite difficult when reviewing the national agro-waste potential, as there are too many layers and sub-layers to make clear assumptions. Barriers to quantifying the waste stream, such as transport costs (if the electricity usage is some distance from the source of the waste), and the commercial value of such waste streams (many crops, fruit and vegetable waste streams have a commercial value as they are used for compost, mulch and animal feed) result in too many uncertainties to include without proper investigation. It must be noted that this does not designate the feedstock source as not providing potential, it simply is *not* included in the model at present from the information available.

6.3 MANURE

Chapter 6.1 on rural biogas potential details the options for rural and small-scale biogas production from manure from agricultural households; therefore, this Chapter will refer only to commercial farms and feedlots. There are a number of discrepancies in the estimates of livestock data between governmental analyses and private organisations/associations estimates as industry associations only gather data from 'member' farms. To avoid referring to a wide range of sources, AltGen has chosen to refer in all possible cases to governmental publications relating to livestock and farm estimates.

6.3.1 Dairy

There are an estimated 1 834 dairy farms operating in South Africa, the number of cows per milk producer varies from 76 (Northern Cape) to 769 (Eastern Cape), averaging at 353 cows per producer (Milk SA & Milk Producers' Organisation, 2015). Andrew Taylor of Cape Advanced Engineering has indicated that according to his investigations there are (approximately) only a 100 dairy farms in South Africa with a sufficient herd size (biomass production) and electricity requirements to justify the implementation of biogas plants for self-consumption of electricity (Claassen, 2015). On the Uilenkraal Dairy Farm, at any given time, 1 200 cows out of 2 350 are housed in the dairy sheds which are equipped with an automatic manure scraper that pushes the manure into the waste-channel for transfer to the AD. Therefore, based on somewhat anecdotal evidence, AltGen have assumed that 1 200 cattle are required for feasibility of AD implementation to generate at least 200kWh per day (based on the case study information). The assumption of 100 viable dairy farms indicated by Taylor (Claassen, 2015) is taken as the conservative assumption of dairy farm potential[20].

6.3.2 Feedlots

Of approximately 50 000 commercial cattle farms in South Africa there are 70 listed commercial scale feedlots, most of which seem to own associated abattoirs, and the remainder are small-scale cattle producers (Department of Agriculture, Forestry and Fisheries, 2012). Commercial feedlots carry 15 000 to 40 000 head of cattle, with the largest farm in Africa located in Heidelberg carrying 120 000 head of cattle (Department of Agriculture, Forestry and Fisheries, 2012). AltGen have made a conservative

20 Although some literature sources make assumptions of methane potential per ton of manure in order to calculate potential, in order to align all sizes and types of biogas plants and also to ensure that plants which make use of multiple feedstocks can be compared, the researchers choose to base the potential off of numbers of cattle. This data was not only more accessible than tons of manure entering the digester, but was also a recommendation from industry with the data that was available at the time of this study.

assumption that 50% of feedlots have the capacity of cattle and infrastructure required for commercial AD feasibility.

Although there are a multitude of feedlots for poultry, sheep, goats and piggeries which also have potential for AD, there is a lack of case study examples and knowledge on these feedstocks, therefore this study has focussed on cattle and dairy farming.

Figure 23:
Karan Beef Feedlot

Dairy farms	• 1 834 farms – *353 cows each (average)*
Commercial cattle farming	• 70 feedlots – *15 000+ heads of cattle per feedlot* • Feedlots often associated with abattoirs
TOTAL POTENTIAL	• **100 Dairy farm medium scale AD's (±200 kW)** • **35 Feedlot large scale AD's (±1 MW)**

Figure 24: Statistics associated with manure streams from different livestock and conservative potential projects (Department of Agriculture, Forestry and Fisheries, 2011 & 2012)

6.4 ABATTOIR WASTE

As mentioned in Chapter 2.3, abattoirs are a significant opportunity for biogas production as waste laws have restricted abattoir waste from entering commercial waste streams (NEM:WA, 2008). Since abattoirs utilise heat and electricity on site, the biogas generated can provide economic benefits by reducing electricity requirements. A number of abattoirs in South Africa are investing in on-site biogas plants, as described in a few case studies in Chapter 5.8.

The Red Meat Abattoir Association statistics note 479 6.5

abattoirs (beef and mutton) in South Africa (Neethling, 2014), however, as mentioned previously, it is worth noting that many feedlots and abattoirs are associated (Department of Agriculture, Forestry and Fisheries, 2012), but due to a lack of information regarding this, they are counted as separate entities. This assumption must be taken into account when analysing the outputs of this Chapter. Stakeholder Interviews (2016) has indicated that a minimum slaughter number of 200 cattle per day are required for an abattoir AD to be feasible.

South African Pork Producers' Organisation (SAPPO) notes 153 pig abattoirs slaughtering about 2.7 million pigs annually (SAPPO, 2016), and South African Poultry Association (SAPA) has 214 registered commercial chicken abattoirs (SAPA, 2012). A minimum of 100 000 chickens slaughtered per day are required for a feasible chicken abattoir AD (Stakeholder Interviews, 2016), and extrapolating the feasibility requirements for cattle and poultry results in a minimum of 180 pig slaughters per day for a feasible abattoir.

Statistics associated with abattoirs are summarised in Figure 25.

Red meat abattoirs
- 479
  - *Feasibility requirement: > 200 cattle per day*

Pig abattoirs
- 153
  - *Feasibility requirement: > 180 pigs per day*

Chicken abattoirs
- 214
  - *Feasibility requirement: > 100 000 chickens per day*

TOTAL POTENTIAL
- **240 red meat abattoir medium scale AD's (±500 kW)**
- **72 pig abattoir medium scale AD's (±500 kW)**
- **107 chicken abattoir medium scale AD's (±500 kW)**

Figure 25: Summary of statistics associated with abattoirs and conservative potential projects (Stakeholder Interviews, 2016; Neethling, 2014; SAPA, 2012; Department of Agriculture, Forestry and Fisheries, 2012 & SAPPO, 2016)

6.5 MUNICIPAL SOLID WASTE (MSW)

6.5.1 Urban and MSW/LFG

The Draft National Waste Information Baseline Report (2012) estimates that 13% of municipal solid waste is organic waste. Although there is a global movement toward prevention, reuse and recycling of waste, South Africa still relies heavily on landfills - the baseline states that 3 million tons of organic waste is generated per annum, 35% is recycled and the rest is sent to landfill (DEA, 2012). Landfills generate large amounts of carbon-dioxide dominated gas, and as mentioned earlier in the study, requires different technology than AD's used for other feedstocks. Although MSW/LFG has not been considered in this AD-focussed study, there are 1 978 formally licenced landfills registered with the South African Waste Information Centre (SAWIC, 2016) as a part of the Department of Environmental Affairs that provide potential biogas-generation.

6.5.2 Commercial

For the purposes of MSW within the biogas potential model, AltGen have considered the diversion of organic waste from agro-processing and food retail stores. As mentioned in Chapter 6.2, of the organic waste generated along the food value chain, 50% is attributed to commercial and consumer streams as shown in Figure 26 (Nahman & de Lange, 2013).

South Africa has a significant agro-processing industry, with an estimated 20 large fruit and vegetable canning factories (Atwood-Palm, 2015), as well as a multitude of meat, dairy, fruit and vegetable processors that are often located on farms or near to city centres for distribution purposes (Tiger Brands, Unilever, SAB to name just a few). There are also many small scale and informal manufacturers contributing to the informal retail sector.

The food retail industry in South Africa is dominated by 5 key players, which contribute to organic waste due to expired or spoiled food stuffs, falling into both the processing and packaging as well as the distribution phases of the food value chain. The number of commercial food stores in South Africa per brand are shown on the right of Figure 26[21].

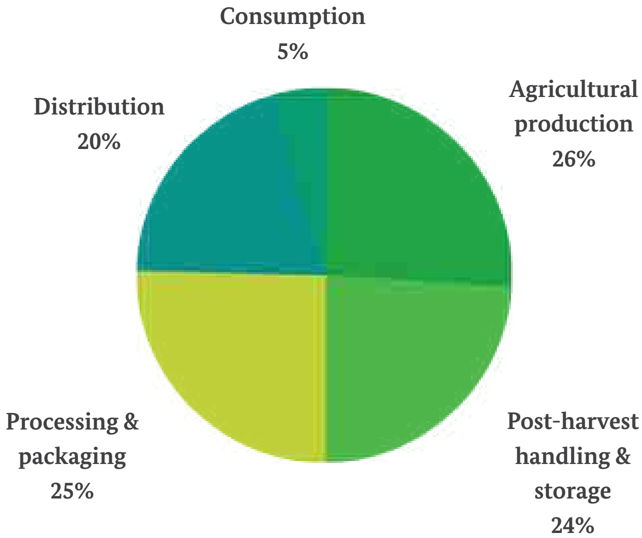


Figure 26: Contribution of food value chain sectors to organic food waste (left) (Nahman & de Lange, 2013) and commercial food retail stores (right) (Pick n Pay, 2016; Shoprite Holdings Ltd, 2016; Thomas, 2012; Spar, 2016 & Massmart, 2016)

21 Numbers are estimates, as per source.

Although the details of organic waste output by each retail store and agro-processing factory is unknown, a broad assumption is taken that 50% of the total retail stores listed are viable AD projects. Stakeholder Interviews (2016) have indicated that 160 AD's for food retail stores can be constructed per year going forward. No estimate is made for the agro-processing industry due to a lack of finite information and statistics.

Food retail	• 3 183 total number of stores
TOTAL POTENTIAL	• **1 592 stores: medium scale AD's (> 30 kW < 300 kW)**

Figure 27: Summary of statistics associated with abattoirs and conservative potential projects (Pick n Pay, 2016; Shoprite Holdings Ltd, 2016; Thomas, 2012; Spar, 2016 & Massmart, 2016)

6.6 URBAN SEWAGE

Commercial sewage treatment generates sludge with a high organic content that has been separated from the clarified water. This sludge can undergo anaerobic digestion to generate electricity that can be used on the plant itself. Anaerobic digestion poses a number of benefits for sludge management, pathogen decrease and dewatering (von Blottnitz, et al., 2009). Approximately 0.5 million tons of sewage sludge is landfilled per annum (DEA, 2012).

As the volumes of wastewater entering the plants vary (peak flow during the day, low flow during the night), WWTP are analysed in terms of median flow per day to estimate the potential for implementing biogas digesters. von Blottnitz, et al. (2009) summarised the capacity of WWTP in South Africa, as shown in Figure 28.

< 0.5 Ml/day WWTW	• 488 plants – *Median flow of 0.25 Ml/day*
0.5-2 Ml/day WWTP	• 108 plants – *Median flow of 1.25 Ml/day*
2-10 Ml/day WWTP	• 208 plants – *Median flow of 6 Ml/day*
10-25 Ml/day WWTP	• 93 plants – *Median flow of 17.5 Ml/day*
25-100 Ml/day WWTP	• 71 plants – *Median flow of 62.5 Ml/day*
TOTAL POTENTIAL	• **164 WWTP's large scale AD's (±1 MW)**

Figure 28: Statistics relating to large WWTP's in South Africa and conservative potential projects (von Blottnitz, et al., 2009)

GIZ and SALGA (2015)[22] performed a feasibility study of implementing biogas on WWTW's in 9 municipalities in South Africa, concluding that only larger scale WWTW processing at least 15ML of sludge per day could produce enough electricity to be considered feasible. Of the WWTW's investigated, many had digester tanks for sludge treatment but few were maintained or utilised. Taking into account the limiting factor of 15 ML/day estimated for feasibility of anaerobic digestion on WWTPs, there are approximately 164 WWTP's that are viable for AD's (including commercial ad municipal WWTW).

6.7 CONCLUSION OF BIOGAS POTENTIAL

In summary of the potential of biogas in South Africa from the statistics and data available in each of the feedstock avenues, the following numbers in Figure 29 are utilised in the model.

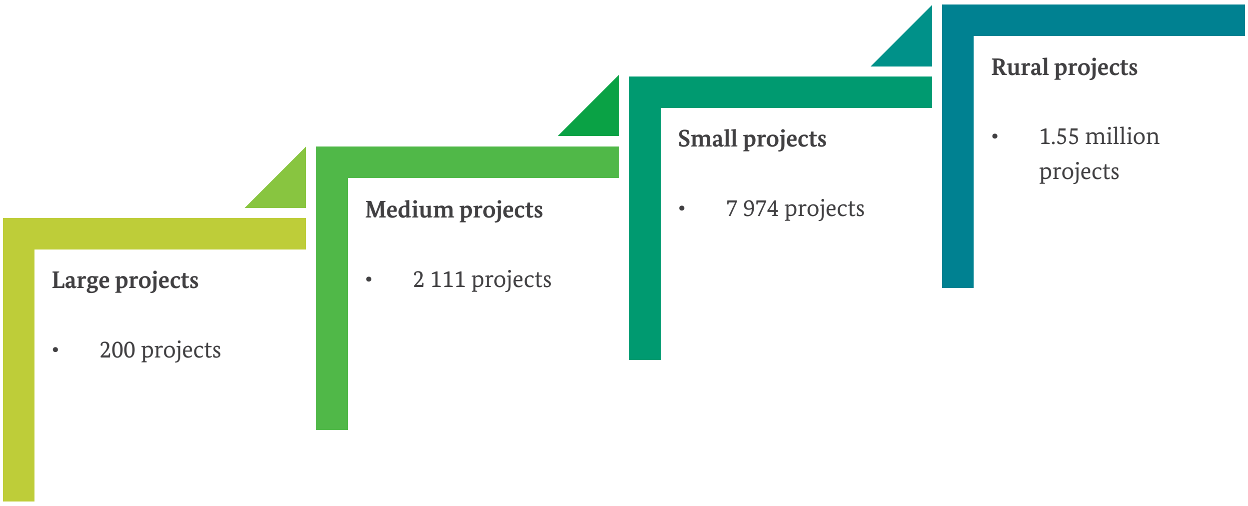


Figure 29: Summary of potential projects per project size

Once again it is iterated that these numbers are assumptive, and that the area of researching the biogas potential would require a more in-depth, grass-roots approach.

6.8 AVENUES FOR FUTURE RESEARCH ON BIOGAS POTENTIAL

As this is an emerging industry, there is not yet a central biogas database that indicates the potential and projects already in place. Due to the size of majority of biogas plants being below 1MW, they are mostly overlooked in the utility-scale REIPPPP projects, with the exception of a few large plants. With the growth of the small-scale IPPPP and development of strategies by the government and SABIA, biogas awareness may increase and more feedstock avenues look towards implementation. This is also backed by the National Development Plan looking to provide electricity, clean fuels and sanitation to all people in South Africa (Department of Energy, 2012).

Many projects have been initiated to better define the biogas industry and potential in South Africa, although specific details are not yet available. SABIA is currently developing a project map of biogas projects around South Africa (SABIA, 2016), but this does not cover potential feedstocks. The Department of Science and Technology are doing research into feedstock potential which may involve a publically available (online) map (Stakeholder Interviews, 2016). Since there is currently no publicly available spatially mapped system that overlays population, income level, infrastructure, agricultural activity, schools and health care facilities, each of these avenues was investigated separately to determine the potential of implementing rural biogas projects. One avenue for future research into this topic is to create a combined map of the country along with feedstocks

22 GIZ & SALGA, 2015. Biogas potential in selected waste water treatment plants, Pretoria: Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH.

and projects already in place, aligning with the Renewable Energy Development Zones (REDZ) and Strategic Environmental Assessment (SEA) Programme initiated by the Department of Environmental Affairs (DEA, 2016), as shown in Figure 30. The REDZ map was formed in 2013 in order to identify the areas in South Africa best suited for wind and solar energy projects, allowing for stream lining of project implementation in those areas with regards to social, environmental and technical aspects of renewable energy projects (CSIR, 2013). Enabling this map to allow for biogas feedstocks would bring this technology in the RE lime-light.

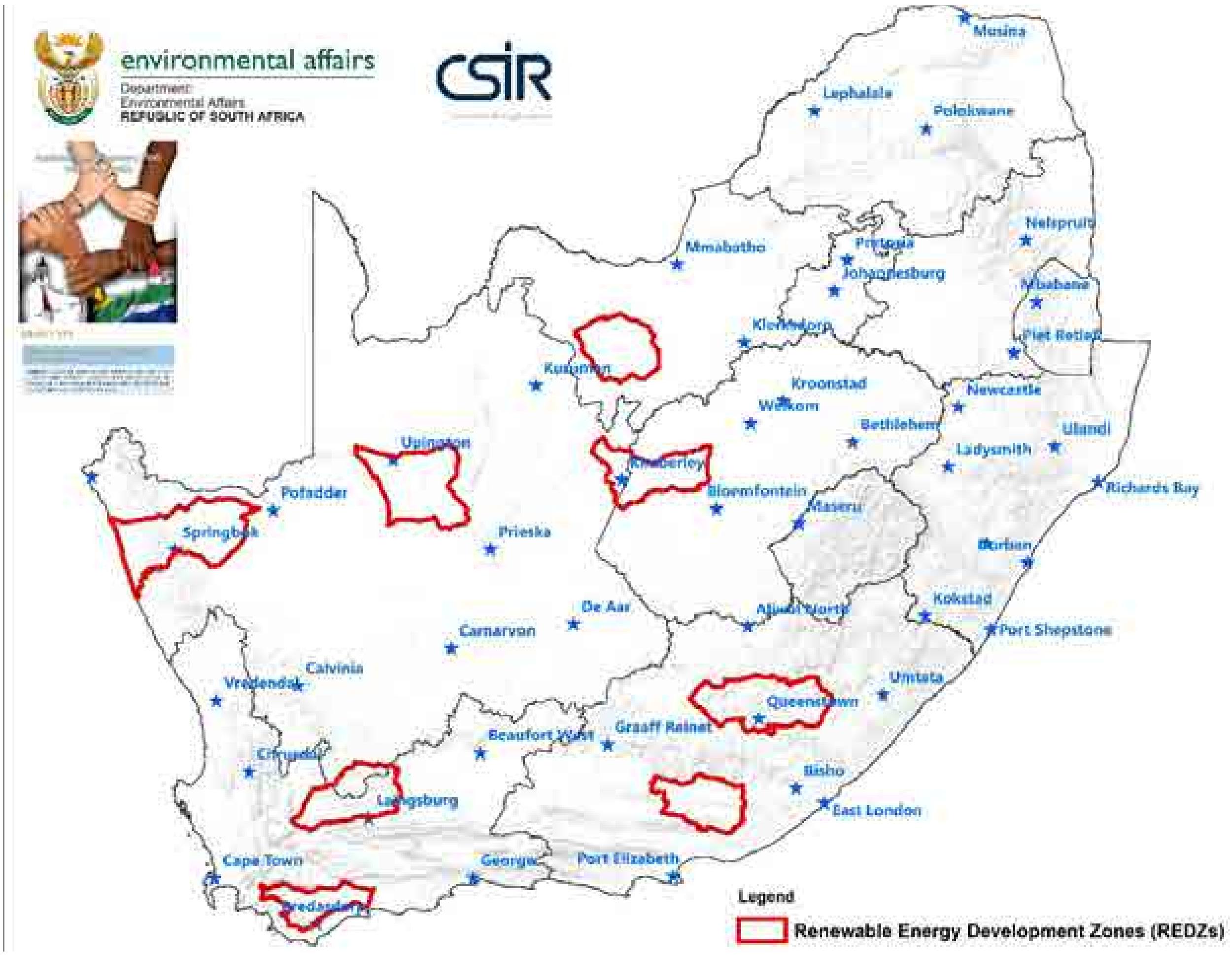


Figure 30: Map of REDZ (CSIR & DEA, 2016)

SECTION 3

Model

7 Model Methodology

7.1 MODEL APPROACH

An input-output (IO) model was used to predict the future employment scenario of the biogas industry in South Africa. IO modelling is common in economic and employment predictions as it is easily understood and incremented from a basic model-user interaction to a more advanced interface.

