

Biogas to Energy at Municipal Waste Water Treatment Works

A Toolkit for Municipalities to Assess the Potential at
Individual Plants



Presentation Notes

Imprint

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South African-German Energy Programme (GIZ-SAGEN)

GIZ office

333 Grosvenor Street

0028 Pretoria, South Africa

T +27 12 423 5900

F +27 12 423 6347

sagen@giz.de

www.giz.de/southafrica

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Björn Rothauge

Photo credits

Sofja Giljova: Cover (Fishwater Flats WWTW at Nelson Mandela Bay)

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For permissions to copy or distribute this document, please contact:

SALGA National Office

Telephone: (012) 639 8000

Fax: (012) 639 8001

PO Box 2094

Pretoria 0001

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Notes to Power Point Presentation

These notes serve as background information to the Power Point Presentation entitled “**BIOGAS TO ENERGY AT MUNICIPAL WASTE WATER TREATMENT WORKS - A TOOLKIT FOR MUNICIPALITIES TO ASSESS THE POTENTIAL AT INDIVIDUAL PLANTS**”

This presentation is aimed at assisting municipal officials to present the energy potential from biogas in their waste water treatment plant to other municipal departments and their management.

There is a substantial amount of information contained in these notes so it is suggested that the presenter reads through the notes to enable him/her to answer most of the questions that would potentially be posed during the presentation.



SECTION 1. What is Biogas?

SLIDE 3: WHAT IS BIOGAS?

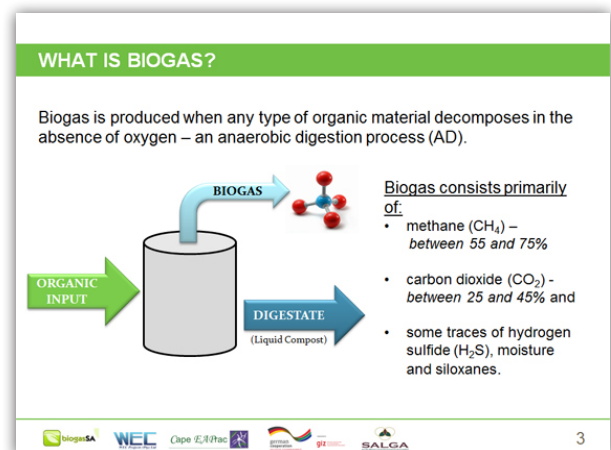
Biogas is produced when any type of organic material decomposes in the absence of oxygen, a process known as anaerobic digestion (AD in short).

The anaerobic microbes responsible for the AD process only live in conditions where there is no oxygen present. In fact, these microbes will die if exposed to oxygen. This is the reason why all biogas digester designs ensure airtight conditions to prevent any chance of these microbes coming into contact with oxygen.

AD is a naturally occurring process, the same process that occurs in the human stomach, where anaerobic microbes digest the food we ingest and creates gas as a waste product.

AD microbes digest organic waste and produces biogas as a waste product. Biogas contains methane (CH_4), which is a combustible gas.

Apart from methane (CH_4) (between 40%-70%), biogas



also contains carbon dioxide (CO_2) (30%-60%), as well as trace amounts of hydrogen sulphide (H_2S), moisture and siloxanes.

The AD process removes a substantial amount of harmful pathogens which essentially converts the waste directly into compost. A further advantage is that the microbes also destroy the volatile organic matter which contributes significantly to the odour associated with sewage sludge.

SLIDE 4: TYPICAL FEEDSTOCKS

A digester can be fed with basically any type of organic waste, from sewerage sludge, to agricultural waste (animal manure and grain/vegetable/fruit wastes), to industrial waste from food processing plants, breweries, abattoirs, etc.

Each type of waste will yield a specific quantity of biogas per unit weight – manure in general will produce around 60m³ biogas/tonne of waste, (60 cubic meters of biogas per tonne of waste) whereas fat based waste could yield more than 500m³/t.

