



Development of a “Capable Plant Model” for Anaerobic Digestion

Marlene vd Merwe-Botha

3rd National Biogas Conference, DBSA, 1-3 November 2017



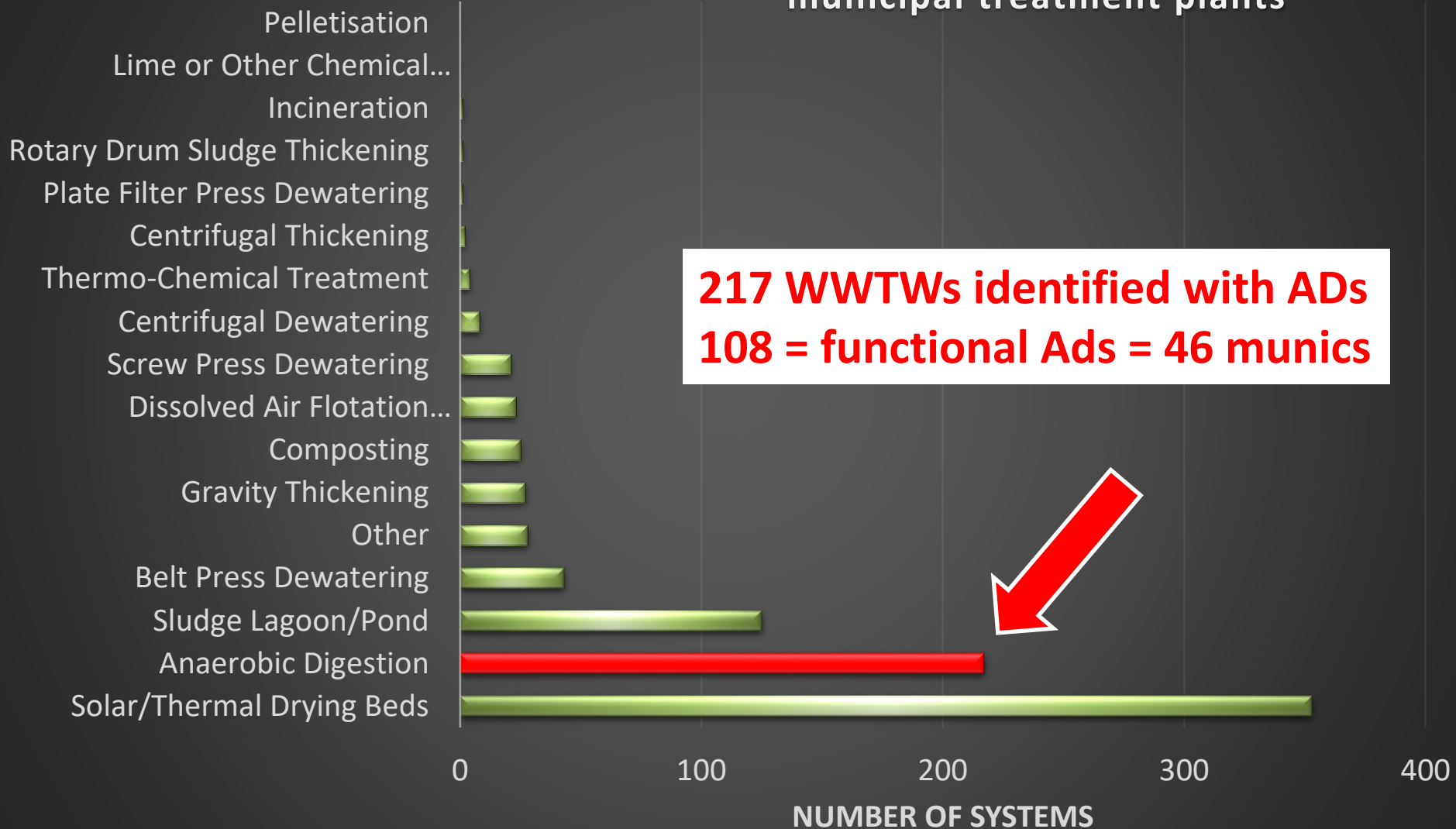
Presentation Outline

- The status of anaerobic digestion in South Africa
- A Capable Plant Model for Anaerobic Digesters
- Development of a Guideline Manual
- Modules 1 – 10
 - Self Assessment / Masterclass
 - Inspection Guideline for Process Controllers
 - PFD - Councillors
- Way forward