The stakeholder engagement outputs were used to form the skeleton of the model, such that it reflects current industry conditions and ideas, and provides the outline for directional growth as indicated by the stakeholders in the industry. The model is built in terms of project size (large, medium, small and rural) and project phase (feasibility and development, construction and operation), as indicated by the stakeholders.

The empirical data collected from stakeholders and industry experts was compared and collated to establish trends to form generalised organograms (Appendix E) and establish an average employment factor, to be used in the

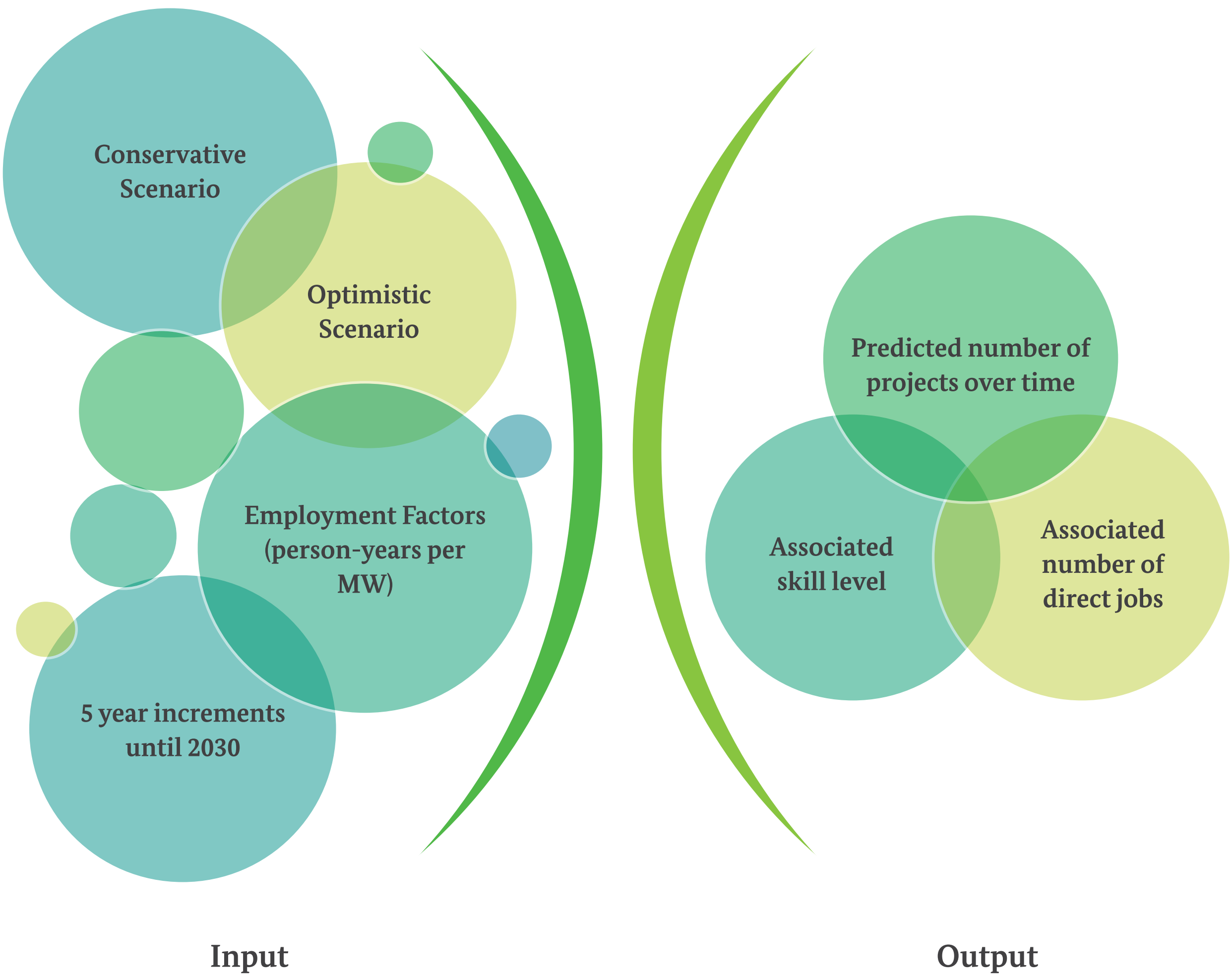


Figure 31: Inputs and outputs of the model

IO model. The empirical data also indicated the skill levels associated with the different project phases and sizes. An overview of the model inputs and outputs is shown in Figure 31. The model forecasts expected jobs and skill levels over 5 year increments until the year 2030, in two different scenarios.

7.2 MODEL BASIS

The model is based on the number of projects currently implemented and in operation to the knowledge of AltGen Consulting as of April 2016. These projects are listed in Appendix D: Biogas Project List.

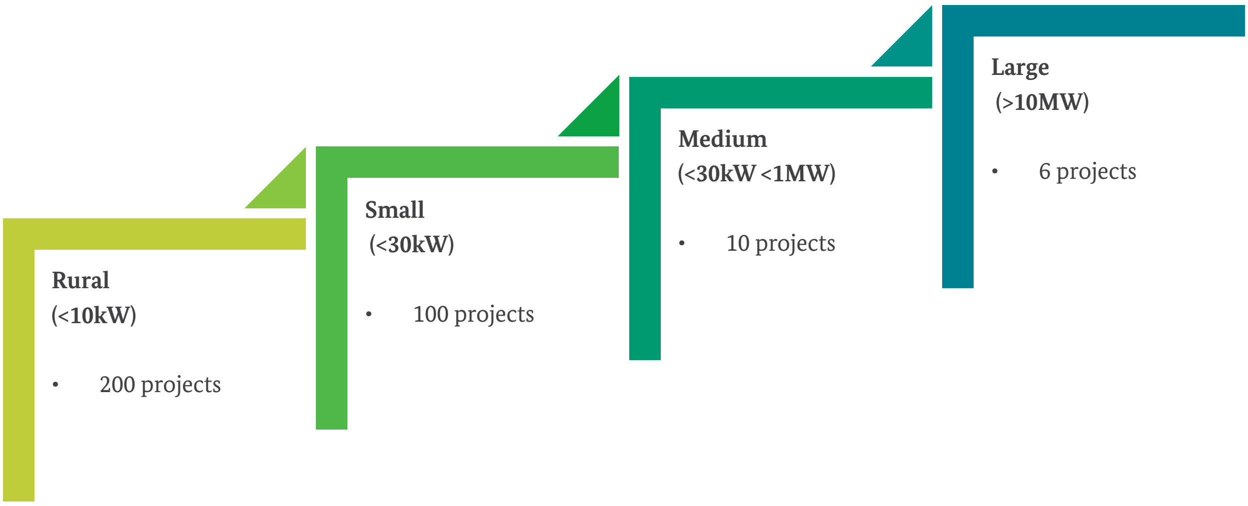


Figure 32: Base case implemented projects (Stakeholder Interviews, 2016)

7.3 SCENARIOS

Two scenarios were used to represent the direction that the biogas industry may take, as shown in Table 6. The first scenario refers to the industry progressing under circumstances similar to what exists presently i.e. a conservative scenario. The second scenario is optimistic, presuming an enabling environment is created for biogas in South Africa. The scenarios are reflected in the model as multipliers for the number of projects predicted over time. The authors have used the base-case, 'status-quo' for the conservative scenario, therefore the multiplier used in this case is unity. To indicate the increase in projects for the optimistic case, a multiplier of 1.5 is used. Both multipliers can be edited in the model when more data presents itself.

The two scenarios assume only possible growth in the industry, and do not consider a decrease in interest in the technology or a decrease in feedstock. This assumption is based on the continued growth of the renewable energy sector both in South Africa and world-wide, as well as the global movement to redirect and reuse anthropogenic waste streams amidst growing concerns about decreasing landfill space and environmental impacts (both in waste and electricity generation). One possible future not considered in this study is the impact of climate change on the South African agriculture industry, particularly with reference to water scarcity. This in turn could add to the economic drivers of urbanisation, as people move out of rural areas where there is little employment opportunities and income flow, and even less should the current agriculture abilities be hampered.

Table 6: Scenarios implemented into model

Scenario	1	2
Description	*Conservative*	*Optimistic*
Legal & Policy Environment	• Upheld at current state, no changes to current legislation or organisational support	• Legislation is promulgated to make for an easier licencing process and increased organisational support • Policy mandates for waste streams • An enabling policy environment
Feedstock Efficiency/ Access	• Upheld at current availability and mechanisms	• Increase in feedstock availability due to changes in legislation, integrated system technology and growing knowledge base of biogas potential • Mitigating increasing farm costs
Education and skill level	• International training courses for highly skilled operators and technicians • 'On the job' learning for skilled, semi-skilled and unskilled employees	• Local training courses and certifications for all skill levels
Associated costs	• Electricity price increases remain on a predictable upward pathway • Importing of 20-50% of technology • Remuneration mechanisms only for specific electricity outputs • Wheeling costs as is • Travel expenses for international training courses	• Significantly increased electricity prices result in economic benefits of self-generation • Decrease in capital costs due to locally made technology • Remuneration mechanisms promulgated • Wheeling costs normalised • Locally trained employees • Increase of micro-grids and off-grid energy applications
Overall growth of installed capacity assumption	• Slow	• Fast

23 For the purposes of this study, fluctuations of electricity tariffs are not considered to have a large enough impact to necessitate inclusion in the model structure. However, it is noted that increases in electricity tariffs may influence the interest in biogas technology. It must be noted that the annual price increase of electricity is reassessed by NERSA every 3 years, taking into account the state of the nation and associated industry.

7.4 ASSUMPTIONS AND JUSTIFICATIONS

- The Employment Factor (Jobs/MW) method has been used in this model as it assists in employment projection studies and is currently the status-quo of all other RE technologies, enabling it to be comparable. However, in reality, many biogas projects (of all project sizes) do not convert their outputs to electricity and the metrics used are of volume of AD or volumetric flowrates of gas output.

- The model baseline is taken from the known projects currently in operation (Table 13). Although the list compiled by AltGen Consulting is thorough, it is not considered to be absolute as many developers chose not to interact and participate in the study, and there are a number of projects that may be missing.

- The project pipelines estimated by the developers are what they believe to be true and are thus assumptions, verified by the relevant stakeholders.

- The total potential feedstocks as calculated in Chapter 6: Biogas Potential in South Africa are taken from available data which is in some cases outdated and inaccurate. Often the statistics published have their own disclaimers associated with them. Due to these inherent uncertainties, a 50% viability assumption was put on all statistics which then pulls through to the model input data. Therefore, the facts are used under the assumption that they hold true for the purposes of this study.

- The size brackets utilised in the model are taken from the stakeholder consensus (through interviews, SABIA presentation and distribution of presentation material for comment), and are once again defined in MW installed capacity. The upper limits (small and rural scale), median value (medium scale) and lower limit (large scale) of these size brackets are used to estimate the installed capacity of future projects.

- All skill-level data has been taken from aggregated project information and input tables from stakeholder engagements, for each project size group. This information reflects that of developers willing to participate, and would differ slightly should more project information be added, especially as more ADs are implemented in the coming years.

- The model does not consider fluctuations in the growth of the industry, as this would require a complicated input system and many more assumptions of the reasons for such fluctuations. Therefore, the study utilises a straight-line growth model.

7.5 EMPLOYMENT FACTOR

The Employment Factor (EF) approach to assess employment projections was chosen for this study due to the paucity of available and accessible data, a method that has become popular in economic analysis, modelling and forecasting in the renewable energy industry due to widely-differing technologies requiring technology-specific employment factors.

Employment factors (EF's) are measured in FTE jobs (person-years or persons) per unit of energy output and are specific to both technology type and project phase (Breitschopf et al., 2011). The authors noted that this is particularly relevant in the biogas industry, where technology varies according to feedstock, and employment varies according to size of plant. Unique to this study is determining a South African employment factor utilising the current plants and employment data available from industry.

$$\textit{Employment factor} = \frac{\textit{Person years (FTE)}}{\textit{Total capacity of plant}} \left[\frac{\textit{Person years}}{\textit{MW}}\right]$$

Equation 7

7.6 SKILL LEVEL FACTOR

A skill level factor has been used to analyse the different levels of skill that may be involved with the industry, which ties in directly with the qualifications and training associated with the industry. The skill levels of the current industry were estimated by stakeholders when analysing case studies. One noteworthy point is that many people referred to as highly skilled and in design, development and operation of ADs, have little or no qualifications directly linked to biogas and have rather gained their skills through experience. This further indicates that there is a large skills gap for education-oriented skills, which is discussed in Chapter 9: Skills Gap Analysis.

$$\textit{Skill level factor} = \frac{\textit{Number of people within skill level}}{\textit{Total onsite work force}} \times 100\ [\%]$$

Equation 7

7.7 POTENTIAL PROJECTS ESTIMATION METHODS

In order to calculate the future installed capacity and therefore jobs associated through the employment factor, the number of potential projects must be estimated. Two methods were used to estimate this data: firstly, the developer pipeline was investigated through stakeholder engagement (Chapter 5) and secondly the total potential from available feedstocks was summarised from statistical data, as summarised in Chapter 6.

In the case of the developer pipeline, the number of projects each developer estimates in the next 5 years was summed to estimate a total number of projects per 5 years. The potential estimates made in Chapter 6 were implemented directly into the model per project size. These designations are referred to as Developer Estimate Outputs and Total Feedstock 'Potential' Estimate Outputs.

7.8 CALCULATIONS

The first calculation performed is to cumulate the projects that will be active at time *t*, in 5 year increments until 2030. This is based off the current installed projects, and the developer pipeline estimates or the potential estimates, depending on the output required.

$$(\textit{Number of projects})_t = (\textit{Number of projects})_{t-1} + (\textit{Developer pipeline estimate} \times \textit{Scenario multiplier})$$

Equation 7.1

$$(\textit{Number of projects})_t = (\textit{Number of projects})_{t-1} + (\textit{Feedstock potential estimate} \times \textit{Scenario multiplier})$$

Equation 7.2

The installed capacity is then calculated with the number of projects and the project capacity average as shown in Equation 7.3.

$$(\textit{Installed capacity})_t = (\textit{Number of projects})_{t-1} \times (\textit{Average project capacity})\quad [MW]$$

Equation 7.3

The FTE direct jobs (person-years) is calculated using the installed capacity and employment factor as shown in Equation 7.4 (Rutovitz, 2010), and illustrated in Figure 33:

$$\textit{Direct jobs} = \textit{Installed capacity} \times \textit{Employment factor}\quad [\textit{Person years}]$$

Equation 7.4

The number of direct jobs at the required skill level is then calculated using Equation 7.5 (AltGen Consulting, 2016):

$$\textit{Required skill level} = \textit{Installed capacity} \times \textit{Skill level factor}\quad [\textit{Person years per skill level}]$$

Equation 7.5

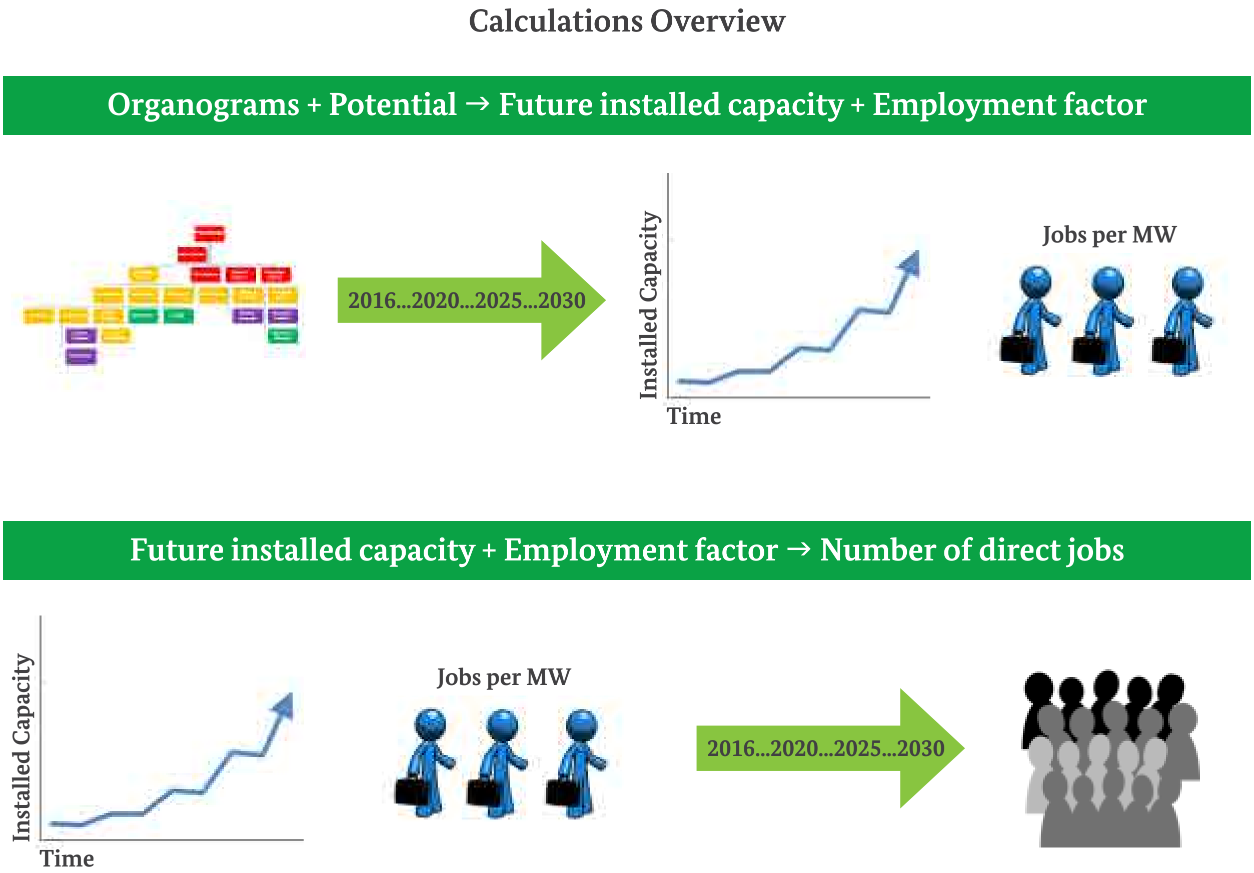


Figure 33: Overview of key calculations

SECTION 4

Model Outputs & Skills Gap Analysis, Recommendations and Conclusion

8 Model Outputs and Analysis

Chapter 8 details the model outputs such that the report may stand alone without the necessity of opening and running the model. The analysis performed on the model outputs relates the data to the function of the report, in terms of job creation and skills development in the biogas industry currently, and going forward to 2030. The model outputs and analysis are based on the conservative output of the model (scenario 1), as this contains the most relevant information to date. Should an enabling environment be fostered, the optimistic values of projects, jobs and skills in the sector can be viewed in the model outputs.