WWTW sewerage could yield on average in the region of 35m³/t of sludge, which can be converted into approximately 70 kWh. The challenge at WWTW is to be able to get an accurate assessment of the actual quantity

TYPICAL FEEDSTOCKS (INPUT)

	Sewerage: domestic, municipal, schools, hotels, etc
	Food waste: domestic & industrial / commercial, incl. fats and oils
	Manure: pig, cattle - dairy or feedlot, chicken, etc
	Agricultural: vegetables, fruit, maize, sugar cane, etc
	Commercial: abattoirs, cheese factories, breweries, wine estates, processing plants, fruit & veg packaging plants, etc






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as well as quality of sludge that could be produced by the plant.

SLIDE 5: TYPICAL APPLICATIONS

Biogas can be used the same way as LPG or natural gas. Typical applications for biogas is as source of fuel for cooking stoves, space heating, hot water geysers, lights, to generate electricity through a biogas powered generator and can also be converted to be used as fuel for vehicles.

TYPICAL APPLICATIONS

Biogas is a combustible gas and can be utilized in the same way as LPG or Natural Gas.

Typical applications of biogas:



Cooking



Light



Hot water



Generate electricity and heat



Fuel for vehicles






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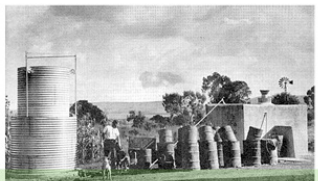
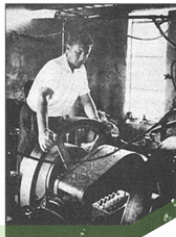
SLIDE 6: JOHN FRY

John Fry had a pig farm just south of Johannesburg and started producing biogas through very simple 45 gallon drums as digesters using pig manure to run his 6hp Lister engine way back in the early 1950's.

These photos appeared in the local Farmers Weekly in 1957. This illustrates that biogas is not a new technology.

South Africa was one of the first countries in the world to utilise biogas on a pig farm south of Johannesburg in the early 1950's

John Fry
BIOGAS PIONEER

Photograph appeared in a Farmers Weekly published in 1957!






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SLIDE 7: EXISTING DIGESTERS AT WWTW

South Africa was one of the first countries in the world to **utilise digesters as part of sludge management at WWTW**, with the first municipal digesters built as far back as 1940's! Even today we still have many WWTW with digesters that were built in the late 1970's and early 1980's.

Digesters at WWTW were however not built to capture and use the biogas produced, but rather to assist in sludge management. Indeed, the AD process removes some harmful pathogens, destroys volatile organic compounds, reduces the volume and improves the composting value of the sludge. It thus making it easier to get rid of as compost to agriculture and composting companies.

Most of the existing digesters at WWTW are however in various degrees of disrepair. Part of the capital required



for a potential biogas to energy plant will have to go towards the refurbishment of the existing digesters if it is proven that they are still sufficiently structurally sound. Should it not be feasible to refurbish, or if there are no existing digesters, then the project would have to make **provision for the construction of new digesters.**

SLIDE 8: COMMERCIAL SCALE DIGESTERS

South Africa has a number of commercial digesters. Some, like the specialised digester used by SA Breweries, was already built more than 12 years ago.

More recently, the first biogas plant at a WWTW was commissioned in 2012 at the Northern Works WWTW of Johannesburg Water. The first phase of the project was to refurbish 4 of the old digesters and then install 1.1MW of generating capacity. Combined heat and power (CHP) units are used in order to capture and utilise the thermal energy to heat the digesters which ensured higher AD efficiency and increased biogas yield (this is also called cogeneration – the simultaneous generation of electricity and heat).



A number of digester has also been built at abattoirs, pig farms and juice making factories.

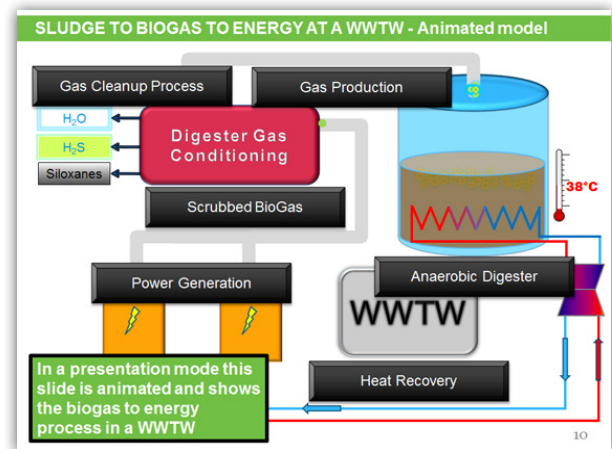
SECTION 2. Biogas to Energy at a WWTW

SLIDE 10: SLUDGE TO BIOGAS TO ENERGY AT A WWTW – Animated Model

In presentation mode, this slide is animated and will show how a digester would lead to the generation of electricity and heat.