Solids treatment technology: status 2015/16

Wastewater sludge treatment technologies at municipal treatment plants





2016-17: DoE&GIZ Scoping Studies



108 ADs - Operational status

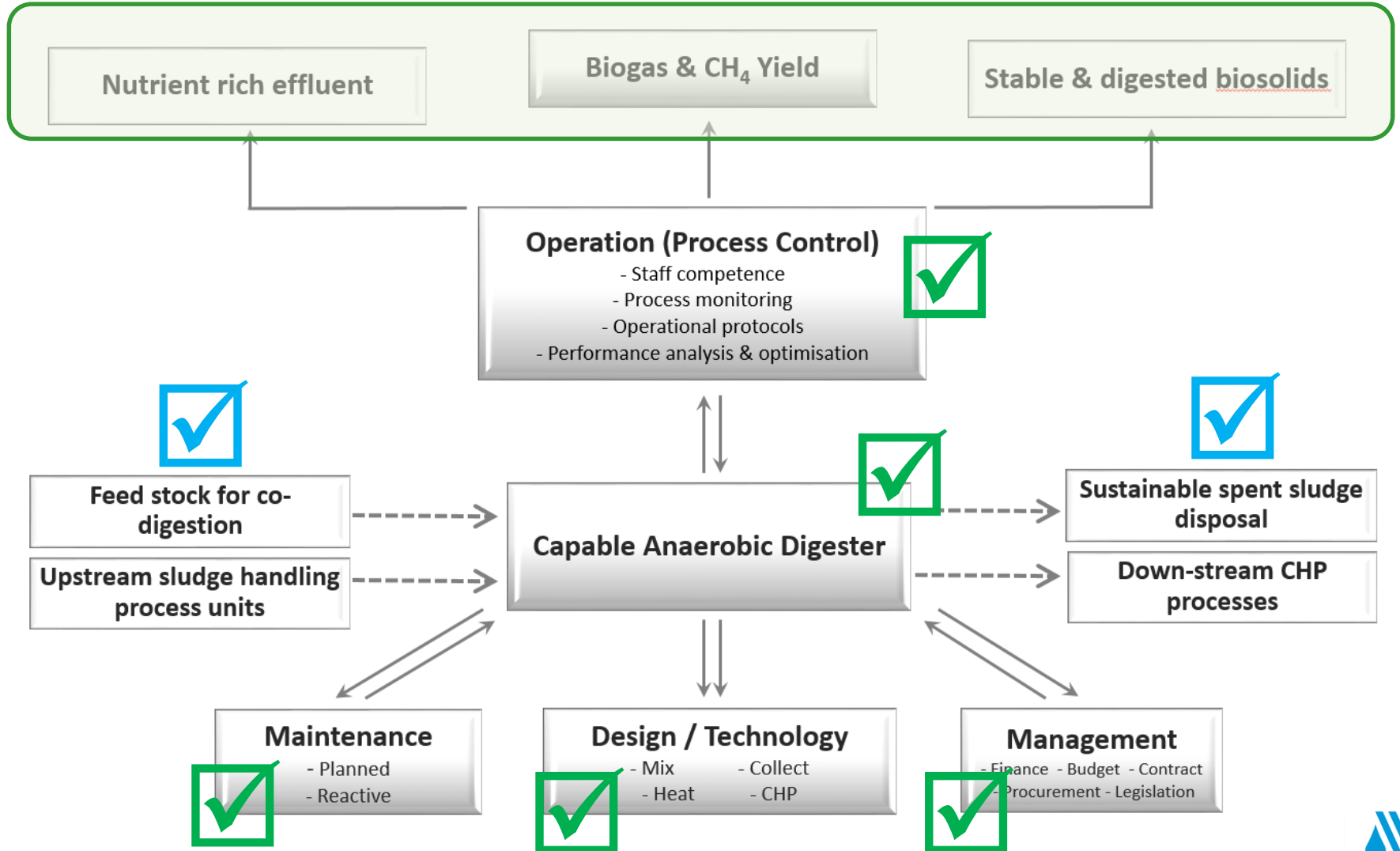
MIX	54%
HEAT	34%
COLLECT	95%
USE BIOGAS	<15%
PLAN to USE	>80%
FLARE	<2%

Most plants do:

- ✓ Hydraulic loading
- ✓ Organic loading – COD, SS, P and N
- ✓ Electricity demand
- ✓ Electricity projection
- ✓ *Liquids treatment performance*

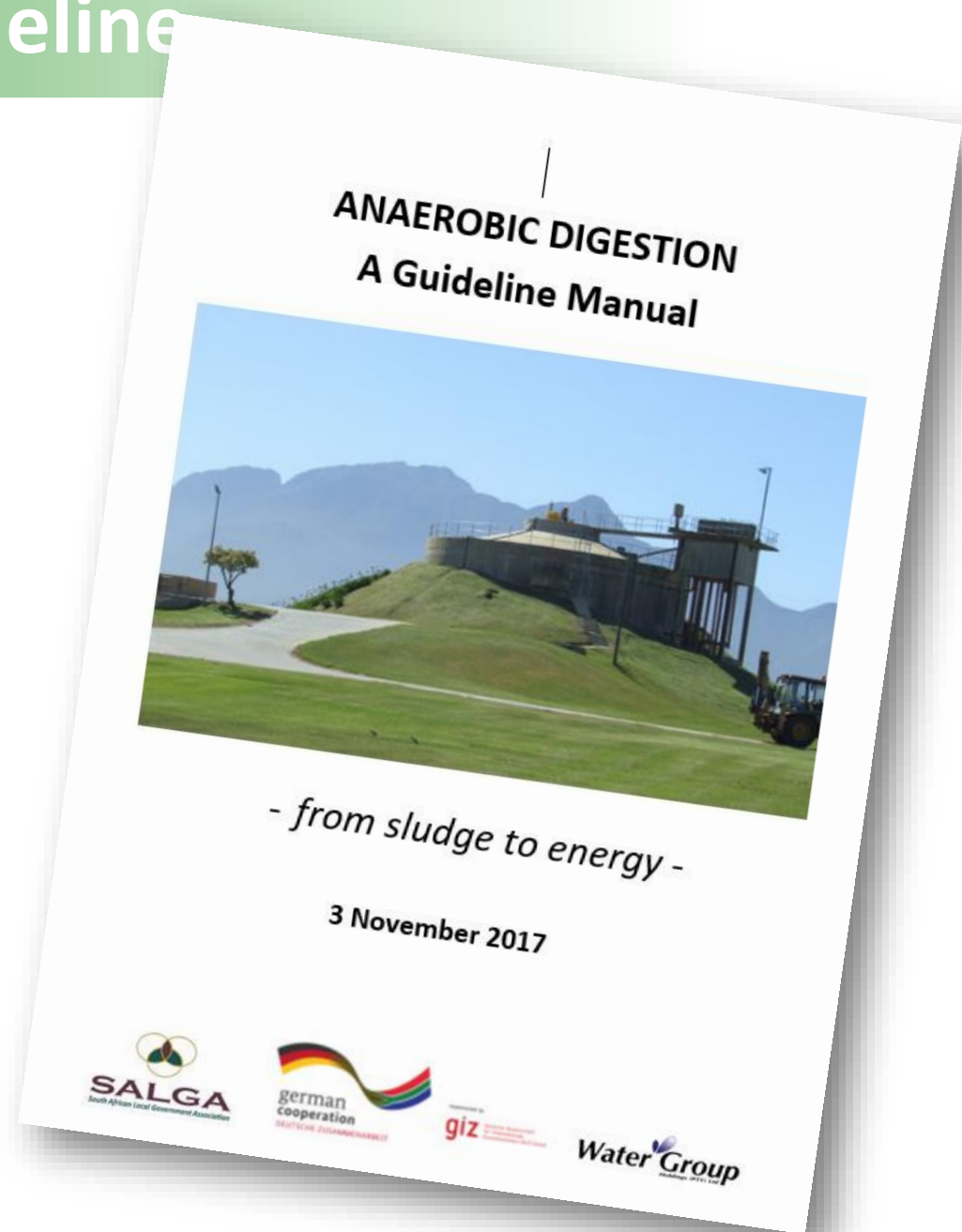
Most plants don't:

- ✗ Settled COD and SS
- ✗ TS, VS, VS reduction
- ✗ Temperature
- ✗ HRT, VS loading
- ✗ Alkalinity, VA, VFA/Alk
- ✗ Biogas production rate
- ✗ Biogas composition
- ✗ *Sludge treatment performance*