Model outputs are graphically represented for ease of understanding, in two sections:

- Developer Estimate Outputs and
- Total Feedstock 'Potential' Estimate Outputs.

Comparing these two sections gives an indication of whether the industry at present has a good awareness of feedstock potential leads to an overlap of assumptions, however general trends can be identified and further elaborated on. The comparison of section results is detailed in Chapter 11.3: Comparison of Developer Pipelines and Total Feedstock 'Potential' Estimate Outputs.

8.1 PROJECTS

The developers predict a large increase in rural and medium scale projects going forward (Figure 34), however this is overshadowed by the amount of rural projects available in the total feedstock 'potential', as shown on Figure 35. The number of rural projects available from the potential calculations exceed those of other project sizes and thus they are shown on a separate graph (Figure 36). Even though the potential calculations were performed using an assumption of only 50% of agricultural households being viable for rural scale ADs, this still results in over 2 million projects online by 2030, whereas by comparison developers estimate a mere 3 350 rural projects. This is due to the other requirements of AD project implementation (other than potential) such as low profit margins and high cost risks associated with rural scale projects.

Additionally, possible beneficiaries of the ADs often do not have funding mechanisms in place to contribute to the capital costs, and therefore the full cost burden lies with the developer. There have been a number of government-funded programs engaging with developers and rural communities to implement 20-30 ADs concurrently, and developers have iterated that they would enthusiastically engage should more opportunities arise[24].

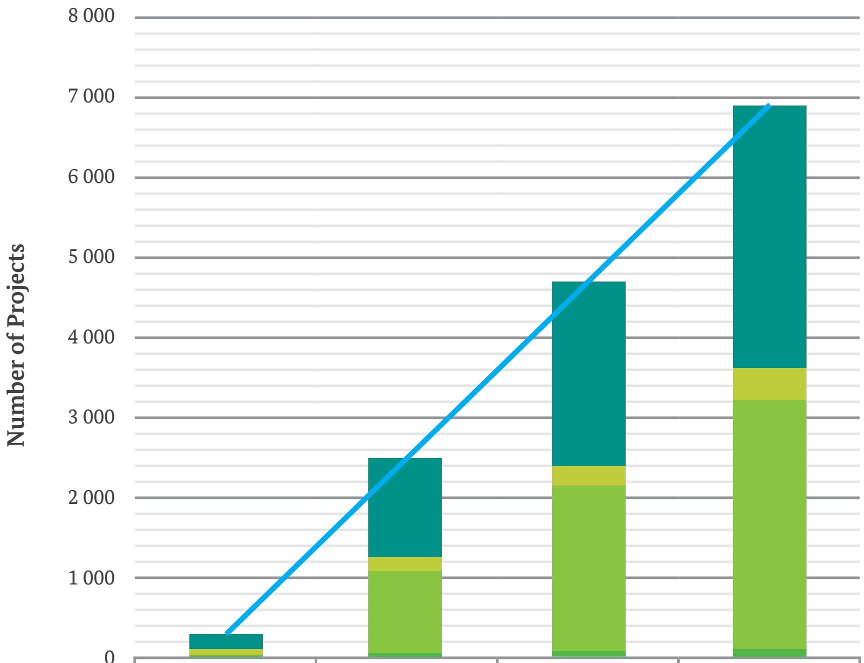
The authors found it particularly difficult to segregate small and rural projects, as the stakeholders were divided in their opinions of where the two project sizes separate. For the purposes of this report, AltGen has chosen to segregate based on output capacity, whilst taking into consideration that many projects are not initiated with the aim of generating electricity. Therefore, small projects are deemed to be those that serve a number of people that congregate together, for example a multi-residence housing development, school or clinic, as opposed to a simple household digester, possibly providing heat or gas energy to one or two households. The differences between the small projects estimated by the developers and the potential feedstocks are attributed to the lack of clear boundaries between rural and small project sizes, as some developer's appropriate schools as rural projects as opposed to small.

The developers predict that by 2020, over a thousand medium scale projects will be online and by 2030, over 3 000. This is contradictory to the 70 projects (2020) and 2 000 (2030) projects available from the potential feedstock estimate. Also, anecdotally, project developers perceive

24 The phenomenon of increasing urbanisation observed throughout South Africa is assumed not to have a large enough effect on the potential or rural projects going forward to be accounted for in the model, as this forecast is over a short period of time and furthermore families are observed to keep their rural houses for older, retired family members take up residence.

an upward trend of abattoirs and commercial food manufacturers and processors opting to generate their own electricity and/or heat in order to decrease operating expenditure as electricity prices rise. A conservative assumption of 50% of known abattoirs as well as food retail stores (Chapter 6: Biogas Potential in South Africa) was made in calculating the feedstock potential partly since these projects require significant capital investment, and few commercial entities may have the necessary financial resources. Many developers have indicated that they foresee these avenues as having the highest likelihood for biogas implementation. Were an enabling environment to be nurtured for the biogas industry in which input costs were to be reduced, technically all abattoirs and commercial food retail stores should be able to implement ADs.

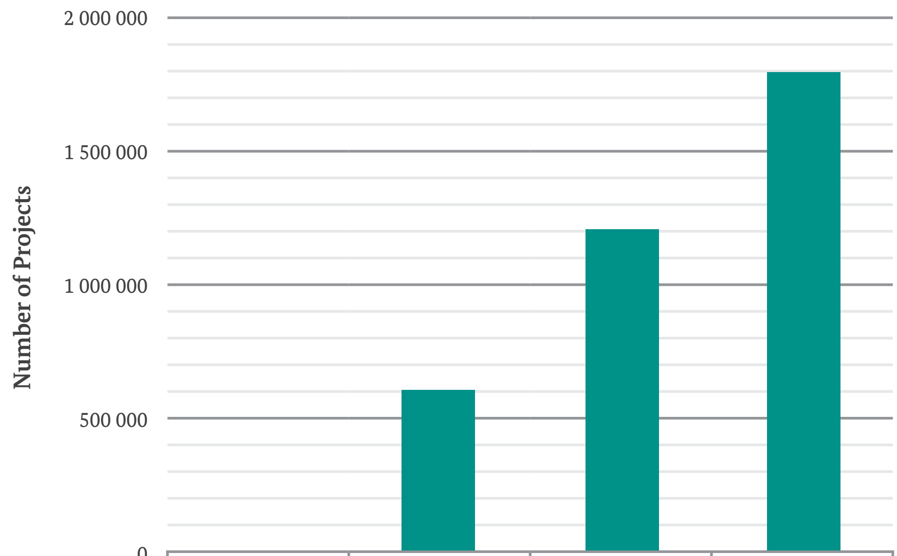
Number of Projects per Size Group: Conservative



Year	2015	2020	2025	2030
Rural (<10kW)	200	1 250	2 300	3 350
Small scale (<30kW)	100	170	240	310
Medium scale (>30kW <1MW)	10	1 052	2 094	3 136
Large scale (>1MW)	10	43	76	109
Total	**320**	**2 515**	**4 710**	**6 905**

Figure 34: Developer Pipeline Estimate of Number of Projects (Conservative Scenario)

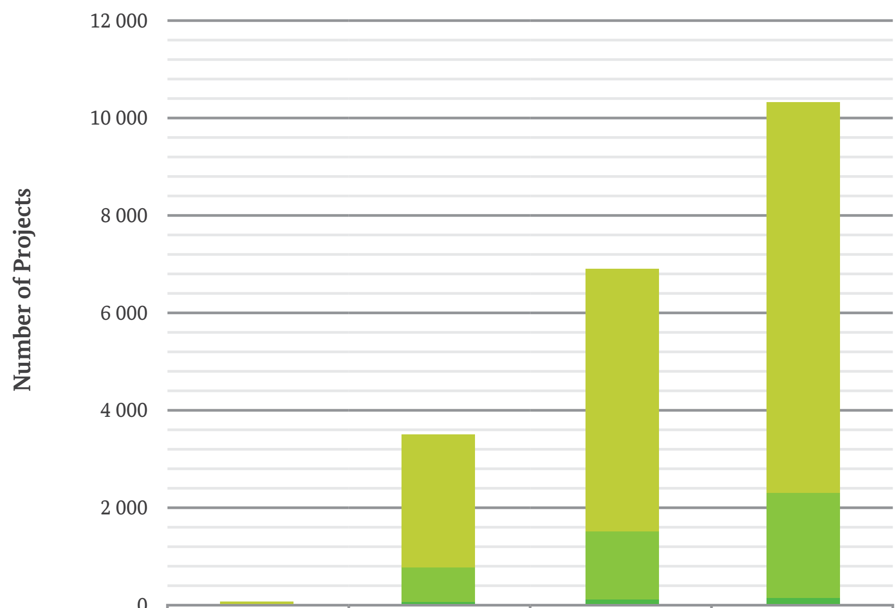
Number of Projects per Size Group: Conservative



Year	2015	2020	2025	2030
Rural (<10kW)	200	60 0133	1 200 067	1 800 000

Figure 35: Potential Estimate of Number of Rural Projects (Conservative Scenario)

Number of Projects per Size Group: Conservative



Year	2015	2020	2025	2030
Small scale (<30kW)	100	2 725	5 349	7 974
Medium scale (>30kW <1MW)	10	710	1 411	2 111
Large scale (>1MW)	10	73	136	199

Figure 36: Potential Estimate of Number of Large, Medium and Small Scale Projects (Conservative Estimate)

8.2 JOBS

The employment factors aggregated from the developer organograms and project information are shown in Table 7. They represent the expected number of people (FTE) that are required for each project phase to ensure a successful project. Individuals are not represented in this model, as it is a projection study or forecast, and rather discussed further in the skills gap analysis.

Table 7: Employment Factors per project size and phase

Project size and phase	Employment Factor (Jobs / MW)			
	Large	*Medium*	*Small*	*Rural*
Feasibility & Development	6,56	11.68	5.06	5.06
Construction	31.17	192.67	2.29	2.29
Operation & Maintenance	3.89	36.16	9.33	9.33
Total Project	41.62	153.92	16.69	16.69

The method of calculating employment factors is to divide the total number of FTE jobs in the particular phase by the total MW output capacity of the plant. Thus, since the same type of jobs and skills are required for the development phase of both large and medium scale projects, the employment factor result is higher for medium scale projects. The two project sizes require similar organograms in the development phase as they are both required to generate electricity and/or heat, therefore involving a constant feedstock supply and monitoring system as well as generators. This contributes to the high costs of implementing medium scale projects, with lower returns than that of large scale projects.

Similarly, the employment factor for the medium scale construction phase is the highest factor in the table. The high employment factor is once again attributed to the amount of work required to construct the plant, and the low output (capacity) of the plants in operation. Even though there are significantly less jobs aggregated into the construction organograms for medium scale projects than large scale, the outputs of medium scale plants are much lower, averaging at around 300kW (compared to large outputs at 1MW+), resulting in a higher employment factor. The same trend of higher employment factor for medium than large holds true for the operation phase of medium scale projects.

Large projects have a low employment factor for the operation phase, since these projects are often highly automated and plants do not scale up equally with regards to the number of people required. Large plants work 24/7 and therefore require worker shifts in the feedstock supply, treatment and monitoring technicians, security, and a plant operator that can monitored the plant remotely. Remote monitoring is reflected as a part time job.

It is also worth noting that small and rural projects are often originated by the same developers, requiring the same set up in all project phases, and therefore reflect similar employment factors.

The conservative estimate of FTE jobs per project size per project phase, as drawn from the model, is shown in Table 8 for the Developer Pipeline Estimates Output. These jobs are shown as cumulative, meaning that the new jobs are compounded by the previous years' total jobs output, and as time goes forward the total jobs in the industry are shown in Table 8. It must be noted, as per the model assumptions, projects and therefore jobs moving offline are not considered in the model outputs. To give an overview of the scenario effect on the model outputs, the model outputs indicate that conservative industry growth could result in about 394 000 direct jobs in 2030, and optimistic growth could increase this number to 590 000 direct jobs.

Table 8: Cumulative Jobs (FTE) over time per project size and phase from the conservative model outputs

Developer Pipeline Output					
Project Phase	Year	Cumulative Jobs (FTE) per Project Size			
		Large	*Medium*	*Small*	*Rural*
Feasibility & Development	**2015**	66	60	15	10
	2020	282	6 327	26	63
	2025	499	12 593	36	116
	2030	715	18 859	47	170
Construction	**2015**	312	992	7	5
	2020	1 340	104 386	12	29
	2025	2 369	207 779	17	53
	2030	3 398	311 173	21	77
Operation & Maintenance	**2015**	39	186	28	19
	2020	167	19 593	48	117
	2025	296	38 999	67	215
	2030	424	58 405	87	313
Potential Estimates Output					
Project Phase	Year	Cumulative Jobs (FTE) per Project Size			
		Large	*Medium*	*Small*	*Rural*
Feasibility & Development	**2015**	66	60	15	10
	2020	479	4 272	414	30 384
	2025	892	8 484	812	60 757
	2030	1 305	12 695	1 211	91 130
Construction	**2015**	312	992	7	5
	2020	2 275	70 483	188	13 771
	2025	4 239	139 975	368	27 538
	2030	6 203	209 466	549	41 304
Operation & Maintenance	**2015**	39	186	28	19
	2020	284	13 229	763	56 012
	2025	530	26 272	1 498	112 006
	2030	775	39 316	2 233	168 000

As indicated from the employment factors, the medium scale projects predict the largest amount of FTE jobs for each project phase going forward until 2030. Construction shows the largest amount of job creation, however as previously mentioned the construction team is not required to be biogas-specific, and also does not work permanently on biogas projects, therefore, construction jobs do not necessarily reflect *new* jobs in the biogas industry, rather they are permanent jobs in the construction industry with a biogas element, and the FTE of 1 year can be allocated to biogas as a fixed term employment opportunity, practically meaning one person can have a part time job and no further work following the opportunity. As the feasibility and development project phase is also not permanent, in future many of these job opportunities may become contractual roles. Therefore, long term and meaningful job creation lies in the direct operation and maintenance of biogas plants, where people are given full time jobs over the lifetime of the project, generally 10-20 years.

As the jobs are calculated using the number of projects predicted by the different outputs, developer pipeline and potential, both sets of these job results are shown in Table 8. As mentioned in the previous Chapter, the developers predict large numbers of medium scale projects, whereas the potential estimates allude to many rural scale projects. Therefore, the same observations can be made in terms of job numbers.

8.3 SKILLS

The skill level requirements per project phase for each project size is shown in Figure 37. The feasibility and development project phases for all sizes of projects require the biggest contribution of highly skilled (and therefore highly-paid or 'expensive') jobs. A small number of highly skilled people are required for overseeing the construction phase, and in the cases of large and medium projects, to oversee and troubleshoot the ADs. Unskilled jobs in the construction phase refer to general labour such as bricklayers, and unskilled jobs in the operation phase refer to people that organise and prepare feedstock, generally under instruction from semi- and skilled individuals monitoring the process.

Figure 37: Skill level requirements for each project phase per project size

9 Skills Gap Analysis

9.1 SKILLS GAP CONCEPTS

Figure 38 illustrates the industry growth process with regards to certification, and shows the two primary skills gaps which exist in the biogas industry:

- The certification skills gap which refers to skills gained through direct education, associated with technology and qualification.
- The experience skills gap refers to individuals with sufficient expertise as to be autonomous in their jobs.

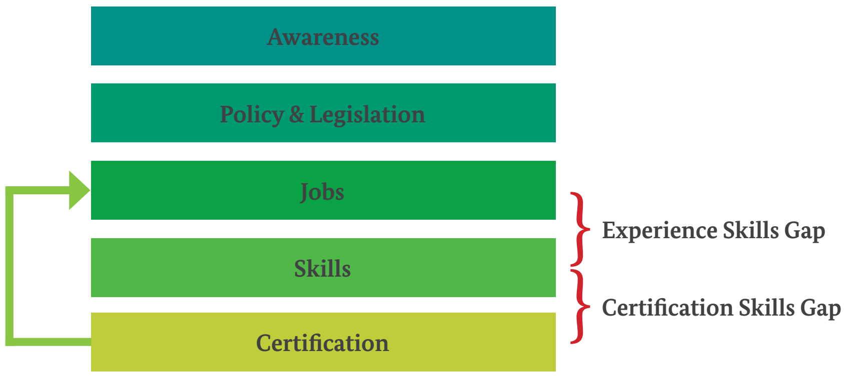


Figure 38: Skill level requirements for each project phase per project size

As a new industry develops, all sections in Figure 38 collaborate to mobilise with it. These sections do not develop at the same rate, and an industry is established with a lag time before skills and certification are standardised. The skills gap has been further widened due to ease of access to the established biogas industries and associated education programs in Europe, China and the United States.

In contrast to other RE technologies such as solar and wind, there has not yet been a policy driven demand for biogas in South Africa (except a small allocation in the REIPP), however the regulatory environment is inhibiting development exemplified by the lack of designated REIPPPP projects within this field. There has, however, been an increase in general awareness of the benefits and uses of biogas over the last decade, as well as the establishment of successful international industries, which has led to interest from commercial entities and developers. This interest has been further piqued with the focus of the South African Government diversifying the energy mix through the REIPPPP initiative. The NDP Vision 2030 lists Sustainable Development as a 'critical action' (DoE, 2012), and also speaks to waste and wastewater management, and refining of waste-to-landfill mechanisms, improved and optimised in the face of a growing waste crisis.

The current policy landscape has been found to have an ambiguous effect on the biogas industry: both inhibiting from complex, unclear requirements, and enabling of an undefined playing field. As awareness increases and more projects come online, the relevant legalisation and policies come under the spotlight as they are accessed more often. SABIA have already begun taking steps toward streamlining these processes through the relevant governmental channels (Stakeholder Interviews, 2016).