This slide shows a typical schematic layout of a biogas to energy plant at a WWTW:

- i. **The digester:** where the sludge from the plant is digested and where biogas produced and captured
- ii. **Gas conditioning:** the gas has to be cleaned to remove undesirable components
- iii. **Biogas generator (CHP)** – converts the biogas into electricity and heat.
- iv. **Heat recovery:** the heat is used to heat the digesters, which in turn increases the amount of biogas produced



- v. **Digestate (effluent)** [not on the slide] – the AD process improves the quality of the sludge by removing harmful pathogens and making it more attractive for farmers and composting companies. It should however be noted that both farmers and composting companies will only be interested in dry sludge, so normal drying beds will still be required.

SLIDE 11: POTENTIAL BENEFITS OF A BIOGAS PLANT

Generation of electricity:

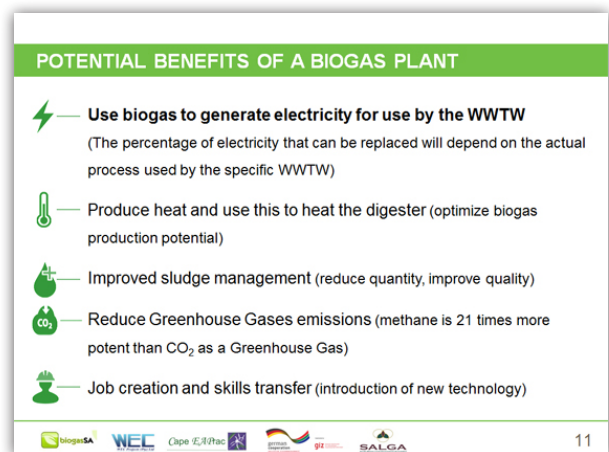
The biogas produced from digesting the sludge can be used as fuel to run a generator. The amount of biogas produced could potentially replace between 40 and 100% of the electricity requirements of the WWTW. The actual percentage will depend on the waste treatment processes used by each WWTW.

Capture free heat from the generator:

The generator installed could be in the form of a Combined Heat and Power (CHP) unit that generate heat at the same time it generates electricity. This heat will be available to heat the digester to optimise biogas production. For optimal microbial activity the digester temperature should be maintained at 37 degree Celsius.

Improve sludge management:

Digesting sludge in a digester will have the benefit of not only reducing the amount of harmful pathogens, but also reducing the actual volume of sludge (solids consumed by the microbes). The reduced pathogens will ensure less harmful substances with enhanced fertilizer qualities,



making it a lot more attractive to farmers and composting companies to be applied in agriculture.

Reduce Greenhouse gases emissions:

Methane is 21 times more harmful than carbon dioxide (CO₂) as a Greenhouse Gas (GHG). Preventing it from entering the atmosphere by burning it in a generator will play a significant role in reducing GHG emissions.

Job creation and skills transfer:

Building and operating a biogas plant will not only provide new job opportunities, but could also contribute to real time skills transfer.

SECTION 3. Assessment of Biogas to Energy Potential at a WWTW

SLIDE 13: BIOGAS POTENTIAL ASSESSMENT

The ultimate viability of a biogas waste to energy project at a WWTW **depends very strongly on the quantity and the quality (or composition) of the sludge** that is produced by the works. **The ultimate quantity of sludge produced will largely be determined by the process employed by each specific WWTW.** The basic premise is that the more sludge is available to be digested in the AD plant, the more electricity can be produced and the more financially viable the project will be.

GIZ, the German development cooperation agency, together with SALGA, appointed WEC Projects to develop a tool to assist municipalities in assessing the biogas potential in their WWTW.