Development of Guideline

- Process Controllers
- Managers
- Decision makers
- Wastewater Practitioners



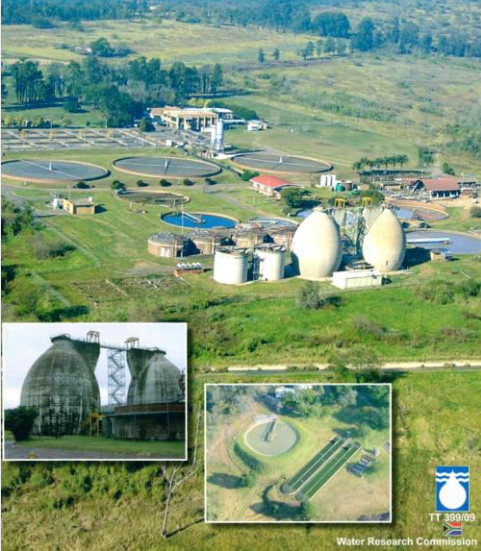
Objective of Guideline

- Raise the capacity of Process Controllers who are responsible for the sustainable operation of anaerobic digesters and optimised performance of biogas production
- ✓ Create awareness within the municipal sector that wastewater sludge and biogas are valuable resources
- ✓ Promote sustainable sludge management & energy recovery in municipalities
- ✓ Build competency in the water sector to manage and operate sludge treatment processes
- ✓ Identify opportunities for municipal uptake and private sector involvement

Energy From Wastewater – A Feasibility Study

ESSENCE REPORT

S Burton, B Cohen, S Harrison, S Pather-Elias,
W Stafford, R van Hille & H von Blottnitz



Energy Efficiency in the South African Water Industry:

A COMPENDIUM OF BEST PRACTICES AND CASE STUDIES

GD Swartz, M van der Merwe-Botha & SD Freese



PROUDLY
SOUTH AFRICAN



Guiding Principles in the Design and Operation of a Wastewater Sludge Digestion Plant with Biogas and Power Generation

Marlene vd Merwe-Botha, Karl Juncker, André Visser, Robert Boyd

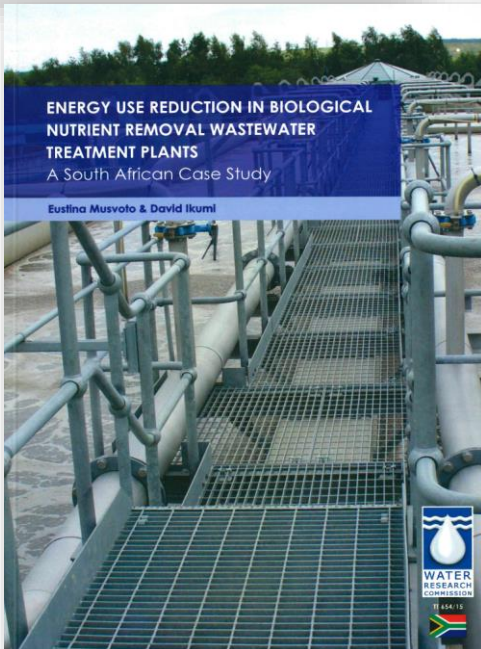


Guiding Principles in the Design and Operation of a Wastewater Sludge Digestion Plant with Biogas and Power Generation

ENERGY USE REDUCTION IN BIOLOGICAL NUTRIENT REMOVAL WASTEWATER TREATMENT PLANTS

A South African Case Study

Eustina Musvoto & David Ikum



german cooperation
DEUTSCHE ZUSAMMENARBEIT

giz

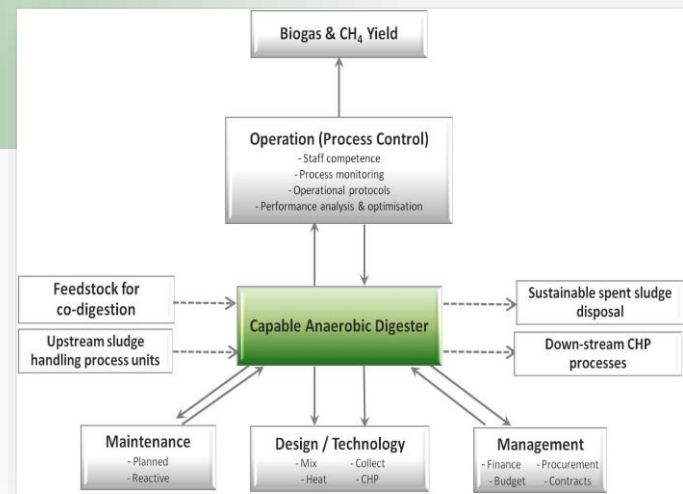


Biogas Potential

A Survey of South African Wastewater Treatment Works

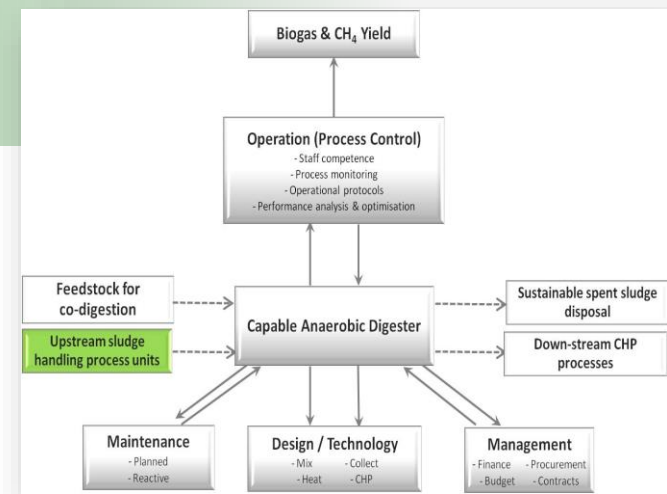
Module 1: Anaerobic Digestion

MODULE 1: ANAEROBIC DIGESTION
1 OBJECTIVES OF ANAEROBIC DIGESTION MODULE
2 ADVANTAGES OF ANAEROBIC DIGESTION
3 ANAEROBIC DIGESTION MICROBIOLOGY
4 CLIMATE CHANGE MITIGATION
5 TYPES OF ANAEROBIC DIGESTER SYSTEMS
6 PROCESS FUNDAMENTALS.....
6.1 SOLIDS AND HYDRAULIC RETENTION TIME.....
6.2 TEMPERATURE.....
6.3 PH VALUE
6.4 ALKALINITY
6.5 SLUDGE FEED
6.6 MIXING.....
6.7 ANAEROBIC CONDITIONS
7 FURTHER READING