With the growth of the industry reflecting international practices and technology, the higher-skilled jobs are influenced strongly by international courses and general experience. The growth of low-skill level jobs in the sector have been through informal, on-site training and courses, mostly regarding health and safety, and the running of the digester.

The 'skills gap' of the biogas sector in South Africa is defined as the difference between the jobs available within the industry (skills demand) and the skills produced from various training and education institutions (skills supply) (Stands, et al., 2014). There are currently no certified training or education programs specific to the biogas industry although many developers have initiated in-house training programs. There are a number of qualifications that address biogas in their syllabi, as shown in Table 4, Chapter 4.3, yet these are not entirely biogas focussed and none are NQF rated. This has created a 100% certification skills gap as there are very few professionals in the biogas sector that have a certificate or degree relating specifically to the AD technology. The experience skills gap is far less: there are certainly skilled and experienced people in the market, however they are only fostered within their current position and development team, and do not receive any external influence to their experience.

As previously mentioned, South Africa is far behind international standards in the biogas sector. The differing levels of establishment of local and international biogas industries has caused an imbalance in the skills supply and demand within the South African market, as developers look to international training and accreditation which ties in with the technology they are using on their projects. Such international education is easily gained through short courses that are widely available in Europe, China and the United States. Low-skill training is supplied by highly trained developers who have acquired the relevant knowledge through international courses and/or experience and therefore, all jobs in operation and maintenance phases in the biogas industry are in fact new jobs.

9.2 SKILLS CURRENTLY AVAILABLE WITHIN THE BIOGAS SECTOR

South Africa currently has a national skills shortage, specifically with regards to engineering and technical skills across all industries (Stands, et al., 2014). Experienced skills in the energy sector often choose to work for large public or private sector firms where the salaries are higher. These skills are therefore expensive, and cannot be easily accessed by an unestablished industry such as biogas.

Feasibility and development of biogas plants across all sizes is performed by highly skilled individuals. Biogas does not require complex machinery, and therefore construction of biogas plants can be performed by regular construction workers without biogas-specific training. Operations and maintenance requires knowledge of the biogas workings, and therefore a skilled person is needed for the duration of the project life time.

As previously mentioned, the highly skilled biogas jobs are currently dominated by people who have received international training. Since there is no education or certification pertaining to the semi-skilled and skilled biogas job requirements, developers have trained these people on site. However, due to the fact that the biogas industry is still very small and highly competitive, trained individuals are often head-hunted by larger competitors who can afford higher remuneration.

9.3 FUTURE DIRECTION OF SKILLS DEVELOPMENT FOR THE BIOGAS INDUSTRY

As the biogas industry in South Africa matures and more experience is gained, the need for skills will grow and a benchmark is needed to ensure that the job market is competitive with regards to salary and expertise. If a benchmark is not established, the skills gap will grow with the industry, skilled workers will continue to be head-hunted from developers that have invested in them and 'on the job' training will dominate without a proper certification. As discussed in Chapter 4.3.2: Current training Institutions/ programmes in South Africa, there are already a few independent developers initiating private training courses for a fee, and these could be brought under an umbrella certification, including the relevance of what is generally included in full degrees relating to chemical processes.

The best way to establish job benchmarks is to standardise the training and certification methods. As discussed previously, international standards and experience is valued within the South African biogas industry and will therefore be utilised when establishing benchmarks, however not in totality. South Africa provides many unique aspects of an industry growing both in the commercial as well as self-consumption areas, which each require a different mix of skills. As described internationally, commercial plant design and operation require longer, more technical and thorough courses whilst self-consumption small scale biogas plants require much shorter, on-site training for operation, overseen by one or two skilled people. Commercial skill benchmarks will most likely be funded and set up through the private sector, whilst self-consumption benchmarks will be initiated by the public-sector. This unique merging of public and private sectors in a single industry in South Africa is seen across the energy industries, most notably due to the government-initiated renewable energy program (REIPPPP) in South Africa.

Inserting a biogas skills development program into the established education system of South Africa will not be an issue. Technical Vocational Education and Training (TVET) colleges as well as Further Education and Training (FET) colleges are well-established around South Africa, with certain room for an increase in these colleges. SARATEC, the first renewable energy-specific training centre in South Africa, is perfectly situated to add a biogas course to their upcoming curricula. Other universities and technikons could also potentially integrate a biogas related module/course into the curriculum of current accredited higher certificates, diplomas and degrees such as Microbiology, Applied Chemistry, Energy Studies, Environmental Science, Engineering (Chemical, Electrical, Environmental, Mechanical and Civil) and Environmental Management to name a few. Additionally, SABIA could act as a central body and steer the organisation and designing of short courses and workshops should there be a need and drive for it.

9.4 POSSIBLE SKILLS DEVELOPMENT ROUTES

From the stakeholder engagement, it is possible to lay out an overview of the potential certification and skills development routes for the biogas industry, should a NQF-rated, nationally approved qualification structure be implemented. This is shown in Table 9. As the growth of the industry already includes both small scale and rural projects, as well as medium and large scale projects, the certification methods must cover all skill levels and enable growth and career development through increasingly in-depth and technical courses. Therefore, the lowest point of the list is for national (vocational) certification, and the highest at the level of post graduate diploma.

Table 9: Possible skills development routes

Certification Topic	Type of course	NQF Level	Skill level	Project phases covered
Biogas Design and Operation	Post Graduate Diploma	8	Highly skilled	Feasibility and development, construction, operation and maintenance
Project Management for Renewable Energy projects	Biogas Mechanisms and Operation	7/8	Highly skilled	Feasibility and development, construction, operation and maintenance
Biogas Design and Operation	Advanced Diploma	7	Highly skilled	Feasibility and development, construction, operation and maintenance
Biogas Design and Operation	Diploma or Advanced National (vocational) Certification	5/6	Skilled or semi-skilled	Feasibility and development, construction, operation and maintenance
Biogas Mechanisms and Operation	Diploma or Advanced National (vocational) Certification	5/6	Skilled or semi-skilled	Operation and maintenance
Biogas Masonry and Operation (Rural/household digesters)	Advanced/ National (vocational) Certification	2/3/4/5	Semi-skilled	Operation and maintenance

9.5 CAREER PATHWAYS IN THE BIOGAS INDUSTRY

Within the currently established energy sector in South Africa, there are a few transferrable technical skills, including electrical, mechanical and chemical engineers that may use their prior knowledge in addition to a few short courses to have the educational and certified basis to become biogas plant design engineers and operators (trouble-shooters). That being said, the model output does show that by 2030, there may be 394 000+ jobs in the biogas industry. Many of the stakeholders had a range of educational backgrounds, from a Matric Certificate with 15+ years of experience in the biogas industry, to holding a MEng Chemical Engineering with practical plant management and/or project management experience within the industry. As with all other industries, practical knowledge and experience is necessary to solidify the theoretical knowledge and thus it is eminent for candidates to become independent biogas professionals and practitioners. The biogas organograms in Appendix E: Industry Organograms show job titles and skill levels currently associated with the different project sizes.

In the biogas-specific industry there are career pathways between all skill level, and within the skilled and highly skilled levels, as shown in Figure 39 for large/medium scale projects and Figure 40 for small/rural scale projects. Due to the specific technology and technical knowledge required to run a biogas digester, there is a disconnection/disjunction between unskilled and semi-skilled jobs such as grounds-men and truck drivers, that would not easily climb the career ladder within the biogas industry without learning professional skills and undergoing a complete change of job position. While the figure depicts upward movement from an unskilled to semi-skilled position, one would have to gain knowledge/education and experience to make the position change.

Figure 39 reflects the organograms given for the large and medium scale projects, and shows how jobs within the industry are expected to mature and expand. Currently, the project developer has primarily highly-skilled and skilled individuals within the industry. Having initiated the project, they take on the role of top management. Stakeholder engagements revealed that, many developers are training semi-skilled and skilled workers to operate and manage the technical aspects of operating plants, which creates a waterfall effect of upliftment and increasing experience based skill levels.

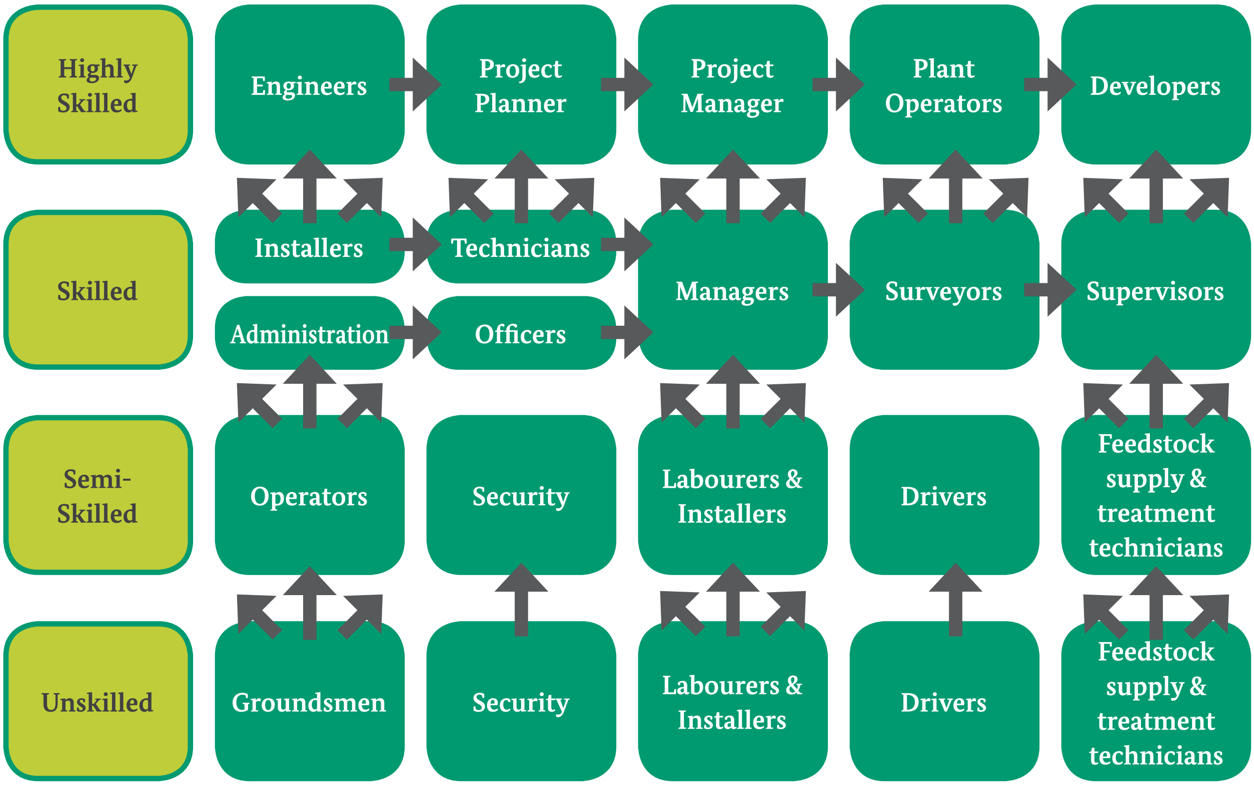


Figure 39: Career Pathways for Large and Medium Projects

Figure 40 shows the current job positions of small and rural projects, and the disconnects within them: it is unlikely that there will be movement of unskilled or semi-skilled jobs into the skilled and highly skilled levels, due to the lack of infrastructure associated with these projects from a community and national perspective. Currently, many of these projects are in the hands of unskilled and semi-skilled patrons, but the development aspect requires a large jump of knowledge and skill-level to move into the design and troubleshooting aspects. Therefore, the higher-skilled jobs are somewhat disconnected from those in the lower skill levels. Figure 40 also shows possible jobs and career pathways that may be created in the case of expansion of projects, and implementation of many ADs in one area.

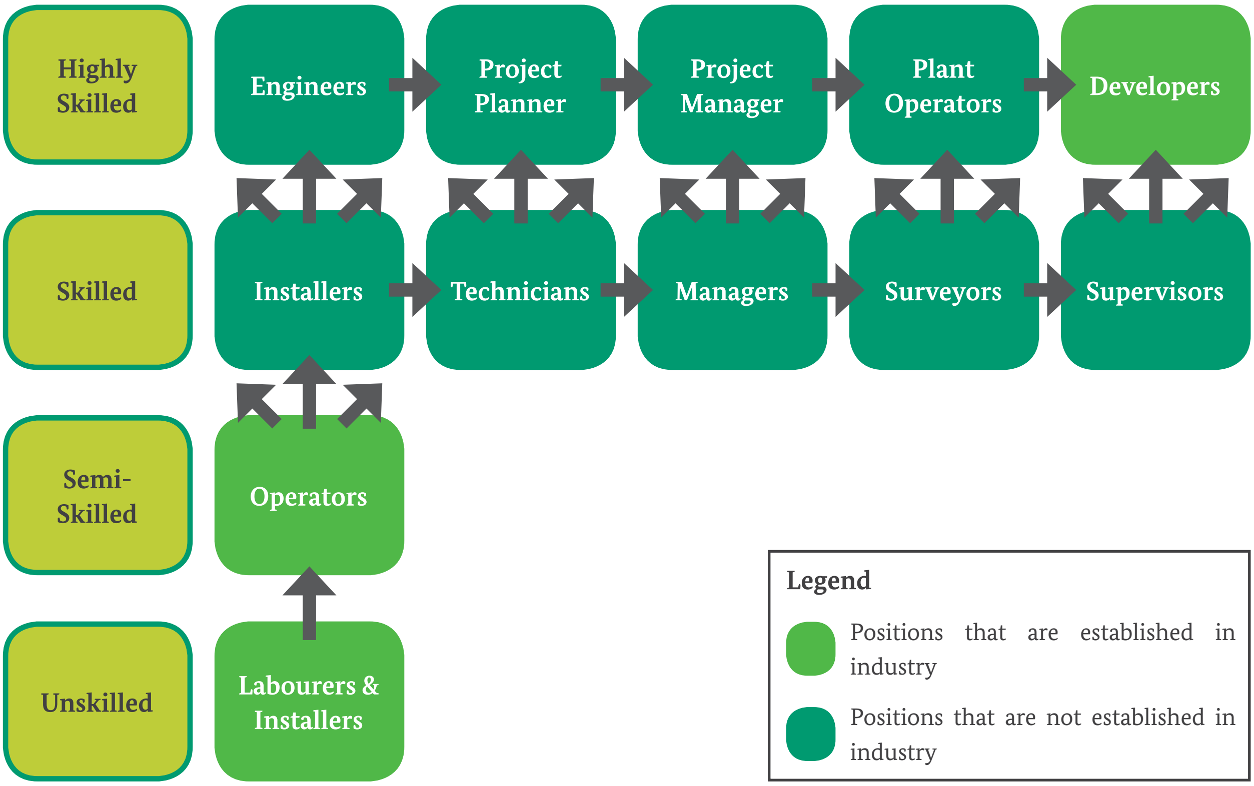


Figure 40: Career Pathways for Small and Rural Projects

10 Conclusion

Currently, there are approximately 38 biogas projects in South Africa either in development, construction or operation (where rural projects are accounted for as 1, although they consist of 20+). Approximately 1 700 direct (FTE) jobs are associated with the industry, across the project phases of feasibility/development, construction and operation/maintenance, with the majority in construction and 270 in operation and maintenance. The model output for the year 2030 shows that with a conservative industry growth, there could be approximately 59 000 direct (FTE) jobs in the operations and maintenance phase of the industry, and under the optimistic perspective, this number could rise to 89 000 direct (FTE) jobs.

With a lack of biogas standards, the certification skills gap remains at 100%, supplemented by practical/self-taught experience and passion for the industry. If no formalisation and benchmarking occurs, the industry will remain at a 100% certification skills gap. Additionally, this will also increase costs to the end user, inhibit potential growth and the associated benefits that the industry can bring to be realised, and also create unsafe working conditions for those practicing the trade and utilising the technology.

With a growing industry (both in biogas and although out of the scope of this study - natural gas on the horizon) and the potential of a large number of jobs/employment opportunities across all skill levels (unskilled, skilled, semi and highly skilled), the need is justified to create biogas standards, certifications and formal education programmes all over South Africa, specifically aligned with the application of biogas. With more knowledgeable skills available in the market, competition and efficiency would increase, and the waste-to-energy field in South Africa could grow to provide all the benefits that are observed internationally such as: safe and dignified work opportunities, the decrease of waste to landfill, a decrease of pollution and an increase of sustainable electricity and gas fuel for rural, urban and commercial use.

An ideal initial biogas certification course for unskilled and semi-skilled workers would be hands-on and application based rather than technical, performed as a short course over a few days (NQF level 3 to 6). Other individuals that could benefit from this course include farmers and owners of biogas plants as they tend to provide a majority of the operational labour, trouble-shooting and conducting maintenance without the help of a seasoned professional. The provision of a standardised series of short courses, would grow a field of in-house biogas operators and trouble-shooters, with knowledge on the running of the biogas digester, treatment and organisation of feedstocks. This in turn could be linked to technical, electrical and mechanical qualifications (for example, TVET's), to extend these jobs to the construction phase (wiring, generators and stoves). SARETEC provides a convenient home for the growth of these courses and the biogas certification procedure, pooling the certification with the other RE technologies.

The feasibility and development phases for biogas projects is expected to remain dominated by highly skilled individuals who have received international training or have a number of years of experience with the technology. This is especially true for larger projects, where the design is highly technical and detailed due to complexity of the technology and sensitivity of the process, as well as the bankability requirements of the projects. Smaller projects may over time, be designed by people who fall into the skilled category: - through in-house training, external certification and experience, they can be taught to design the simpler ADs that will only be used to generate fuel gas.

The construction of biogas projects involves primarily civil construction works and does not require much specialised training. This civil work can be completed by existing South African construction companies in the market (larger projects) and by unskilled general labourers overseen by a developer or manager (smaller projects). This trend is not expected to change going forward.

The operation phase provides the greatest amount of meaningful and decent jobs[25] in the biogas sector. As a result

25 'Decent jobs' refer to work that provides fair income, dignified, secure and free working conditions, gender equality and social protection (International Labour Office, 2011).

of the duration of operations (project life time of around 20 years), the plant requires a consistent need of permanent/full-time technical skills, allowing for training and development, as well as career progression opportunities with regards to optimisation, troubleshooting, and general maintenance. Furthermore, this phase provides an employment opportunity for all skill levels in various locations (including rural and agricultural regions), in contract to the highly skilled development phase or the short term needs of the construction phase. Larger plants require a skilled or highly skilled plant operator, whereas smaller projects can be run by a semi- or unskilled person. The operation phase is also the main target stream for a biogas certification, and standardising the requirements of a biogas operator would also address the safety issues currently seen as a risk in legislation.