BIOGAS POTENTIAL ASSESSMENT

The ultimate viability of establishing a cogeneration plant from biogas at a municipal WWTW is primarily dependant on the **quantity and quality** of sludge being produced by the works, which can then be used as feedstock for the biogas digester.

The quantity and quality in turn is highly dependant on the specific **treatment processes** used by each WWTW.

GIZ, SALGA and the service providers involved do not take any responsibility for the results of the tool. These results highly depend on the assumption and need to be verified through an in-depth assessment.


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The Tool requires basic input, mainly on WWTW processes in order to calculate biogas yield potential and thus ultimately the actual viability of establishing such a plant at the works.

SLIDE 14: WWTW PROCESSES

The specific process employed by the WWTW will give an indication of the quantity/quality of sludge that will be produced by the works. It should be noted that the primary function of a WWTW is to treat water, not to produce biogas.

More precisely the main purpose of a WWTW is to remove the Chemical Oxygen Demand (COD) or Biological Oxygen Demand (BOD). The BOD load depletes oxygen in the receiving water, thus creating an environment which cannot support a healthy aquatic ecosystem.

The higher the BOD/COD is, the higher the potential energy of the sewage is.

Sewage treatment

Sewage can be treated aerobically or anaerobically. **Aerobic treatments** use energy as an input to treat and stabilise

WWTW PROCESS



Each WWTW employs a different treatment process:

- ✓ each process produces different quantities and quality of sludge
- ✓ each process has specific electricity needs

Lower electricity needs		Plants with PST's (Primary settling tanks)		Higher sludge potential
⚡			💧💧💧💧	
⚡⚡		Trickling plant	💧💧💧	
⚡⚡⚡		BNR (Biological Nutrient Removal)	💧💧	
⚡⚡⚡⚡		Activated sludge	💧	
⚡⚡⚡⚡⚡		Extended aeration	💧	Lower sludge potential

Other factors influencing biogas yields:

- Retention time
- Volatile solids (VSS)
- Operating capacity


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sewage. On the other hand, **anaerobic processes** can generate energy because methane is produced during the treatment process. Most of the newer larger municipal plants utilise both aerobic and anaerobic process step to optimise unit treatment cost while facilitating a compliant effluent quality.

The main sewage treatment steps can be categorised into the following sequences:

Treatment steps with main impact on biogas production			
Preliminary treatment	Primary treatment	Secondary treatment	Tertiary treatment
Screening	Anaerobic ponds	Oxidation ponds	Chemical precipitation
De-gritting	Primary settling tank	Trickling filter	Filtration
etc.	Septic tank	Rotating biological contactor	Disinfection
	etc.	Activated sludge	etc.
		MBR	
		etc.	

Primary sludge has the highest nutrient content and thus the highest biogas potential. Primary sludge from Primary Settling Tanks (PSTs) is the best source of sludge for digestion and biogas generation. Humus sludge from trickling plants has fewer nutrients than primary sludge. **Secondary sludge or Waste Activated Sludge (WAS) is more stabilised than primary sludge and would therefore produce less biogas per unit mass of sludge.**

Typical processes found at most WWTW in South Africa are as follows:

- Trickling plant
- Plants with PST's (Primary settling tanks)
- BNR (Biological Nutrient Removal)
- Extended aeration
- Activated sludge

Extended aeration and activated sludge plants thus have the lowest biogas potential but also the highest energy requirement. Conversely trickling plants use considerably less electricity and thus show the highest energy potential per kilowatt of installed capacity.

Other factors also influencing biogas potential are:

- Retention time – the longer the sludge remains in the works before it is extracted, the lower the biogas potential as more methane is lost in the process.
- Volatile solids (VS) – the percentage of volatile solids in the sludge will give a clear indication of the biogas potential
- Flow Capacity of the WWTW – the closer to capacity the works operates at, the shorter the potential retention time and thus the lower the biogas yield. From a biogas generation point of view, it is therefore better the closer to capacity the works operate at.