Module 2: Upstream raw sludge mngt

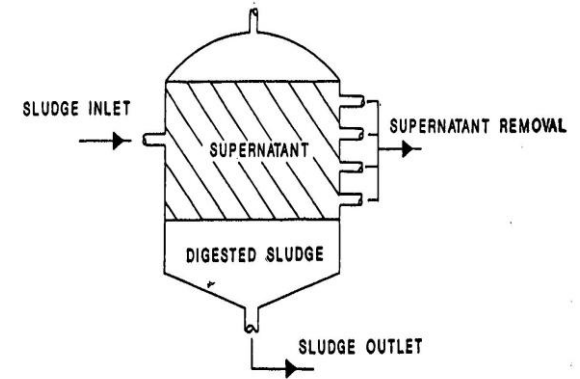
MODULE 2: UPSTREAM RAW SLUDGE MANAGEMENT
1 OBJECTIVES OF UPSTREAM RAW SLUDGE MANAGEMENT MODULE
2 SLUDGE TYPES.....
2.1 PRIMARY SLUDGE.....
2.2 HUMUS TANK SLUDGE
2.3 WASTE ACTIVATED SLUDGE.....
3 PRIMARY SEDIMENTATION
3.1 PRIMARY SEDIMENTATION TANK PERFORMANCE INDICATORS.....
3.2 DESLUDGING PROGRAMME
3.3 TROUBLESHOOTING THE PST
3.4 OPERATIONAL PROCEDURES
4 SECONDARY SEDIMENTATION
4.1 HUMUS TANKS
4.2 CLARIFIERS
5 SLUDGE THICKENING
5.1 SLUDGE GRAVITY THICKENER PERFORMANCE INDICATORS.....
6 FURTHER READING



Indicators



The ratio of volatile acids to alkalinity should be < 0.3

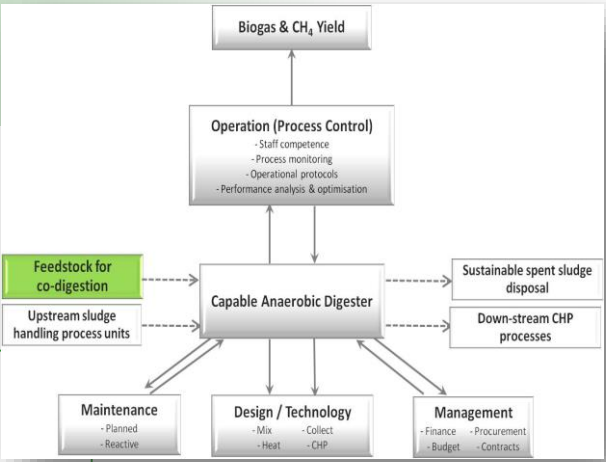


$$E=mc^2$$



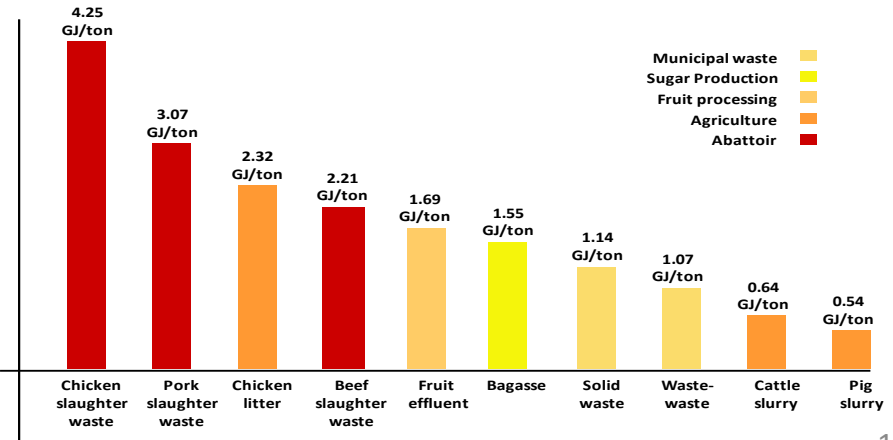
**OPERATION
RED ALERT**

Module 3: Co-digestion

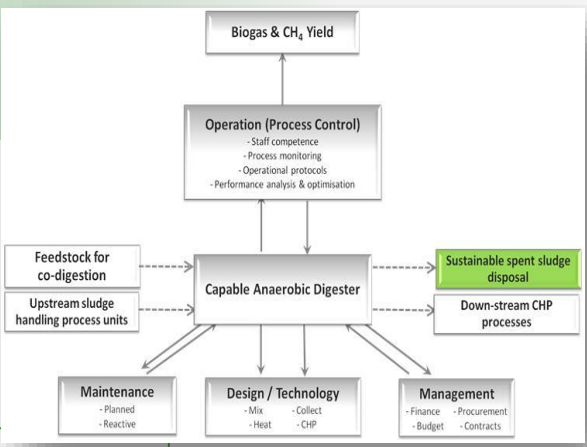


MODULE 3: CO-DIGESTION.....

- 1 OBJECTIVES OF THE CO-DIGESTION MODULE.....
- 2 BENEFITS OF CO-DIGESTION
- 3 IMPORTANT ISSUES TO CONSIDER FOR CO-DIGESTION ...
- 4 DRIVERS FOR CO-DIGESTION
- 5 FURTHER READING



Module 4: Down stream sludge mgnt



MODULE 4: DOWNSTREAM FINAL SLUDGE MANAGEMENT

1 OBJECTIVES OF DOWNSTREAM FINAL SLUDGE MANAGEMENT MODULE .

2 SLUDGE CLASSIFICATION

3 SLUDGE DEWATERING

3.1 DRYING BEDS

3.1.1 *Drying Bed Design Principles*.....

3.1.2 ROUTINE MAINTENANCE AND PROCESS OPTIMISATION

3.1.3 *Troubleshooting*

3.2 BELT PRESS FILTRATION

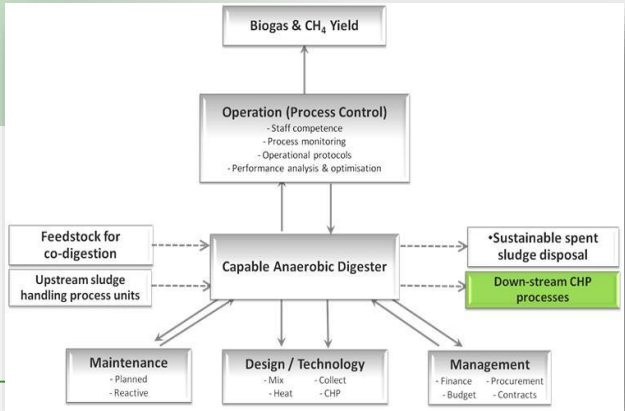
3.2.1 *Routine Maintenance and Process Optimisation*.....