The skills gap realised by the current status of the South African market is a result of the lack of biogas available and qualified skill development routes in South Africa, the access to local and international biogas specific education, and the 'make-do' in-house training currently conducted by developers. Currently, developers invest in skills training, therefore there is no push and pull of skills within the industry: - skills do not approach the industry from the outside, rather it is derived from inside the industry. This skills gap will compound with the growing market should there be no intervention and standardisation of skills to increase competition and quality of the technical aspects of the industry.

Should the South African biogas skills gap be closed through various training courses, the career pathways of those within the industry would expand and this in turn would create an appeal for new members to join the industry, as well as for new companies to emerge with the trust that employees could be found within the market.

10.1 THE WAY FORWARD

In order to build up the certification standards, similar international cases should be investigated for course content and topics, and adjusted for relevance in South Africa. Courses presented in Germany and China may provide a reference point for the types of information required.

As discussed previously, the current need in the South African industry points to operations and maintenance technicians. Short courses on biogas operation seems to be the simplest departure point for biogas education, such as a 3–5 day course on the fundamentals of biogas including, for example, the anaerobic digestion process, environment and engineering considerations, high level gas yield calculations, feedstock selection criteria, AD operation, chemical process parameters, equipment demonstration, and other AD variables. A similar course was presented at UCT in February of 2016 through the International Biogas and Bioenergy Centre of Expertise (IBBK, 2016), and could be offered on a regular basis at SARETEC.

The second step in the development of this programme could be the introduction of a longer and more in-depth look at biogas and the associated feedstocks looking into the anaerobic digestion process and environmental and engineering parameters in greater depth, a course of around 2–3 weeks with deeper investigation into all of the topics above but with an emphasis on project development compliance requirements and biogas governance in the South African context. Both of these courses would encourage the dissemination of information into industry in South Africa and enhance awareness around the use of biogas, building course work and awareness of more formalised courses to be offered through centres of excellence in renewable energy and biogas, such as SARETEC.

The development of these (lower NQF levels) roles will allow for a natural growth curve and establishment of higher skills (higher NQF levels). The interested educational bodies could proceed with the course development, eventually passing it through the QCTO and independent validation bodies.

11 Recommendations and Further Studies

This chapter elaborates on certain avenues of insight that AltGen have not included in the study, but deem relevant for consideration for further studying in order to gain a more complete overview of the current and future biogas industry.

11.1 TECHNICAL ASPECTS: FEEDSTOCKS AND TECHNOLOGY

Several technologies were not included in the outputs of this study and therefore in the employment potential. The focus included biogas feedstocks that could be aggregated and used to estimate the potential of AD implementation. LFG was excluded as the technology vastly differs from traditional AD technology and therefore the employment data could not be aggregated into the model. However, the application of LFG provides a high potential avenue for biogas generation and meaningful job creation. Key players in the biogas market focus solely on LFG as a technology and several projects have been awarded 'preferred bidder' status in the policy driven DoE RE program (the REIPPPP). To understand the employment potential of LFG, a full analysis of the state of landfills in South Africa would be required for research into this field.

The movement of people into biogas-specific roles from jobs currently situated on a farm/process that is to implement an AD is not thoroughly investigated in this report as the focus has been on new jobs. Quantifying the current number of people that could benefit from O&M training with immediate effect could give an understanding of the time-scale of effectiveness of certification initiation, and therefore provides an insightful avenue of future research.

Waste streams generated and utilised as a part of sugar mills is also disregarded in the study according to the status quo of burning the carbon rich waste onsite as fuel. In order to estimate the biogas potential of these waste streams, the mass currently being burned would need to be redirected and therefore, is another avenue for potential research.

In order to fully understand the biogas potential of WWTW plants, the technology currently utilised in each and every WWTW is required to be investigated, and this provides another opportunity for research. The technology employed at present directly impacts the feasibility of adding an AD for sludge treatment and biogas generation.

Generating accurate estimates of feedstock available for biogas production in South Africa is an in-depth study in itself, as the data available is outdated and difficult to obtain. The latest nation-wide census was performed in 2011, along with a number of industry profile analyses (which have been used in this study). However, a disconnect was noted between private industry associations statistics and statistics from the public sector, most likely due to distrust, disagreement and lack of participation. Further to that, the biogas industry in South Africa is growing with two separate streams i.e. rural and small scale projects, and medium, commercial, large and utility scale projects. Therefore, to analyse the feedstocks potentially to be utilised by each stream, the statistics are required in terms of area and type of settlement classification (rural and urban).

As noted from the case studies (Chapter 5.8), many projects utilise a mixture of feedstock types to run their digesters (co-digestion). Previous studies in this field such as Maia, et al., 2011 and McDermott, 2012, divide the different feedstock streams into project groupings in order to estimate the projects that can be generated from each resrouce, as has been done in this study. The result is not a true reflection of the industry, and a more accurate analysis could be performed using a geographical information system that then reflects all feedstock sources within a certain radius, that could be brought together to initiate a biogas plant.

11.2 METHODOLOGY OF QUANTIFICATIONS

Another point of conflict in predicting the future of the biogas industry is that there is aleady a wide range of projects with different capacities in the field. Linking number of projects to potential capacities requires estimates of the capacity of the majority of projects, and also assumes that the plants will generate electricity rather than utilise the biogas generated[26]. There are already large scale plants in construction that will not generate electricity, as it is more efficient to utilise the gas for commercial applications (Stakeholder Interviews, 2016). Further, different feedstocks generate biogas of differing composition and therefore the energy value of gas is also difficult to calculate. Consequently, it may be best to use an alternative quantification of capacity, such as volumetric flowrate of gas generated, or volume of digester.

This study and model was designed to be interactive, and therefore adapted as the industry grows and information and data become more available. A recommendation would be to continuously update the project data with relevent inputs and outputs (updated project information and feedstock/potential data) that change the employment forcasts in South Africa. It is recommended that the outputs from the model be updated annually in order to have relevant figures that can be used in government reports and inform the decisions that are taken at a political level, thus benefitting the socio-economic framework of the country.

Lastly, an estimation of feedstocks and quantities of available resources cannot be reviewed in isolation when calculating biogas potential. Social, economic, environmental, political (policy and legislation) and other relevant layers need to also be considered and therefore evaluated to calculate a more robust employment and job creation potential.

11.3 COMPARISON OF DEVELOPER PIPELINE ESTIMATES AND TOTAL FEEDSTOCK 'POTENTIAL' ESTIMATE OUTPUTS

A comparison of the total projects per a 5-year increment period as predicted by the stakeholders and the potential available feedstock, results in a wide range of dissimilarities which could offer a range of further studies and reiterates the necessity of constantly updating the data on feedstocks. Firstly, it must be noted that South Africa has a 1.58% population growth rate (StatsSA, 2014), with a growing services sector that is the major contributor to the GDP. Agriculture contributes a small part of the primary sector, which decreased by 8.4% in 2015 (StatsSA, 2015). With the water shortages and current economic climate, the agriculture sector is not predicted to grow considerably in the coming years. That being said, South Africa also has a growing middle class that do not rely on agricultural incomes and prefer to buy fresh and manufactured foodstuffs from retail stores. Variable growth in the feedstock streams is not considered in analysing the model outputs, but may be cause for a more in-depth study on the topic, and is briefly overseen in this Chapter.

With a number of landfills reaching the volume limit, and increasingly stringent waste laws, the waste to energy sector is one that will be sustained into the future, as evidenced by international trends. From the projects listed in this study, biogas project lifetimes can be considered to be around 10-20 years, depending on the size. Once the technology has been set up, the process is sustainable as long as the AD is maintained properly and the feedstock is available.

Comparing the project pipelines that developers predict over the following 5 years and the total estimated feedstocks, it clearly shows the difficulties in predicting the growth patterns of a new industry. Subtracting the current projects already implemented from the total amounts of projects estimated in potential, and then dividing by the number of projects that developers estimate to be initiating per year, results in the number of years the potential and growth rate can be sustained. As shown in Figure 41, large scale projects, determined only from the available feedstock streams that were considered in this study, will be accounted for within 30 years should the developers continue to expand in this sector as predicted. Developers estimated a higher potential for medium-scale projects than is available from feedstocks (such as abattoirs), and therefore at the developer estimated rate, the current feedstocks would be depleted in 10 years. This creates an anomaly that is contrary to the status quo of industries, that the potential feedstocks for large projects would outlast that of medium, but this is only due to the disconnect noted between developer estimated pipelines and AltGen's assumption of feedstocks. It must be noted that these are purely assumptive figures and the industry may not be constrained in this manner at all.

From these outputs, it is clear that there is a large amount of rural projects available for biogas implementation than developers predict or have in their pipeline. Developers

26 Utilising the biogas for use in vehicles or as a gas fuel requires the gas to be cleaned, separated and bottled at source, as South Africa does not currently have gas grid infrastructure (Stakeholder Interviews, 2016). As it would be difficult to estimate the associated statistics with this use of biogas, it is not included in the model.

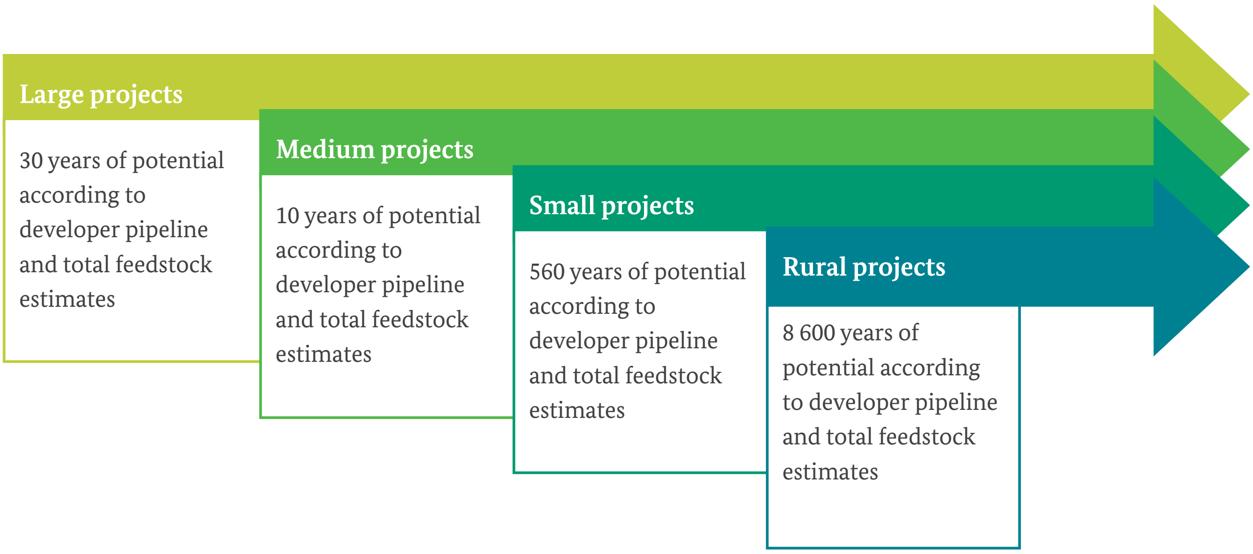


Figure 41: Years of potential at growth rate estimated by developers (Stakeholder Interviews, 2016)

implementing rural scale projects have indicated that there is not enough government support for projects of this type, and little or no capital is contributed by the owners of the ADs. At the predicted growth rate by developers, rural and small scale projects will be sustained for 8 600 and 560 projects respectively, showing that both areas leave room for more developers to enter the market, or each developer to greatly increase their rate of output of small and rural projects.

REFERENCES

Ackroyd, B., 2014. *Recycling the only solution to South Africa's landfill shortage.* [Online]
Available at: https://www.enca.com/south-africa/recycling-only-solution-south-africas-landfill-shortage
[Accessed 12 02 2016].

African Climate and Development Initiative, 2015. *A Status Quo Review of Climate Change and the Agriculture Sector of the Western Cape Province.* [Online]
Available at: https://kaaimans2touwktt.files.wordpress.com/2015/06/a-status-quo-review-of-climate-change-and-the-agriculture-sector-of-the-western-cape-province.pdf
[Accessed 17 02 2016].

AGAMA Biogas (Pty) Ltd, 2009. *Sustainable Cities: Biogas Energy from Waste*, Cape Town: AGAMA Biogas (Pty) Ltd.

AltGen Consulting, 2016. GIZ-SAGEN proposal: *An Assessment of Skills Needs and Estimation of the Job Potential for the Biogas Industry and South Africa*, Stellenbosch: AltGen Consulting.

American Biogas Council, 2016. *American Biogas Council.* [Online]
Available at: http://www.americanbiogascouncil.org/index.asp
[Accessed 26 02 2016].

Atwood-Palm, J., 2015. *The Impact of IPAP on the South African Processed Fruit & Vegetable Industry.* [Online]
Available at: https://www.thedti.gov.za/parliament/2015/SAFVCA.pdf
[Accessed 11 03 2016].

Austin, G. & Blignaut, J., 2007. *South African National Rural Domestic Biogas Feasibility Assessment*, s.l.: AGAMA Energy (Pty) Ltd.

Austin, G. et al., 2003. *Employment potnetial of Renewable Energy in South Africa*, Cape Town: AGAMA Energy (Pty) Ltd.

Baltic Deal, 2012. *Biogas from manure.* [Online]
Available at: http://www.balticdeal.eu/measure/biogas-benefits/
[Accessed 17 02 2016].

Barnard, L. & Holzbaur, U., 2013. *Sustainability with Biogas as a form of Alternative Energy*, s.l.: Central University of Technology of the Free State.

BAU-Afrika, n.d. *Anearobic Digester.* [Online]
Available at: http://www.bau-afrika.co.za/project_item/anaerobic-digester/
[Accessed 10 Januray 2016].

Bio2Watt, 2014. *Bronkhorstspruit Biogas Plant.* [Online]
Available at: http://www.bio2watt.com/bio2watt%E2%80%99s-bronkhorstspruit-biogas-plant-%28pty%29-ltd.html

BiogasSA, 2015. *BiogasSA.* [Online]
Available at: http://www.biogassa.co.za/index.php/sa-biogas-projects/commercial-biogas-plants
[Accessed 7 January 2016].

BIOMA, 2015. *BIOMA holds training course on biogas technology.* [Online]
Available at: http://www.caas.cn/en/newsroom/international_cooperation_update/256848.shtml
[Accessed 18 03 2016].

BMW Group, 2015. *BMW South Africa's Rosslyn plant recieves first renewable energy from Bio2Watt biogas plant.* [Online]
Available at: https://www.press.bmwgroup.com/south-africa/article/detail/T0239122EN/bmw-south-africa%E2%80%99s-rosslyn-plant-receives-first-renewable-energy-from-bio2watt-biogas-plant
[Accessed 06 04 2016].

Boulle, M., Boyd, A. & Cunliffe, G., 2015. *Understanding the implementation of the REIPPPP in South Africa - using the 5C Protocol*, Cape Town: Mitigation Action Plans & Scenarios (MAPS).

Breitschopf, B., Nathani, G. & Resch, G., 2011. *Review of approaches for employment impact assessment of renewable energy deployment.* [Online]
Available at: http://iea-retd.org/wp-content/uploads/2011/11/EMPLOY-task-1.pdf
[Accessed 12 02 2016].

Campbell, T. & Gunning, P., 2014. *New Biogas Opportunities Roadmap is Part of Climate Change Solution.* [Online]
Available at: http://energy.gov/articles/new-biogas-opportunities-roadmap-part-climate-change-solution
[Accessed 25 01 2016].

Carr, B., 2015. *BIO2WATT'S BIO-ENERGY COMES TO LIFE! Bronkhorstspruit Biogas Plant.* [Online]
Available at: http://www.boschprojects.co.za/bio2watts-bio-energy-comes-to-life-bronkhorstspruit-biogas-plant/
[Accessed 28 January 2016].

Claassen, J., 2015. *Farmer's Weekly.* [Online]
Available at: http://www.farmersweekly.co.za/article.aspx?id=74400&h=Exploring-intuitive-farming-
[Accessed 7 February 2016].

CRSES, 2016. *Centre for Renewable and Sustainable Energy Studies.* [Online]
Available at: http://www.crses.sun.ac.za/
[Accessed 16 02 2016].

CSIR & DEA, 2016. *Strategic Environmental Assessment for wind and solar PV energy in South Africa - Renewable Energy Development Zones (REDZ).* [Online]
Available at: https://redzs.csir.co.za/
[Accessed 15 03 2016].

CSIR, 2013. *Best areas for renewable energy identified: CSIR and Department of Environmental Affairs release map.* [Online]
Available at: http://www.csir.co.za/enews/2013_oct/02.html
[Accessed 19 04 2016].

de Lange, W. & Nahman, A., 2015. *Costs of food waste in South Africa: Incorporating inedible food waste*, Pretoria: CSIR.

DEA, 2012. *National Waste Information Baseline Report.* [Online]
Available at: http://sawic.environment.gov.za/documents/1880.pdf
[Accessed 10 03 2016].

DEA, 2016. *Cabinet Approves Gazetting of Renewable Energy Development Zones.* [Online]
Available at: https://www.environment.gov.za/mediarelease/cabinet_gazetting_redz
[Accessed 14 03 2016].

Delhi, C. f. R. D. a. T. I., 2009. *Virendra Kumar Vijay*. [Online]
Available at: http://web.iitd.ac.in/~vkvijay/
[Accessed 26 01 2016].

Department of Agriculture, Forestry and Fisheries, 2011. *A Profiile of the South African Mutton Market Value Chain*. [Online]
Available at: http://www.nda.agric.za/docs/AMCP/MuttonMVCP11-12.pdf
[Accessed 10 03 2016].

Department of Agriculture, Forestry and Fisheries, 2012. *A Profile of the South African Beef Market Value Chain*. [Online]
Available at: http://www.nda.agric.za/docs/AMCP/Beef2012-13.pdf
[Accessed 08 03 2016].

Department of Agriculture, Forestry and Fisheries, 2012. *A Profile of the South African Pork Market Value Chain*. [Online]
Available at: http://www.nda.agric.za/docs/AMCP/Pork2012.pdf
[Accessed 10 03 2016].

Department of Agriculture, Forestry and Fisheries, 2015. *Abstract of Agricultural Statistics*. [Online]
Available at: http://www.daff.gov.za/daffweb3/Portals/0/Statistical%20Information/Abstract%202015.pdf
[Accessed 17 02 2016].

Department of Basic Education, 2011. *Action Plan to 2014: Towards the Realisation of Schooling 2025*. [Online]
Available at: http://www.education.gov.za/LinkClick.aspx?fileticket=XZGwrpV9gek%3d&tabid=418&mid=1211
[Accessed 07 03 2016].

Department of Energy, 2012. *National Development Plan 2030*. [Online]
Available at: http://www.gov.za/sites/www.gov.za/files/Executive%20Summary-NDP%202030%20-%20Our%20future%20-%20make%20it%20work.pdf
[Accessed 24 02 2016].