SLIDE 15: BIOGAS POTENTIAL ASSESSMENT

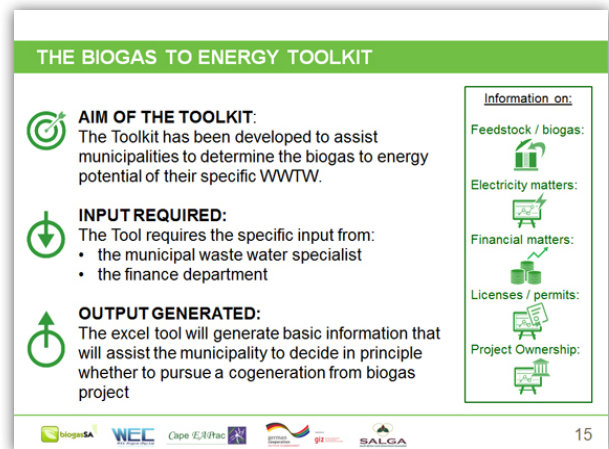
Aim of the Toolkit:

The Toolkit has been developed to assist municipalities to determine the biogas potential of their specific WWTW. The results generated by the Toolkit, provided the input is correct, will provide information equivalent to a **high level pre-feasibility study**. This will enable the municipality to decide whether they should appoint consultants to further study such a biogas project.

Input required:

The Tool requires the specific input from:

- **the municipal waste water specialist** to provide the correct information required around the processes used by the works
- **the finance department** to provide the necessary information related to funding



Output generated:

The excel tool will generate basic information that will assist the municipality to decide in principle whether to pursue a biogas project.

The toolkit (excel tool + notes) provides specific information on:



Feedstock / biogas

How much biogas can be produced? (in the excel toolkit)



Electricity matters

How much electricity can be generated? How much will be saved? (in the excel toolkit)



Financial matters

How much will it cost (CAPEX and operational costs)? (in the excel toolkit)



Licenses / permits

High level information on licenses needed (in these notes)



Project Ownership

Possible and preferred project structure (in these notes)

SECTION 4. Licensing and Regulatory Framework

SLIDE 17: LICENSING AND AUTHORISATIONS

Building a biogas plant could potentially trigger the need for several licenses and authorisations. These will depend on the specific WWTW and on the specificities of the plant to be built.

The following key Acts should be prioritised:

- National Environmental Management Act (NEMA)
- National Environmental Management Waste Act (NEMWA)
- National Environmental Management Air Quality Act (NEMAQA)
- National Water Act (NWA)

The responsibility lies with the Municipality to verify the need for any license / authorisation or permit that may be required. The municipality can transfer these tasks to the service provider appointed to build and operate the plant.

In general, the necessary approvals for the WWTW need to be valid and to include the digesters. The approvals are commonly:

- a Water Use License (WULA) – discharge permit for treated effluent,
- a Waste Management License (WML) – for treatment of waste in biogas digester,
- an Environmental Authorisation (EA) for original construction / operation of the WWTW

LICENSES AND AUTHORISATIONS:



- The authorisations required (depending on size and location of the project):
 - Environmental Authorisation (EA)
 - Water Use License (WULA) or General Authorisation (GA)
 - Air Emissions License (AEL)
- Existing WWTW must be lawful i.e. have the necessary approvals / licenses / permits to operate
- The relevant **Acts are amended on a continuous basis**
- The need for specific licenses and authorisation is triggered by project and waste amounts. Each project will require different licenses.






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- an Air Emissions License AEL, if any flaring occurs at the facility.

If existing digesters are to be expanded or if (new) digesters are to be built, then new approvals might be needed (consult with Department of Water Affairs).

It should be noted that according to Schedule 3 of NEMWA (dated 2 June 2014), Listing 1 categorises sewage as 'hazardous' waste as such attracts a number of regulations that needs to be considered.

Changes to a permit that govern the release of emissions or pollution e.g. sewage sludge treatment (i.e. refurbishing a digester at a WWTW that was decommissioned previously) requires prior authorisation from the Department of Water Affairs.

SECTION 5. Results of the Biogas Potential Assessment Tool

SLIDES 19 - 24: RESULTS OF THE BIOGAS POTENTIAL ASSESSMENT TOOL

These slides aim to present the results of the tool specifically for your WWTW. They summarise both the main assumptions and the results.

They can be adapted based on the audience and objective of the presentation. The results of the excel tool can be copied / pasted here to replace the specimen results presented in the generic power point.