3.2.2 *Troubleshooting*

4 FURTHER READING



Module 5: Biogas to CHP

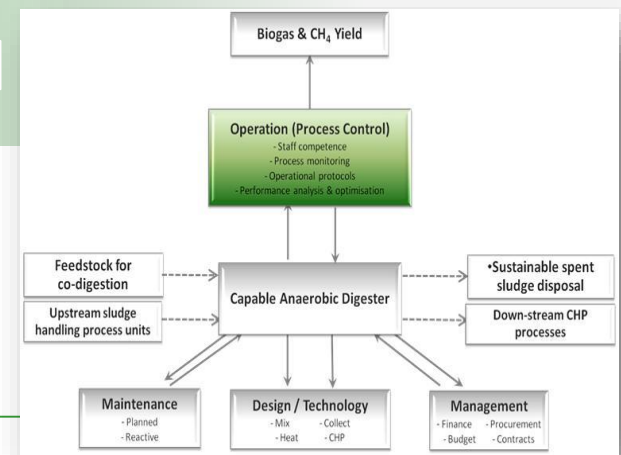


MODULE 5: BIOGAS TO COMBINED HEAT AND POWER PRODUCTION.....

- 1 OBJECTIVES OF THE COMBINED HEAT AND POWER PRODUCTION M.....
- 2 INTRODUCTION TO CHP SYSTEM
- 2.1 GAS PRE-TREATMENT
- 2.1.1 *Moisture*.....
- 2.1.2 *Hydrogen Sulphide*
- 2.1.3 *Siloxanes*
- 3 TOOLKIT FOR MUNICIPALITIES TO ASSESS THE POTENTIAL AT INDIVIDUAL PLANTS ...
- 4 CALCULATIONS.....
- 5 FURTHER READING



Module 6: Operations & Process Control



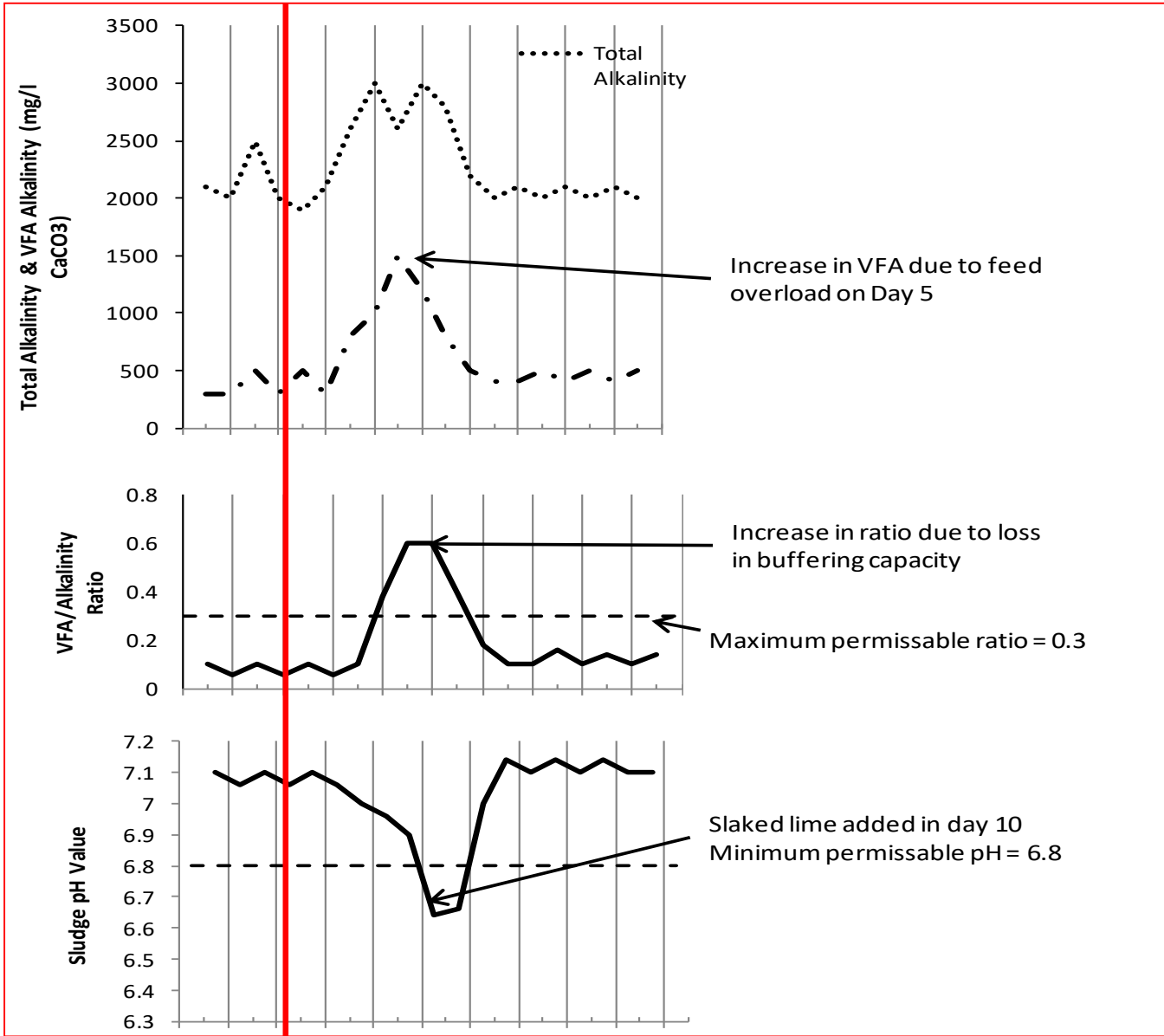
MODULE 6: OPERATIONS AND PROCESS CONTROL.....