Department of Energy, 2012. *Non-Grid Households Electrification Policy Guidelines.* [Online]
Available at: http://www.energy.gov.za/files/policies/electrification/NON%20GRID%20ELECTRIFICATION%20POLICY%20 2012.13.pdf
[Accessed 07 03 2016].

Department of Energy, 2015. *Suite of Supply Policy Guidelines for the Integrated National Electrification Programme (INEP): 2016/17.* [Online]
Available at: http://www.energy.gov.za/files/policies/electrification/Suite-of-Supply-Policy-Guidelines-for-the-Integrated-National-2016-17.pdf
[Accessed 15 02 2016].

Department of Environmental Affairs and Tourism, 2011. *South Africa: a water scarce country.* [Online]
Available at: https://www.environment.gov.za/sites/default/files/docs/water.pdf
[Accessed 25 02 2016].

Department of Provincial and Local Government & Business Trust, 2007. *Expanding economic opportunity in the Presidential poverty nodes*, Pretoria: Department of Provincial and Local Government & Business Trust.

Dicla Training Centre, 2008. *Dicla Training and Farming Courses.* [Online]
Available at: http://www.diclatraining.com/training_courses/index.asp
[Accessed 16 02 2016].

Doya, D., 2015. *Africa's first grid-linked biogas plant starts running in Kenya; firm plans Ghana project too.* [Online]
Available at: http://mgafrica.com/article/2015-08-22-africas-first-grid-linked-biogas-plant-starts-running-in-kenya-firm-plans-ghana-project-too
[Accessed 25 01 2016].

Education, D. o., 2006. *National Skills Development Framework for Employees in Public Education*, Pretoria: Department of Education.

Electric Power Research Institute, 2013. *Electricity Use and Management in the Municipal Water Supply and Wastewater Industries.* [Online]
Available at: http://www.waterrf.org/PublicReportLibrary/4454.pdf
[Accessed 17 02 2016].

Energy, C., 2015. *The Potential for Biogas in Africa.* [Online]
Available at: https://www.clarke-energy.com/2015/the-potential-for-biogas-in-africa/
[Accessed 10 January 2016].

eNews Channel Africa, 2014. *Recycling the only solution to South Africa's landfill shortage*. [Online]
Available at: https://www.enca.com/south-africa/recycling-only-solution-south-africas-landfill-shortage
[Accessed 03 02 2016].

eThekwini Municipality, 2014. *Project Summary Document: Durban Landfill-Gas to Electricity.* [Online]
Available at: https://www.iea.org/media/technologyplatform/workshops/southafricabioenergy2014/Sitevisit_Durban_LandillGas_to_Electricity_22_Nov.pdf
[Accessed 29 02 2016].

EurObserv'er, 2014. *Biogas Barometer 2014*, Paris: EurObserv'er.

EWSETA, 2013. *Energy and Water Sector Education and Training Authority.* [Online]
Available at: http://www.ewseta.org.za/
[Accessed 25 01 2016].

F.M.o. Food, Agriculture & Consumer Protection, 2012. *Bioenergy in Germany: Facts and Figures*, Rostock: Fachagentur Nachwachsende Rohstoffe e.V. (FNR).

Fachverband Biogas e. V., 2011. *Biogas Can Do It*, Berlin: Fachverband Biogas e. V..

GIZ & SALGA, 2015. *Biogas potential in selected waste water treatment plants*, Pretoria: Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH.

Greben, H. A. & Oelofse, S. H., 2009. *Unlocking the resource potential of organic waste: a South African perspective*, Pretoria: CSIR.

Greben, H., Burke, L. & Szewczuk, S., 2009. *Biogas, as a Renewable Energy Source, Produced During the Anaerobic Digestion of Organic Waste*, Pretoria: CSIR.

Health Systems Trust & Department of Health, 2013. *National Health Care Facilities Baseline Audit.* [Online]
Available at: http://www.health-e.org.za/wp-content/uploads/2013/09/National-Health-Facilities-Audit.pdf
[Accessed 07 03 2016].

Health Systems Trust, 2015. *South African Health Review*. [Online]
Available at: http://www.hst.org.za/sites/default/files/Complete_SAHR_2014_15.pdf
[Accessed 07 03 2016].

IBBK, 2016. *International Biogas and Bioenergy Centre of Expertise.* [Online]
Available at: http://ibbk.fachgruppe-biogas.de/index.php?id=1&L=1&id=23
[Accessed 05 02 2016].

iBert, 2015. Turning waste problems into environmentally friendly energy and income solutions.

iBert, 2016. *iBert (Pty) Ltd.* [Online]
Available at: https://www.linkedin.com/company/ibert-pty-ltd
[Accessed 8 February 2016].

IEA, 2012. *Methodological guidelines for estimating the employment impacts of using renewable energies in electricity generation.* [Online]
Available at: http://iea-retd.org/wp-content/uploads/2012/12/EMPLOY-Guidelines-Annex-2.pdf
[Accessed 15 01 2016].

International Labour Office, 2011. *Towards Decent Work in sub-Saharan Afria: Monitoring MDG Employment Indicators,* Geneva: International Labour Office.

IRENA, 2016. *Renewable Energy Benefits: Measuring the Economics,* Abu Dhabi: IRENA.

Lutge, B. & Standish, B., 2013. Assessing the potential for electricity generation rom animal waste biogas on South African farms. *Agrekon: Agriculture Economics Research, Policy and Prctice in Southern Africa,* 52(2), pp. 1-24.

Magama, P., Mugodo, K. & Modiselle, S., 2015. *Biogas Production Potential for South African Sugar Cane Industry.* [Online]
Available at: http://www.grainsa.co.za/biogas-production-potential-for-south-african-sugar-cane-industry
[Accessed 22 02 2016].

Maia, J. et al., 2011. *Green Jobs: An estimate of the direct employment potential of a greening South African economy,* s.l.: Industrial Development Corporation, Development Bank of Southern Africa, Trade and Industrial Policy Strategies.

Massmart, 2016. *Massmart Geographic Profile.* [Online]
Available at: http://www.massmart.co.za/geographic-profile-massmart/
[Accessed 11 03 2016].

McDermott, F., 2012. *UK jobs in the bioenergy sector by 2020,* York: The National Non-Food Crops Centre Bioeconomy Consultants.

Milk SA & Milk Producers' Organisation, 2015. *LACTODATA Statistics.* [Online]
Available at: http://www.milksa.co.za/sites/default/files/BIPLAC020%20May%202015.pdf
[Accessed 08 03 2016].

Mostert, F., 2015. *Fact Sheet on a site visit to Elgin Fruit Juices Anaerobic Digester.* s.l., SAIREC.

Musyoki, A. & Tinarwo, D., 2015. A pro-poor strategy for the emerging green economy: a case study of Marubini Multi-Purpose Women's Co-operative Biogas Project in Maila, Limpopo, South Africa. *Journal of Public Administration,* 50(1), pp. 143-156.

Nahman, A. & de Lange, W., 2013. *Costs of food waste along the value chain: Evidence from South Africa.* Noordwijkerhout, CSIR.

Naidoo, C., 2013. JOHANNESBURG WATER'S FORAY INTO RENEWABLE ENERGY. *Civil Engineering.*

National Association of Clean Water Agencies, 2012. *Biogas Production at Wastewater Treatment Facilities*. s.l., American Biogas Council.

Neethling, G., 2014. *Waste Management: Red Meat Abattoirs,* s.l.: Red Meat Abattoir Association.

Odendaal, N., 2013. *Engineering News.* [Online]
Available at: http://www.engineeringnews.co.za/article/biogas-2013-10-22
[Accessed 10 02 2016].

Okudoh, V., Trois, C., Workneh, T. & Schmidt, S., 2014. The potential of cassava biomass and applicable technologies for sustainable biogas production in South Africa: A review. *Renewable and Sustainable Energy Reviews,* Volume 39, pp. 1035-1052.

Pick n Pay, 2016. *Store Search.* [Online]
Available at: http://www.picknpay.co.za/store-search
[Accessed 09 03 2016].

Power, T., 2016. *Gorge Farm Energy Park.* [Online]
Available at: http://www.tropicalpower.com/projects/gorge-farm-energy-park/
[Accessed 28 01 2016].

Programme, T. D. B., 2016. *Bio-digesters having a positive impact on rural communities.* [Online]
Available at: http://www.biogas-tanzania.org/highlights/view/bio_digesters_having_positive_impact_on_rural_communities
[Accessed 27 01 2016].

Projects, W., 2016. *WEC Projects.* [Online]
Available at: http://www.wecprojects.co.za/
[Accessed 7 February 2016].

QCTO, 2014. *Quality Council for Trades and Occupation.* [Online]
Available at: http://www.qcto.org.za/
[Accessed 25 01 2016].

REN21, 2015. *Renewables 2015 Global Status Report,* Paris: REN21 Secretariat.

RENEN, n.d. *Renewable Energy Solutions Services.* [Online]
Available at: http://renen.co.za/services/
[Accessed 16 02 2016].

Renovaveis, C. E., 2016. *Updating Course on the Biogas Energies.* [Online]
Available at: https://www.cibiogas.org/en/course_biogas_energies
[Accessed 25 01 2016].

Rutovitz, J., 2010. *South African Energy Sector Jobs to 2030.* [Online]
Available at: http://www.greenpeace.org/africa/Global/africa/publications/climate/south-african-energy-sector-jobs-to-2030.pdf
[Accessed 29 02 2016].

SABIA, 2016. *South African Biogas Industry Association.* [Online]
Available at: http://www.biogasassociation.co.za/
[Accessed 28 01 2016].

SABIA, D. & G., 2013. *Biogas, conversations around challenges and opportunities.* Johannesburg , SABIA, DBSA & GIZ.

SAPA, 2012. *South African Poultry Association Industry Profile.* [Online]
Available at: http://www.sapoultry.co.za/pdf-docs/sapa-industry-profile.pdf
[Accessed 09 03 2016].

SAPA, 2014. *The Provincial Distribution of Chicken farms in South Africa: January 2014 to June 2014.* [Online]
Available at: http://www.sapoultry.co.za/pdf-statistics/provisional-distribution-of-chickens-in-sa.pdf
[Accessed 10 03 2016].

SAPPO, 2016. *South African Pork Producers' Organisation.* [Online]
Available at: http://www.sapork.biz/about-sappo/
[Accessed 09 03 2016].

SAQA, 2015. *The South African National Qualifications Framework.* [Online]
Available at: http://www.saqa.org.za/list.php?e=NQF
[Accessed 28 01 2016].

SARETEC, 2016. *South African Renewable Energy Technology Centre.* [Online]
Available at: http://www.saretec.co.za/
[Accessed 16 02 2016].

SAWIC, 2016. *South African Waste Information Centre.* [Online]
Available at: http://sawic.environment.gov.za/?menu=88
[Accessed 14 03 2016].

Schneider, M., 2015. *Biogas: Second National Biogas Conference 2015,* Johannesburg: DoE.

Scholtz, L., 2013. *Golder and Zitholele take top honours at SAICE awards*. [Online]
Available at: http://www.golder.com/mz/modules.php?name=News&sp_id=828&page_id=970
[Accessed 10 Januray 2016].

Schooling, N. I. o. O., 2012. *Biogas Energy Technician.* [Online]
Available at: http://www.nos.org/departmentsunits/vocational-education/stand-alone-courses/biogas-energy-technician.aspx
[Accessed 26 01 2016].

Sciences, C. A. o. A., 2013. *Biogas Institute of the Ministry of Agriculture.* [Online]
Available at: http://www.caas.cn/en/administration/research_institutes/research_institutes_out_beijing/77774.shtml
[Accessed 26 01 2016].

Shoprite Holdings Ltd, 2016. *Store Locator.* [Online]
Available at: http://www.shopriteholdings.co.za/Pages/StoreLocator.aspx
[Accessed 10 03 2016].

Spar, 2016. *Spar: Our Business.* [Online]
Available at: https://www.spar.co.za/About-SPAR/Company
[Accessed 10 03 2016].

Stafford, W. et al., 2013. Technologies for recovery of energy from wastewaters: Applicability and potential in South Africa. *Journal of Energy in Southern Africa,* 24(1), pp. 15-26.

Stands, S., Moodley, T. & Gibson, S., 2014. *Renewable Energy & Energy Efficiency Career Pathways,* Stellenbosch: AltGen Consulting, EWSETA, Northern Cape Urban TVET College, PEETS, Univerisity of Johannesburg.

StatsSA, 2009. *Changed in standard of living among population groups in South Africa 1998-2006.* [Online]
Available at: http://www.statssa.gov.za/publications/Report-03-03-02/Report-03-03-02.pdf
[Accessed 11 03 2016].

StatsSA, 2011. *Census 2011: Agricultural Households Key Highlights.* [Online]
Available at: http://www.statssa.gov.za/census/census_2011/census_products/Agricultural_Households.pdf
[Accessed 07 03 2016].

StatsSA, 2013. *A giant step in agriculture statistics.* [Online]
Available at: http://www.statssa.gov.za/?p=1447
[Accessed 25 02 2016].

StatsSA, 2014. *General Household Survey.* [Online]
Available at: http://www.statssa.gov.za/publications/P0318/P03182014.pdf
[Accessed 17 02 2016].

StatsSA, 2014. *Mid-year Population Estimates,* Pretoria: Statistics South Africa.

StatsSA, 2015. *The economy: winners and losers of 2015,* Pretoria: Statistics South Africa.

Steinberg, D., Goldberg, M. & Porro, G., 2012. *Preliminary Analysis of the Jobs and Economic Impacts of Renewable Energy Projects Supported by the 1603 Treasury Grant Program. [*Online]
Available at: http://www.nrel.gov/docs/fy12osti/52739.pdf
[Accessed 29 02 2016].

Sustainability Institute, 2016. *Sustainability Institute: Learn.* [Online]
Available at: http://www.sustainabilityinstitute.net/learn/short-courses/2502-systems-technologies-for-sustainable-agriculture
[Accessed 16 02 2016].

Taylor, A., 2015. *The Uilenkraal Bio-Gas Power Generation Plant.* Cape Town , Cape Advanced Engineering .

Technology, K. I. o. I., 2009. *Biogas Development and Training Center.* [Online]
Available at: http://www.kiit.ac.in/recognisedcentres/bdtc.html
[Accessed 26 01 2016].

The Biogas Association, 2013. *The Canadian Biogas Study: Benefits to the Economy, Environmetn and Energy,* s.l.: Kelleher Environmental.

The National Non-Food Crops Center (NNFCC), 2016. *The Official Information Portal on Anaerobic Digestion.* [Online]
Available at: http://www.biogas-info.co.uk/
[Accessed 12 02 2016].

The World Bank, 2015. *World Data: Rural Populations.* [Online]
Available at: http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS
[Accessed 11 02 2016].

Thomas, Sean (www.bio2watt.com), 2015. *THE DEVELOPMENT OF THE BRONKHORSTSPRUIT BIOGAS PROJECT.* Johannesburg, Bio2Watt.

Thomas, S., 2012. *Woolworths' history.* [Online]
Available at: http://www.financialmail.co.za/profiles/2012/11/28/woolworths-history
[Accessed 10 03 2016].

Training, D. o. H. E. a., 2013. *Guidelines: Organising Frameowkr for Occupations (OFO),* Pretoria: Department of Higher Education and Training.

UFH, 2016. *University of Fort Hare: Dr Sampson Mamphweli.* [Online]
Available at: http://ufh.ac.za/centres/rvsc/drmamphweli
[Accessed 16 02 2016].

United Nations, 2015. *Sustainable Development Goals.* [Online]
Available at: http://www.un.org/sustainabledevelopment/sustainable-development-goals/
[Accessed 21 03 2016].

University o Florida, 2015. *Biogas: a renewable biofuel.* [Online]
Available at: http://biogas.ifas.ufl.edu/biogasdefs.asp
[Accessed 17 02 2016].

van der Merwe, A., 2014. *A State of Waste to Energy Research in South Africa,* Pretoria: Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH, South African - German Energy Programme (SAGEN), Renewable Energy Centre of Research and Development (RECORD).

van Rooy, T., Fischer, T. & Crous, D., 2012. *Doing business in South Africa: Waste to Energy.* [Online]
Available at: http://worldviewmission.nl/wp-content/uploads/2013/09/WM-Agentschap-NL-1120-Waste-to-Energy-LowRes-for-Viewing-DPS.pdf
[Accessed 23 02 2016].

von Blottnitz, H. et al., 2009. *Energy from Wastewater - A Feasibility Study,* Cape Town: Water Research Commission.

Wagner, L., 2015. *Trends from the use of biogas technology in Germany,* Bangkok: Fachverband Biogas e.V..

WasteMart waste management services, 2016. *WasteMart Waste Management Services.* [Online]
Available at: http://www.wastemart.co.za/
[Accessed 19 04 2016].

Wisonsin Bioenergy Initiative, 2011. *The Biogas Opportunity in Wisconsin.* [Online]
Available at: https://www.americanbiogascouncil.org/pdf/Biogas%20WI%20Plan%202011.pdf
[Accessed 15 01 2016].

WRAP, 2014. *A survey of the UK Anaerobic Digestion industry in 2013.* [Online]
Available at: http://www.biogas.org.uk/images/upload/news_89_ASORI-2013-report.pdf
[Accessed 15 01 2016].