RESULTS OF THE BIOGAS POTENTIAL ASSESSMENT TOOL

MAIN TECHNICAL ASSUMPTIONS:

- Number of modules: *xx modules*
- Total installed capacity: *xxx Ml/day* - Current inflow: *xxx Ml/day*
- Main processes used:
- Sludge management processes:
(and any current challenges with sludge if any):
- Existing operational digesters: *xxx digesters (not) heated / (not) mixed*
- Electricity consumption (in kWh and/or Rands): *xxx kWh/month or xxx rands/months*

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RESULTS OF THE BIOGAS POTENTIAL ASSESSMENT TOOL

FLOW DIAGRAM

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RESULTS OF THE BIOGAS POTENTIAL ASSESSMENT TOOL

RESULTS FROM THE PREVIOUS FLOW DIAGRAM

- A biogas plant could results in electricity saving of *XXXXX KWh/day (or per month or per year)*
- This could lead to savings of *XXXXXX rands/year (using average electricity price)*
- The installed capacity of the engine could be *XXX kW*
- Sludge production can be reduced by *XXX tons of dry solid / day*

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RESULTS OF THE BIOGAS POTENTIAL ASSESSMENT TOOL

ELECTRICITY GENERATION RESULTS

- The results show that:
 - the overall cost to generate electricity from biogas is *HIGHER / LOWER* than buying electricity from *Eskom / the municipality*
 - A biogas plant could generate up to *XX %* of the electricity requirement of the plant (with maximum inflow)

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RESULTS OF THE BIOGAS POTENTIAL ASSESSMENT TOOL

MAIN FINANCIAL RESULTS

Total Capex	R	19,166,667	Rand Value
Municipal Funding	R	1,916,667	10%
Working Capital Requirement (Overdraft)	R	-1,506,883	Rand Value
Loan Repayment Period			Prime -2.0%
Year 1 cost per kWh - Utility (weighted)		40.73	c/kWh
Year 1 cost per kWh - CHP Plant (incl. cost of gas)		40.73	c/kWh
Escalation		6%	
Project useful lifespan		15 years	
Equity repayment period		8 years	
Income Tax Rate		0%	
Total Project Savings over Project Life	R	41,888,565.27	

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RESULTS OF THE BIOGAS POTENTIAL ASSESSMENT TOOL

MAIN FINANCIAL RESULTS

- Total investment costs: *xxx million Rands*
- Total operational cost: *xxx Rands/month*
- Average electricity price currently paid by the WWTW: *xxx c/kWh*
- Average electricity price from CHP engines: *xxx c/kWh*
- Total project savings over project life: *xxx million Rands*
- Repayment period (payback period): *xx years*

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SECTION 6. Recommendations and Way Forward

SLIDE 26: RECOMMENDED BUSINESS MODEL

It is recommended (to save time and money) that the municipality retains full ownership of the plant. Service provider should be appointed to design, build, manage and operate the plant.

RECOMMENDED BUSINESS MODEL


Because of the project size and in order to save time and complicated contractual issues, a successful business model has been found to be:

- Full ownership of the plant by the municipality
- Investment by the municipality
- Appointment, through competitive tender, of a service provider to design, build, manage and operate the plant for a period of 7 – 10 years







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SLIDE 27: CONCLUSION AND WAY FORWARD

It is important to note that **this tool can only assist with a high level evaluation**. Should the municipality decide to further investigate the project, they should **appoint a service provider to verify the data and assist with tender documents**. It is also recommended to contact municipalities with existing biogas projects to use their procurement documents and contracts to save resources.

WAY FORWARD


- This is just a high level evaluation
- Should a decision be taken for the project, an in-depth study should be conducted to:
 - Confirm these results
 - Identify additional opportunities and optimisation options which could lead to higher biogas potential
 - Prepare the tender documents
 - Secure funding







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Do not hesitate to contact GIZ or SALGA for more information (and for an updated list of existing municipal projects).

For GIZ:

Contact: Sofja Giljova

Cell: 012 423 5900

Email: sofja.giljova@giz.de or sagen@giz.de

For SALGA:

Contact: Aurelie Ferry

Cell: 012 369 8000

Email: aferry@salga.org.za