- 1 OBJECTIVES OF THE OPERATIONS AND PROCESS CONTROL MODULE
- 2 STAFFING LEVELS
- 3 PROCESS MONITORING.....
 - 3.1 ANAEROBIC DIGESTION PROCESS CONTROL INDICATORS
 - 3.1.1 *Volatile Acids*.....
 - 3.1.2 *Alkalinity*
 - 3.1.3 *Volatile Acids to Total Alkalinity Ratio*
 - 3.1.4 *pH Value*.....
 - 3.1.5 *Biogas Production Rate*
 - 3.1.6 *Carbon Dioxide Content of Biogas*.....
 - 3.1.7 *Volatile Solids Reduction*.....
 - 3.1.8 *Sensory Evaluation*
 - 3.1.9 *Typical Digester Performance Criteria*

Module 6: Operations & Process Control

4	DIGESTER OPERATION.....
4.1	TEMPERATURE CONTROL
4.2	SUPERNATANT AND SLUDGE WITHDRAWAL.....
4.2.1	<i>Supernatant Withdrawal</i>
4.2.2	<i>Sludge Withdrawal</i>
4.3	BIOGAS HANDLING SYSTEM.....
4.3.1	<i>Biogas System Safety Considerations</i>
4.4	PH ADJUSTMENT USING CHEMICALS
4.5	SCUM AND FOAM FORMATION AND CONTROL.....
4.5.1	<i>Scum Control</i>
4.5.2	<i>Foam Control</i>
4.6	TOXICITY CONTROL
5	DIGESTER SHUT DOWN
5.1	INTERRUPTION OF DIGESTER OPERATION.....
5.2	PROCEDURES TO SHUT DOWN THE DIGESTER
5.3	PROCEDURES TO CLEAN A DIGESTER
5.4	PROCEDURES TO START UP THE DIGESTER.....
5.5	FEEDING SCHEDULE TO CONTROL LOADING.....
6	TROUBLESHOOTING
7	OPERATIONAL RECORDS
7.1	GRAPHICAL RECORDING OF ANAEROBIC DIGESTION PROCESS CONTROL INDICATORS

Module 6: Graphical recordings

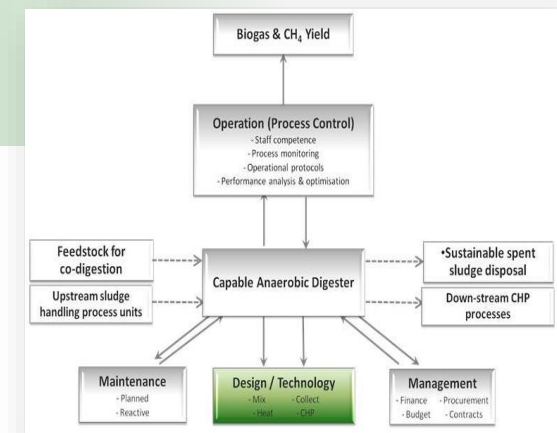


7-Nov-17

Parameters		Typical Concentration or Range
Feed Sludge:	Total solids	5%
	Volatile solids	4.2%
	% volatile solids of TS	84%
Digested Sludge:	Total solids	2.5%
	Volatile solids	1.7%
	% volatile solids of TS	68%
Volatile Solids reduction		40 – 60%
Digester Loading:	High	1.5 – 3.0 kgVS/m ³ /d
Standard rate		0.5 – 1.4 kgVS/m ³ /d
Hydraulic Retention Time:	High	15 – 25 days
Standard rate		30 – 60 days
Temperature of Mesophilic Digester:		32 - 37°C
Thermophilic		55 - 65°C
Mixing of Digester:		Once per 24 hours
Turnover rate		
Power input		5 – 10 w/m ³
Biogas Production Rate		1m ³ biogas/kgVS destroyed
Biogas Composition:		50 – 75%
Methane		
Carbon dioxide		25 – 40%
Colour of flame		Yellow flame with blue at base
Volatile Fatty Acid:	Digester liquor	50 – 300 mg/l
Total Alkalinity:		2,000 – 3,000 mg/l
Ratio VFA:Total Alkalinity:	Digester liquor	Less than 0.3
pH Value:	Digester liquor	7.0 – 7.5
C:N:P:S ratio	Digester liquor	500 – 600:15:5:3

Problem	Probable Cause	Action
A rise in the volatile to alkalinity ratio to 0.3	a) Hydraulic overload caused by accidental pumping b) Organic overload due to septic tank sludge discharged to plant c) Discharge of toxic materials due to industrial wastes	a) Decrease sludge withdrawal rate to keep sludge in digester b) Decrease feeding c) Add seed sludge from secondary digester d) Liquid dilution
pH value starts to drop and CO ₂ increases above 45% so no burnable gas is obtained	Severe organic overload over a period of time so that the VA:ALK ratio has increased above 0.8	a) Add alkalinity by addition of chemicals b) Decrease digester loading
Supernatant has a sour odour	Digester pH is too low	a) Add alkalinity by addition of chemicals b) Decrease digester loading
Digester temperature is falling and cannot be maintained above normal level	a) Sludge is blocking external heat exchanger b) Feed solids concentration is too low and not sufficient biogas is being generated	a) Open heat exchanger and clean b) B) Thicken feed solids
Scum blanket is too thick	a) Lack of mixing b) High grease content	a) Break up blanket by using mixers b) B) Check grease removal mechanism at PST and gravity thickener
Gas is leaking through pressure relief valve on digester roof	Valve is not seating properly or is stuck open	Remove valve cover and rotate weight holder until it seats properly; Install new ring is needed
Flare is not firing on biogas	a) Low gas pressure b) Low methane content c) Pilot flame out d) Excess water in lines	a) Check for leaks in system and repair b) Check methane content of gas c) Relight according to standard procedure d) Drain lines and water traps
Excessive noise in gearbox of mechanical mixer	a) Lack of proper lubrication b) Misalignment of equipment c) Unit worn	a) Lubricate as per manual b) B) Check alignment c) C) Check for wear