APPENDICES

Appendix A:
Stakeholders in the Biogas Industry

Name	Company
Andrew Taylor	CAE (Cape Advanced Engineering)
Bonte Edwards	Jeffares and Green
Brian van Oerle	Prana Energy
Clemens Findeisen	GIZ (Germany). Seconded to Fachverband Biogas e.V.
Darius Boshoff	Founders Engineering
David Cilliers	Ennovation
David Cornish	Ener-G
David Sobey	Renew
Dr Harro von Blottnitz	University of Cape Town
Dr Sampson Mamphweli	Fort Hare University
Dr John Grewar	Elsenburg Campus – University of Stellenbosch
Dunesha Naicker	Elgin Fruit Juice
Francois Cilliers	BioPower
Fred Mostert	Elgin Fruit Juice
Gerhard Neethling	Red Meat Abattoir Association
Gordon Ayres	Agama Biogas (Pty) Ltd
Gracia Munganga	Anaergia Africa
Hein Fourie	GCX Africa
Marnus van der Merwe	GCX Africa
Horst Unterlechner	Ibert
Jaco Oosthuizen	Veolia
Jacques Rossouw	Distell
Jason Gifford	WEC Projects
Jimmy Sell	Embassy of Denmark: The Trade Council

Name	Company
Justin Butt	Fountain Civils
Karen Surridge-Talbot	SANEDI
Louise van Zyl	Cape EAPrac
Manfred Dutschke	Green Cape
Marcel Steinberg	Clean Energy Africa
Mark Tiepelt	BiogasSA
Neville Sharwood	John Thompson
Paul de Mattos	Agaricus Clarke – Energy
Paul Hoekman	Scania
Petrus Britz	ARC Institute for Agricultural Engineering
Pieet Stein	Botala Energy Solutions
Quinton Williams	Green Cape
Riaz Hamid	SANEDI
Robert Cloete	Selectra
Robin Thomson	Agama Biogas (Pty) Ltd
Rudi Kriese	FarmSecure
Rudy Schwaeble	Fountain Civils (Durban Civils)
Sayuri Chetty	GIZ-SAGEN
Sean Thomas	Bio2Watt
Sofja Giljova	GIZ-SAGEN
Tarik Höppener	Re-energise Africa
Thilisha Moodley	Energy Partners
Valens Baranyanga	Moto Maluti Resources: Biogas Technology

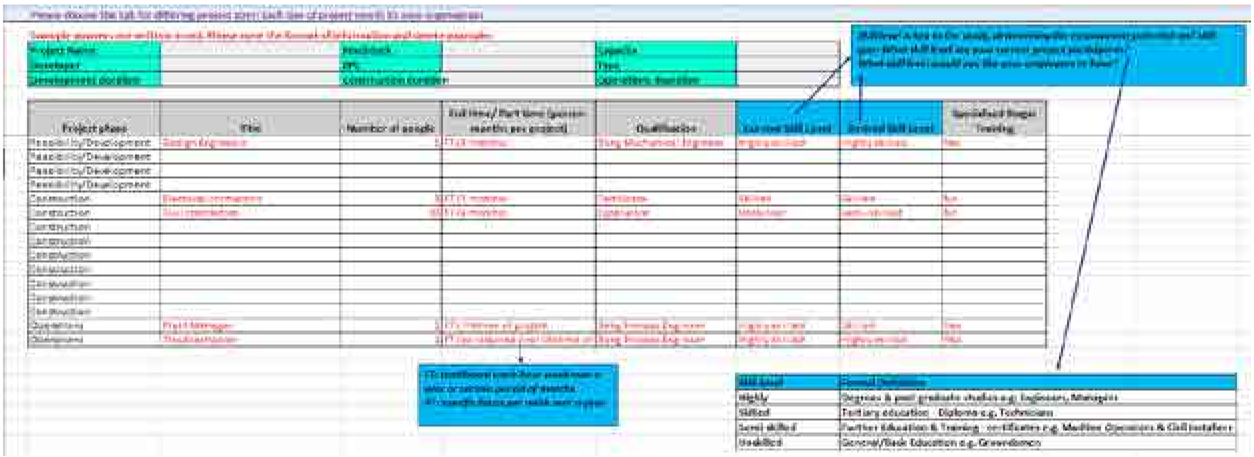
Appendix B:
Questionnaire and Organogram Table

The questionnaire circulated through stakeholders is shown in Table 10.

Table 10: Questionnaire

1.	**Interviewee Status:**		
	1.1.	How many projects are in operations?	
	1.2.	What is their capacity, feedstock and what year were they commissioned?	
	1.3.	How many projects do you have in development and construction?	
	1.4.	In your opinion, what is the status of the industry and where does the potential lie?	
	1.5.	Do you agree with the below, commissioned project per year ratio? If not, please provide your perception of the potential pipeline for the industry:	
		•	2 projects per 5 years (>1MW)
		•	5 projects per year (<300kW)
		•	20 projects per year (<30kW)
	1.6.	Can you confirm the following definitions?	
		1.6.1.	Rural (SMALL) <10kW
		1.6.2.	Domestic (SMALL) <30kW
		1.6.3.	Commercial/Industrial (MEDIUM): >30kW<300kW
		1.6.4.	LARGE Scale: >300kW – 8MW
2.	**Quantitative analysis of job creation and skills required in biogas:**		
	2.1.	Does anyone on your team or the project have or receive specialist biogas training? Please expand on the training, in-house, international etc.	
	2.2.	Elaborate on who is responsible for safety during construction and operations?	
	2.3.	How would the industry benefit from having certified and formal qualifications/skills biogas?	
	2.4.	What skills are required for the treatment of feedstock?	
3.	**Local Content:**		
	3.1.	What percentage of the plant value is local content?	
	3.2.	What key components were imported? Dome, monitoring systems, engine, AD mixers, transformers, etc	
4.	**Enabling the industry:**		
	4.1.	What skills would enable the biogas industry growth?	
	4.2.	In terms of national policies and legislature, what would be required for an enabling industry in SA?	
	4.3.	What challenges have you encountered? How did you resolve them?	
	4.4.	What led to the success of your projects/pipeline?	

The project organogram table is shown in Figure 42.



Project phase	Title	Number of people	Full time/ Part time (person-months per project)	Qualification	Current Skill Level	Desired Skill Level	Specialised Biogas Training
Feasibility/Development	[illegible]	1	[illegible]	[illegible] Engineer	[illegible]	[illegible]	[illegible]
Feasibility/Development							
Feasibility/Development							
Feasibility/Development							
Construction	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Construction	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Construction							
Construction							
Construction							
Construction							
Construction							
Construction							
Construction							
Operations	[illegible]	[illegible]	[illegible]	[illegible] Engineer	[illegible]	[illegible]	[illegible]
Operations	[illegible]	[illegible]	[illegible]	[illegible] Engineer	[illegible]	[illegible]	[illegible]

Skill Level	General Definition
Highly	Degrees & post graduate studies e.g. Engineers, Managers
Skilled	Tertiary education - Diploma e.g. Technicians
Semi-skilled	Further Education & Training - certificates e.g. Machine Operators & Grid installers
Unskilled	General/Basic Education e.g. Greenkeepers

Figure 42: Project organogram information table

Appendix C: Previous Research, Policies and Legislature

Table 11: Previous research in the biogas field of South Africa

Date	Author/s	Position	Main findings[27]
2015	Musyoki and Tinarwo	A Pro-Poor Strategy for the Emerging Green Economy: A Case Study of Marubini Multi-Purpose Women's Co-operative Biogas Project in Maila, Limpopo, South Africa	Biogas projects provide social upliftment as a part of the green economy, and allow for women involvement and employment.
2015	De Lange and Nahman	Costs of Food Waste in South Africa: Incorporating Inedible Food Waste	The cost of sending organic food waste to landfill amounts to R5 963 per tonne (including loss of resource and social and environmental impacts).
2015	GIZ & SALGA	Biogas Potential in Selected Wastewater Treatment Plants	Although all WWTW investigated have digesters, they were not optimised for biogas production and would require refurbishment for efficient biogas collection. Plants with an inflow of >15ML/day would benefit from biogas investment.
2014	Van der Merwe (SANEDI, RECORD, GIZ)	The State of Waste to Energy Research in South Africa	A number of researchers and institutions are involved in biogas research in South Africa.
2013	Barnard & Holzbaur	Sustainability with Biogas as a Form of Alternative Energy	Great potential for biogas in South Africa from available waste streams.
2013	Lutge & Standish	Assessing the Potential for Electricity Generation from Animal Waste Biogas on South African Farms	Pig farms are potentially viable for electricity generation whilst dairy farms do not show as good a potential due to high capital cost of biogas plant.
2013	Smith, Goebel & Blignaut	The Financial and Economic Feasibility of Rural Household Biodigesters for Poor Communities in South Africa	Biodigesters are not financially feasible investments for rural households without governmental or private support.
2013	Stafford et al.	Technologies for Recovery of Energy from Wastewaters: Applicability and Potential in South Africa	Anaerobic digestion can be utilised on wastewaters, particularly rural sewage and municipal WWTP, however skills-training and skilled management is required for the success of the technology.

27 In relation to this report

Table 11 continued...

Date	Author/s	Position	Main findings[27]
2013	Van Rooy, Fischer & Crous	Doing Business in South Africa: Waste to Energy	The waste to energy market in SA is growing and will continue to grow as landfills become problematic
2011	Maia et al.	Green Jobs: An Estimate of the Direct Employment Potential of a Greening South African Economy	Estimation of employment potential over short, medium and long term growth of industry as is.
2009	AGAMA Biogas (Pty) Ltd	Sustainable Cities: Biogas Energy from Waste	Overview of wastewater streams, relevant legislature and policies and case studies (local and international).
2009	Greben, Burke & Szewczuk	Biogas, as a Renewable Energy Source, Produced During the Anaerobic Digestion of Organic Waste	Biogas is a viable renewable energy source for rural areas to replace wood and paraffin.
2009	Greben & Oelofse	Unlocking the resource potential of organic waste: A South African perspective	An enabling legislative environment is key for progression of the field, although it has the potential to greatly improve rural sanitation, waste management and landfill problems.
2007	Austin and Blignaut (AGAMA Pty Ltd.)	South Africa National Rural Domestic Biogas Feasibility Assessment: Prepared for Ministry of Development Co-operation, The State of Netherlands	9.5% of rural households have technical viability for a rural biogas programme, assuming houses with grid access would not be viable for ADs, and targets of households that can contribute financially to the AD over time.
2003	Austin et al. (AGAMA Pty Ltd.)	Employment Potential of Renewable Energy in South Africa	Biogas can create 1 341 direct jobs per TWh-equivalent in 2020

Table 12: Current policies, legislature and framework upholding the green economy in South Africa (adapted from Musyoki & Tinarwo, 2015; van der Merwe, 2014)

Policy/legislature	Year	Department
Minimum requirements for handling, classification and disposal of hazardous waste	1998	Department of Water Affairs and Forestry
National Environmental Management Act (NEMA)	1998	Department of Environmental Affairs
Municipal Systems Act	2000	Department of Cooperative Governance and Traditional Affairs
White Paper on Integrated Pollution and Waste Management	2000	Department of Environmental Affairs
Gas Act	2001	National Energy Regulator of South Africa
Municipal Finance Management Act	2003	National Treasury
White Paper on the Renewable Energy Policy	2004	United Nations Framework Convention on Climate Change
National Environmental Management Act: Biodiversity Act	2004	Department of Environmental Affairs
National Environmental Management: Air Quality Act (NEM:AQA)	2004	Department of Environmental Affairs
Amended Electricity Regulations Act	2006	Government Gazette
The Energy Efficiency Strategy	2008	Department of Energy
National Environmental Management: Waste Management Act (NEM:WA)	2008	Department of Environmental Affairs
South Africa National Policy on the Thermal Treatment of General and Hazardous Waste	2009	Department of Environmental Affairs
Medium Term Strategic Framework	2009 - 2014	National Treasury
Electricity Regulations on New Generation Capacity	2010	Department of Energy
New Growth Path Framework	2010	Economic Development Department
Reducing greenhouse gas emissions: the carbon tax option	2010	National Treasury

Table 12 continued...

Policy/legislature	Year	Department
Amended Electricity Regulations on New Generation Capacity	2011	Department of Energy
Green Economy Model	2011	Department of Environmental Affairs
Integrated Resource Plan	2011	Department of Trade and Industry
National Climate Change Response White Paper	2011	Department of Environmental Affairs
NGP: Green Economy Accord	2011	Economic Development Department
Renewable Energy Independent Power Producer Procurement Programme	2011	Department of Energy
National Skills Development Strategy III	2011	Department of Higher Education and Training
Integrated Energy Plan	2012	Department of Energy
National Development Plan	2012	National planning commission
National Waste Management Strategy (NWMS)	2012	Department of Environmental Affairs
National Strategy for Sustainable Development and Action Plan	2011 - 2014	Department of Environmental Affairs
Industrial Policy Action Plan (IPAP)	2012 / 2013	Department of Trade and Industry

Appendix D: Biogas Project List

Table 13: AD projects currently in operation in South Africa (excluding rural AD projects)

Area	Developer / Owner	Input	Output
	Selectra	Sewage, silage, manure	0,5MW
	Selectra	Sewage, silage, manure	1MW
	Selectra	Sewage, silage, agri waste	1MW
Alice, Eastern Cape	CAE / University of Fort Hare	4000 m^3 of dairy and piggery manure	2x132kVa generators
Athlone Industria	FarmSecure Energy, Wastemart, CEA / New Horizon waste to energy	±400 tons of organic waste per day	
Bela-Bela, Limpopo	CAE / Humphries Boerdery Piggery		
Belville		Wastewater Treatment Plant	
Bonnievale	FarmSecure Carbon	>5 tons bovine manure	
Bredasdorp	iBert	4 tons abattoir waste per day	~100kw
Cavalier	iBert	20 tons abattoir waste per day	~500kw
Darling - Uilenkraal	CAE / Uilenkraal Dairy Farm	Bovine manure	600 kW
Darling - GrootPost	FarmSecure Energy	Bovine manure	
Durban	Bisasar Road LFG	3500-5000 tons refuse per day	6MW
Durban	Mariannhill LFG	550-850 tons refuse per day	1,5MW
Grabouw	Elgin Fruit and Juices	> 5 tons of fruit waste per day	500 kW
Jan Kempdorp	iBert	5,5 tons abattoir waste per day	~135kw
Johannesburg	WEC / Northern Waste Water Treatment Works	Sewage sludge	1,2MW
Klipheuwel	Reliance Composting	~700 tons organic waste per day	

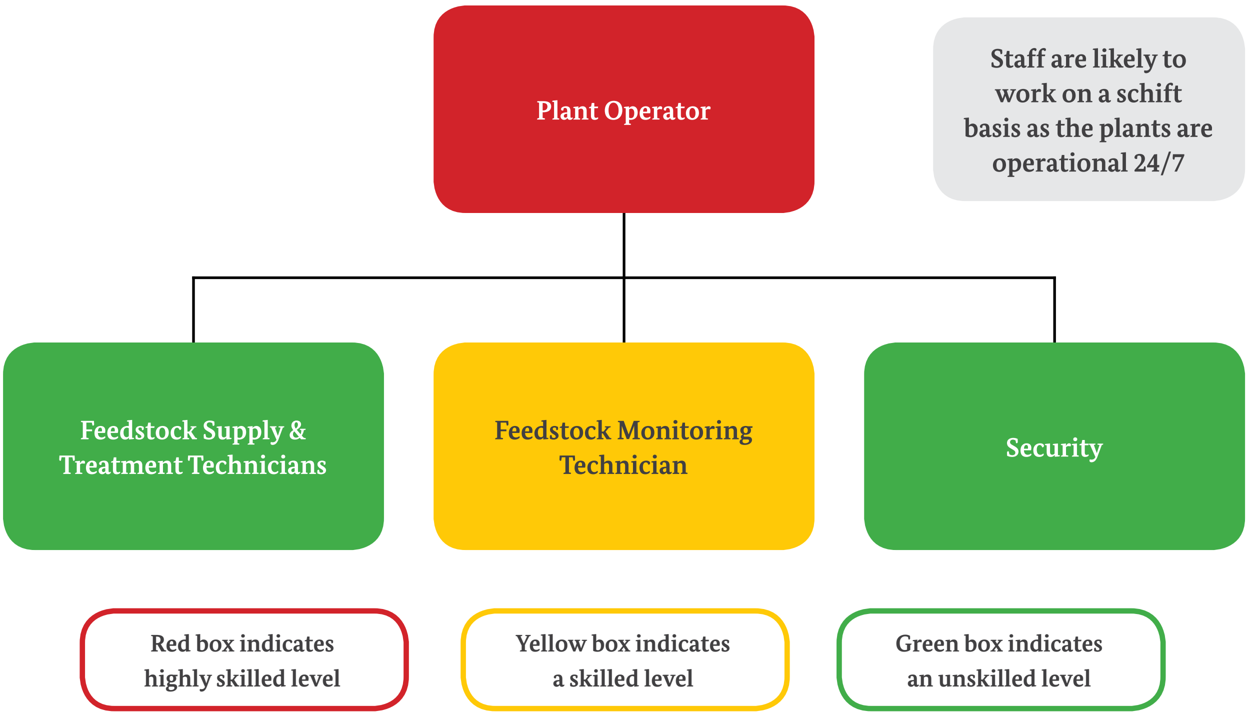
Table 13 continued...

Area	Developer / Owner	Input	Output
Klipheuwel (Zandam)	Farmsecure	> 5 tons of manure per day	600-700 kW
Mossel Bay	BioTherm SA, Mossel Bay PetroSA	Refinery waste water	4,2MW
Newlands	SAB Miller	4500m^3 of wastewater per day	10% of the plants energy demand
Paarl	Drakenstein Municipality		2 MW (Phase 2) 10-12MW (Phase 3)
Pretoria	Bio2watt / Bronkhorst-spruit Biogas Plant	Manure	4,6MW
Queenstown	iBert	42 tons mixed waste from a piggery per day	
Riverdale	iBert	4 tons abattoir waste per day	~100kw
Springs	BiogasSA / Morgan Springs Abattoir	Slaughter waste and organic waste	0,4MW
Stellenbosch	Veolia Water Technologies / Distell	1000m^3 wastewater per day	
Stellenbosch / Franschhoek	Rhodes Food Group	35kg per day (testing feedstock)	
Table View	Jeffares & Green / Bayside Mall	0,6 - 1 ton of food waste per day	
KZN	Khanyisa Projects	Manure from 2+ cows, school organic and sewage waste	cooking fuel (Rural)
KZN	SANEDI	Manure from 2+ cows, school organic and sewage waste	cooking fuel (Rural)
EC, WC, KZN	AGAMA	Manure from 2+ cows, school organic and sewage waste	cooking fuel (Rural)