Module 7: Design & Technology



MODULE 7: DESIGN/TECHNOLOGY

1 OBJECTIVES OF THE DESIGN/TECHNOLOGY MODULE ...

2 ANAEROBIC DIGESTION DESIGN PRINCIPLES

2.1 TANK DESIGN

2.2 MIXING SYSTEM.....

2.3 HEATING

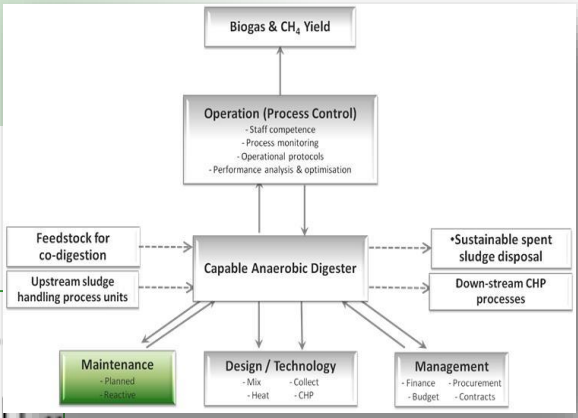
2.4 SLUDGE PRE-CONDITIONING

2.5 STRUVITE RECOVERY.....

2.6 COST BENEFIT ANALYSIS

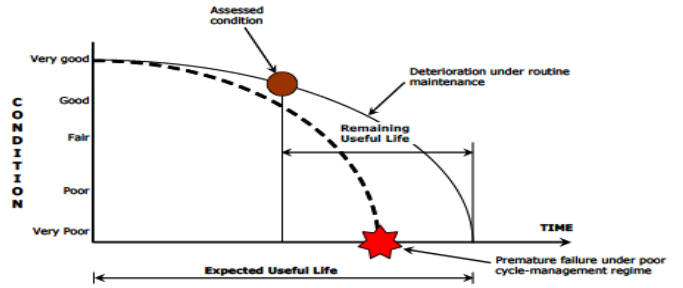
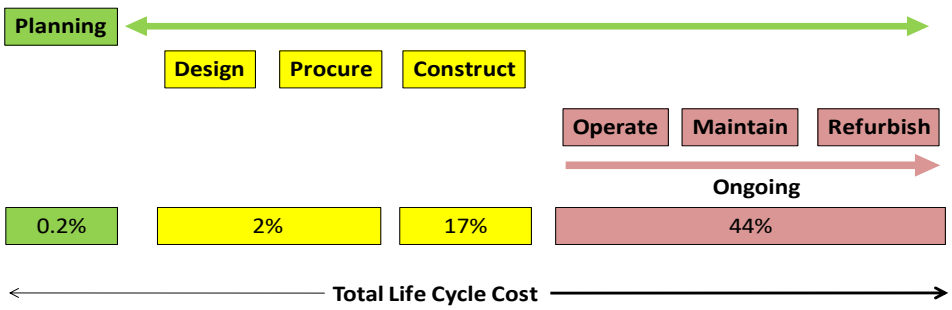
3 FURTHER READING

Module 8: Asset management (Maint)



MODULE 8: ASSET MANAGEMENT (MAINTENANCE)

- 1 OBJECTIVES OF THE ASSET MANAGEMENT (MAINTENANCE) MODULE
- 2 ASSET MANAGEMENT PRINCIPLES
- 3 ASSET REGISTER
- 4 ASSET REPLACEMENT PROGRAMME
- 5 MAINTENANCE PROGRAMMES
- 5.1 SCHEDULED MAINTENANCE PROGRAMME
- 5.2 REACTIVE MAINTENANCE
- 6 FURTHER READING



Module 9: Management

MODULE 9: MANAGEMENT

1 OBJECTIVES OF THE MANAGEMENT MODULE

2 LEGISLATIVE FRAMEWORK

- 2.1 ENVIRONMENTAL AUTHORISATION FOR ESTABLISHMENT, CONSTRUCTION AND/OR UPGRADING
- 2.2 WASTE LICENCE
- 2.3 ATMOSPHERIC EMISSION LICENCE
- 2.4 WATER USE AUTHORISATION
- 2.5 INSTITUTIONAL ARRANGEMENTS FOR OPERATION OF WASTEWATER TREATMENT PLANT
- 2.6 BENEFICIAL USE OF DIGESTED SLUDGE
- 2.7 GREEN DROP CERTIFICATION
- 2.8 INTEGRATED DEVELOPMENT PLAN
- 2.9 WATER SERVICE DEVELOPMENT PLAN
- 2.10 MUNICIPAL BYLAWS
- 2.11 BIOGAS TO ENERGY REGISTRATION/LICENSING

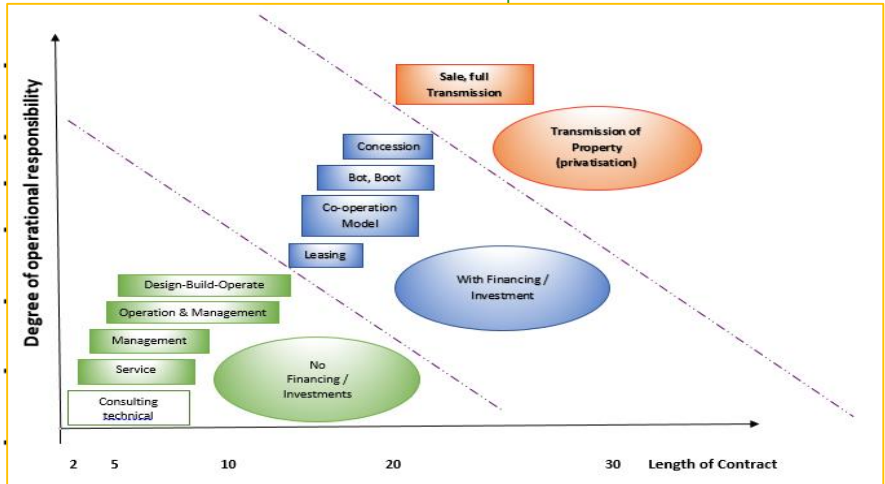
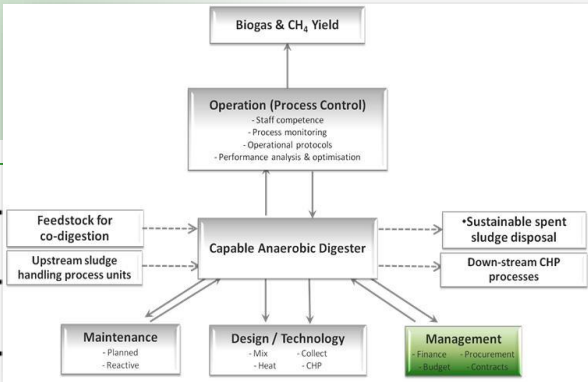
3 BUSINESS MODELS

- 3.1 CHP DECISION PROCESS
- 3.2 FINANCING MODELS
- 3.3 CONTRACT MANAGEMENT

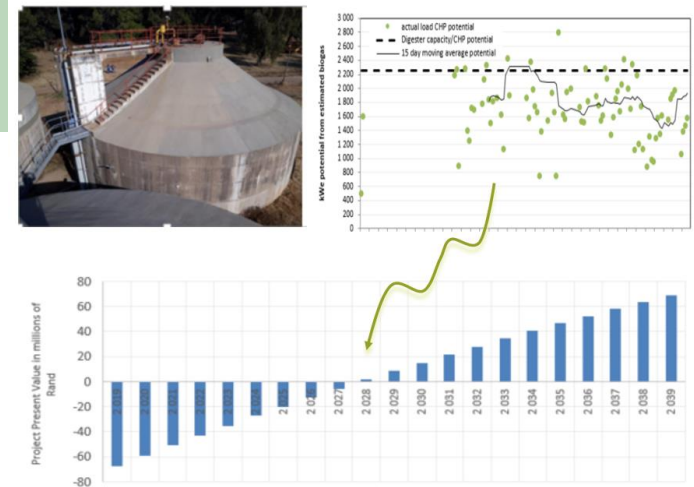
4 BUDGET ALLOCATION

5 HUMAN RESOURCES POLICIES

6 FURTHER READING



Module 10: BtEnergy Opportunities



MODULE 10: BIOGAS TO ENERGY OPPORTUNITIES.....