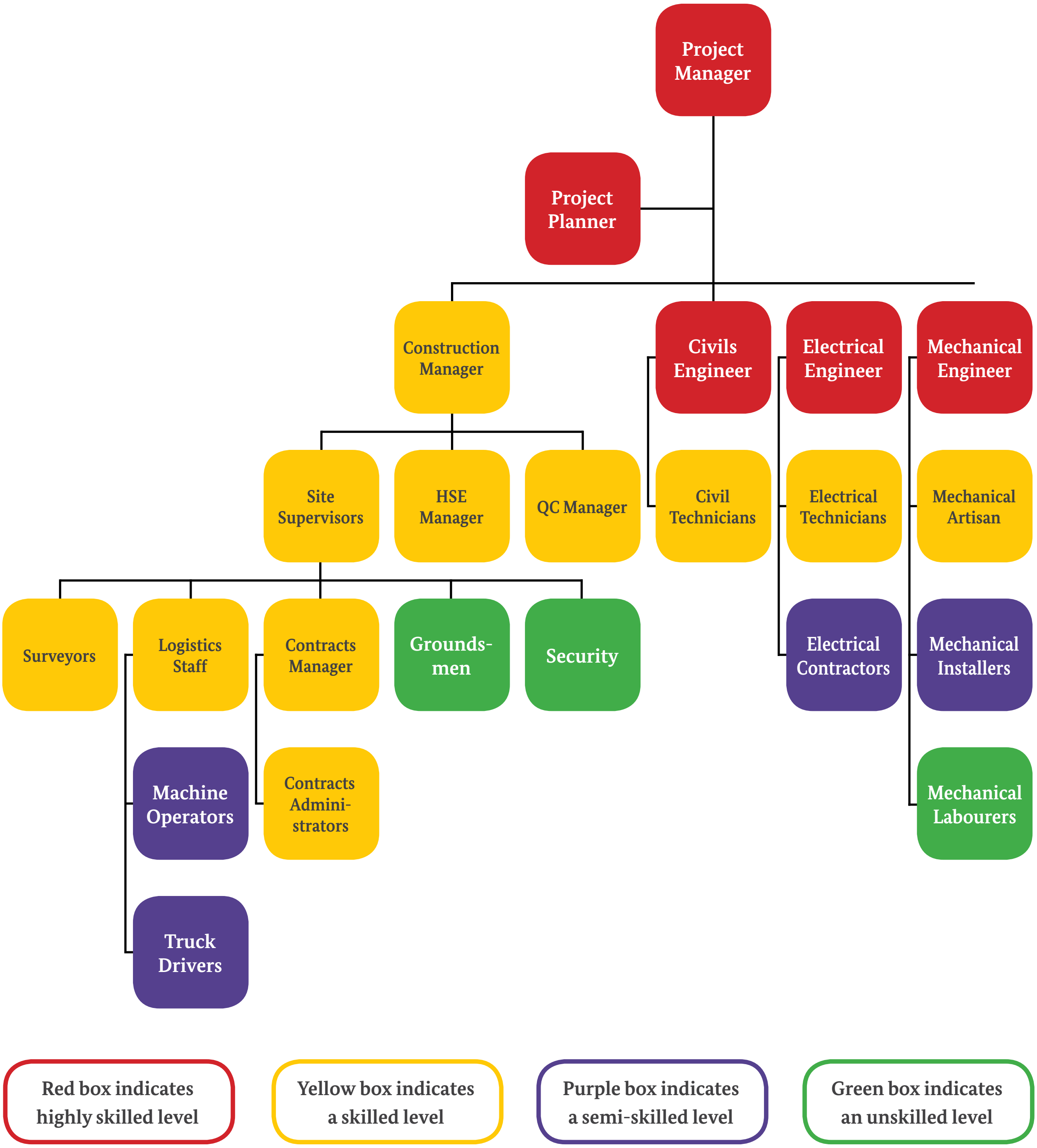
Appendix E: Industry Organograms

Large >300kW

(O&M Phase)

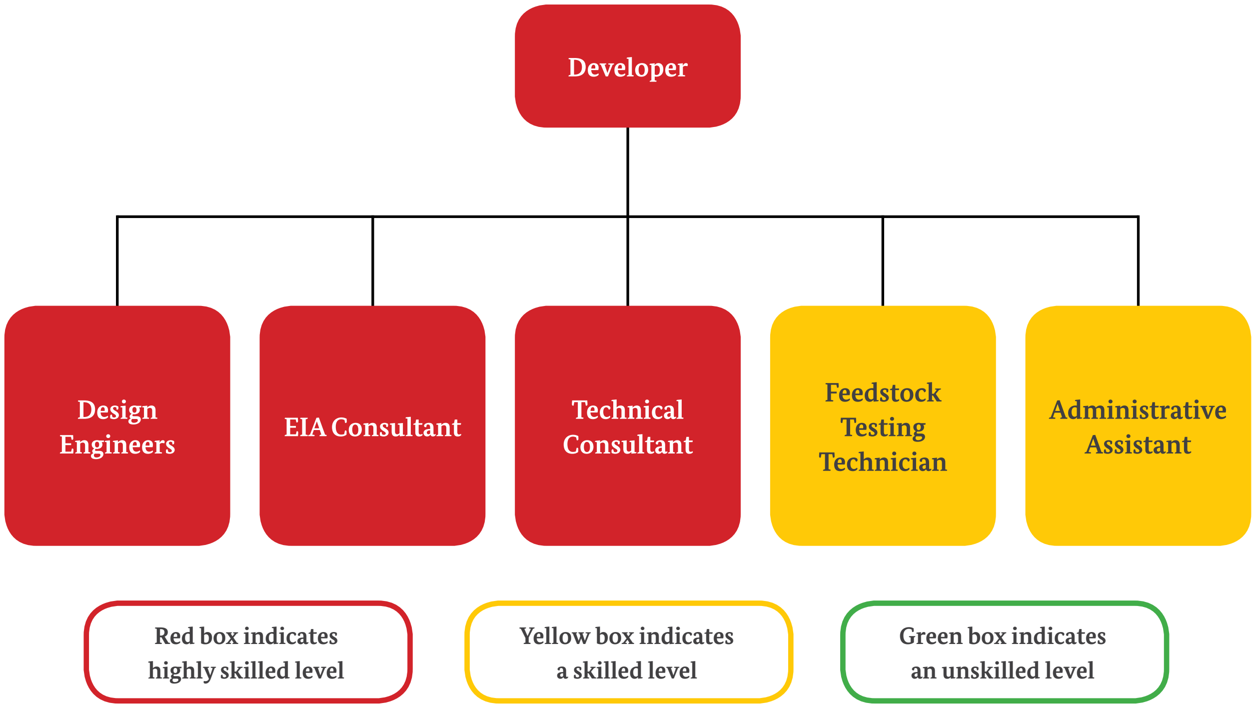


Large >300kW
(Construction Phase)



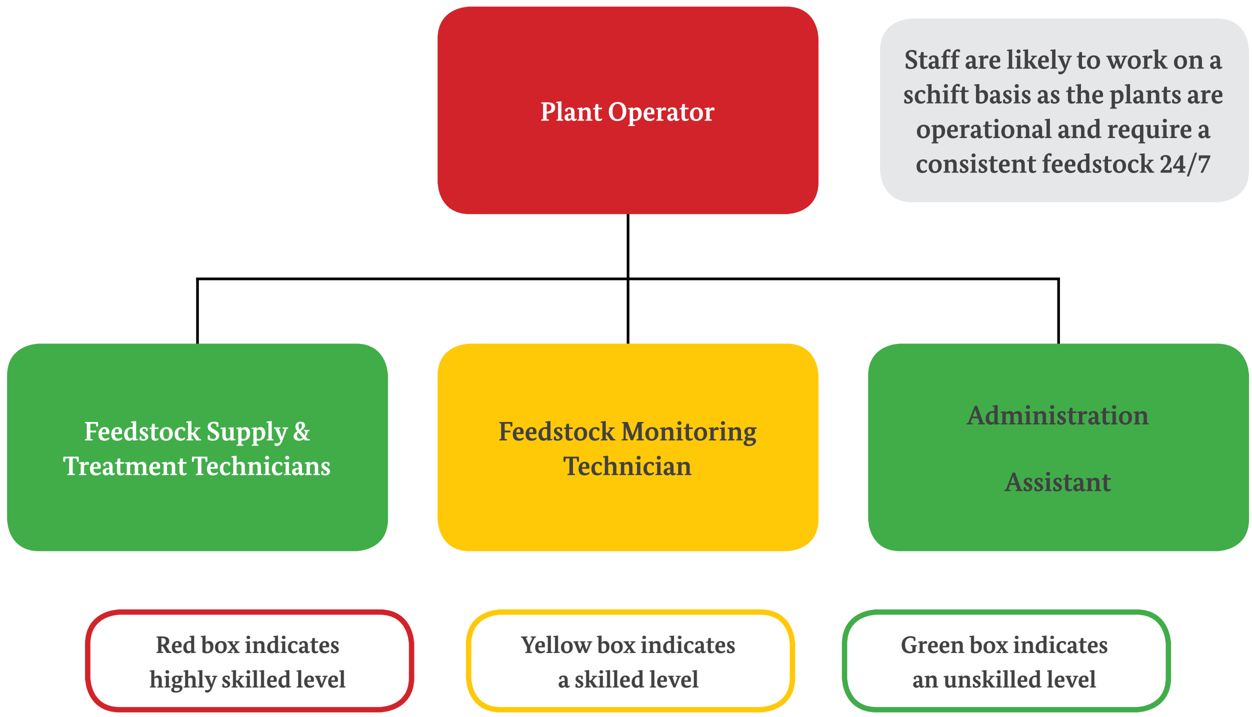
Large >300kW

(Development Phase)



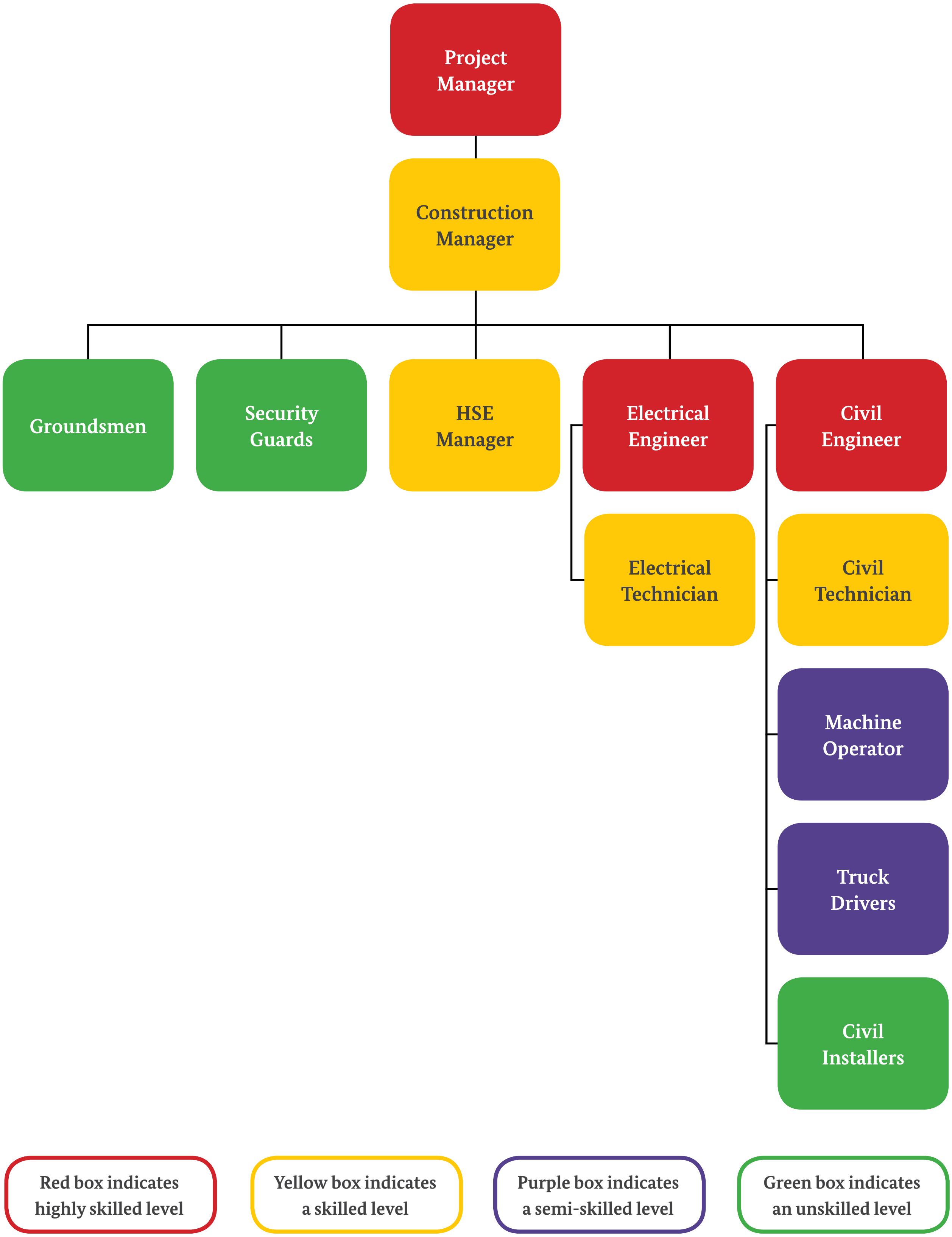
Medium >30kW <300kW

(O&M Phase)



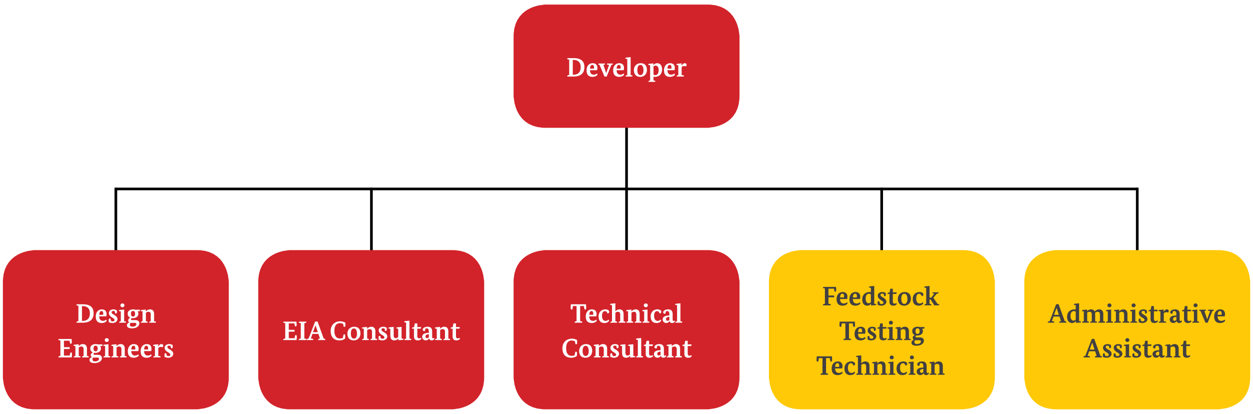
Medium >30kW <300kW

(Construction Phase)



Medium >30kW ,300kW

(Development Phase)



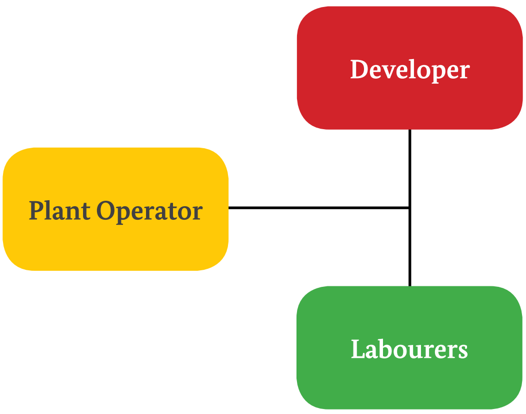
Red box indicates highly skilled level

Yellow box indicates a skilled level

Green box indicates an unskilled level

Rural / Small ,30kW

(Development - Construction - O&M)



The Developer will generally be incolved in all phases.

Once a steady demand has been established and enough digesters are installed, Semi-skilled Operators will be assigned per region

The Organogram remains the same for Rural and Small / Domestic scale systems.

Red box indicates highly skilled level

Yellow box indicates a skilled level

Green box indicates an unskilled level

Appendix F:
Potential Feedstock Statistics

Table 14: Crop production statistics of South Africa (Department of Agriculture, Forestry and Fisheries, 2015)

Type of crop	Total production (1 000 tons)	Year reference
Maize	14 925	2014
Wheat	1 783	2014
Grain Sorghum	206	2014/2015
Groundnuts	77	2014/2015
Sunflower seed	597	2014/2015
Soya Beans	938	2014/2015
Oats	21	2014
Barley	310	2014
Canola	123	2014
Dry beans	88	2014/2015
Sugarcane	17 756	2014/2015
Tobacco	12.90	2013/2014
Apples	799 524	2013/2014
Apricots	48 567	2013/2014
Grapes	1 928	2013/2014
Pears	411.991	2013/2014
Peaches	155.086	2013/2014
Plums	69.648	2013/2014
Prunes, cherries and quinces	2.925	2013/2014
Figs	2.068	2013/2014
Strawberries and other berries	7.566	2013/2014
Watermelons, melons and other summer fruit	90.497	2013/2014
Avocadoes	97.27	2013/2014

Table 14 continued...

Type of crop	Total production (1 000 tons)	Year reference
Bananas	463.395	2013/2014
Granadillas	0.6	2013/2014
Litchis	8.321	2013/2014
Guavas	27.655	2013/2014
Mangoes	54.285	2013/2014
Papayas	13.66	2013/2014
Pineapples	96.74	2013/2014
Oranges	1 821.914	2014/2015
Lemons and limes	257.832	2013/2014
Grapefruit	400.151	2014/2015
Naartjies	40.422	2014/2015
Potatoes	2 193	2013/2014
Tomatoes	525	2013/2014
Pumpkins	245	2013/2014
Green mealies	362	2013/2014
Onions	592	2013/2014
Sweet potatoes	69	2013/2014
Green peas	12	2013/2014
Beetroot	61	2013/2014
Cauliflower	12	2013/2014
Cabbage and red cabbage	145	2013/2014
Carrots	184	2013/2014
Green beans	19	2013/2014

Table 15: Type and number of health care facilities in South Africa (Health Systems Trust & Department of Health, 2013)

Type of health care facility	Number
Satellite clinic	125
Clinic	3 074
Specialised Clinic	4
Maternal Obstetrics Unit	1
Community Day Centre	44
Community Health Centre	238
District Hospital	253
Regional Hospital	55
Tertiary Hospital	10
National Central Hospital	6
Rehabilitation Hospital	3
Children's Hospital	1
Chronic Hospital	4
Orthopaedic Hospital	1
Psychiatric Hospital	23
TB Hospital	35
TB and Psychiatric Hospital	2
Private Hospital	1
Total	**3 880**

Table 16: Livestock statistics of South Africa (Department of Agriculture, Forestry and Fisheries, 2015)

Type of livestock	Number (1 000)	Year reference
Cattle	8 240	2014
Sheep	21 201	2014
Goats	1 987	2014
Pigs	1 562	2013/2014
Poultry: Broiler birds[28]	113 556	2014
Poultry: Layer birds[29]	23 605.584	2014

Table 17: Livestock slaughtering statistics (Department of Agriculture, Forestry and Fisheries, 2015)

Type of animal	Slaughtering's (1 000)	Year reference
Cattles	3 274	2013/2014
Calves	20	2013/2014
Pigs	2 844	2013/2014
Sheep, lambs, goats	7 963	2014/2015

28 African Climate and Development Initiative, 2015. *A Status Quo Review of Climate Change and the Agriculture Sector of the Western Cape Province.* [Online]
Available at: https://kaaimans2touwktt.files.wordpress.com/2015/06/a-status-quo-review-of-climate-change-and-the-agriculture-sector-of-the-western-cape-province.pdf
[Accessed 17 02 2016].

29 African Climate and Development Initiative, 2015. *A Status Quo Review of Climate Change and the Agriculture Sector of the Western Cape Province.* [Online]
Available at: https://kaaimans2touwktt.files.wordpress.com/2015/06/a-status-quo-review-of-climate-change-and-the-agriculture-sector-of-the-western-cape-province.pdf
[Accessed 17 02 2016].