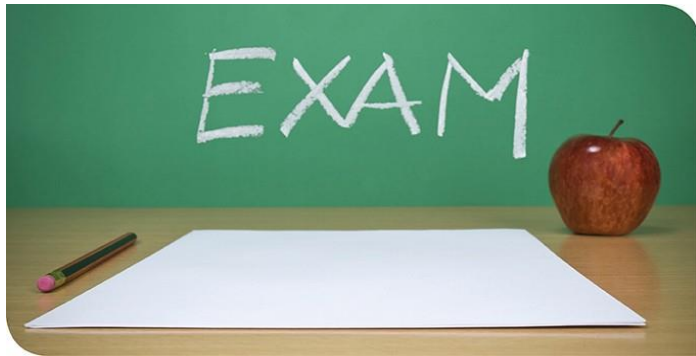
- 1 OBJECTIVES OF THE BIOGAS TO ENERGY OPPORTUNITIES MODULE ..
- 2 BIOGAS POTENTIAL.....
- 3 OPPORTUNITY COSTS.....
 - 3.1 FEEDSTOCKS
 - 3.2 ENERGY SAVINGS
 - 3.3 LANDFILL COST SAVING
 - 3.4 CO-DIGESTION FEEDSTOCK GATE FEE
 - 3.5 BY-PRODUCT USE.....
 - 3.6 GHG EMISSION REDUCTIONS.....
 - 3.7 SOCIO CO-BENEFITS

Annexures

ANNEXURE 1: SELF ASSESSMENT QUESTIONNAIRE.....	98
ANNEXURE 2: BIOGAS TO CHP EVALUATION TOOL.....	121
ANNEXURE 3:STANDARD OPERATING PROCEDURE FOR ANAEROBIC DIGESTION	125
ANNEXURE 4: GREEN FUNDING OPPORTUNITIES.....	132
ANNEXURE 5: EXAMPLE OF SAQA UNIT STANDARD ON THE OPERATION OF AN ANAEROBIC DIGESTER.....	133
ANNEXURE 6: CHECKLIST FOR THE INSPECTION OF AN ANAEROBIC DIGESTION SYSTEM	136

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ANNEXURE 5: EXAMPLE OF SAQA UNIT STANDARD ON THE OPERATION OF AN ANAEROBIC DIGESTER.....	133

Self Assessment, Masterclass, SAQA

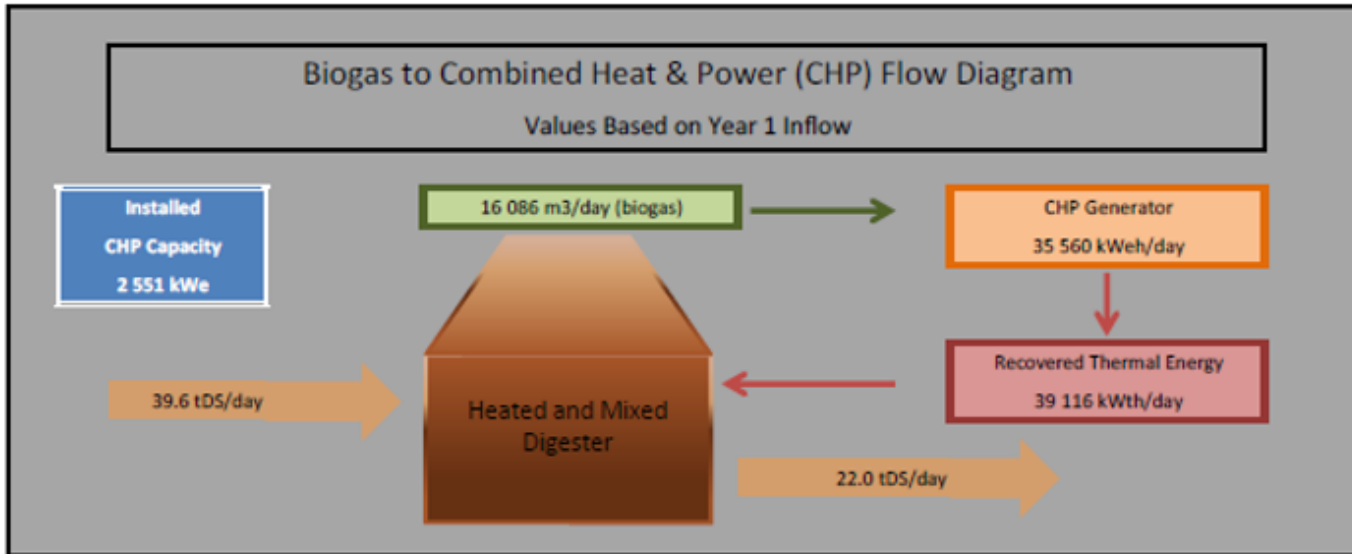
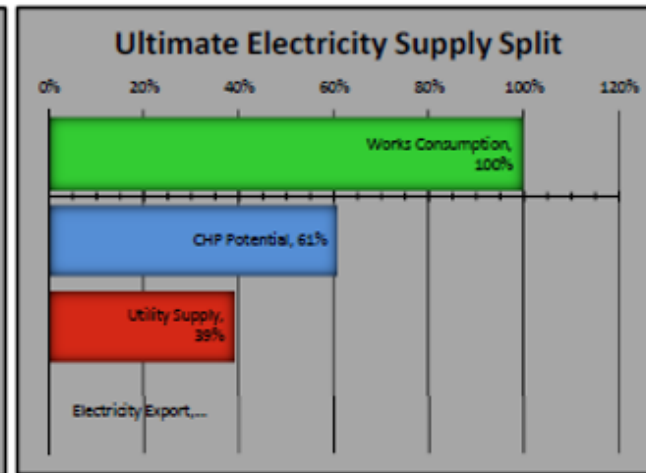
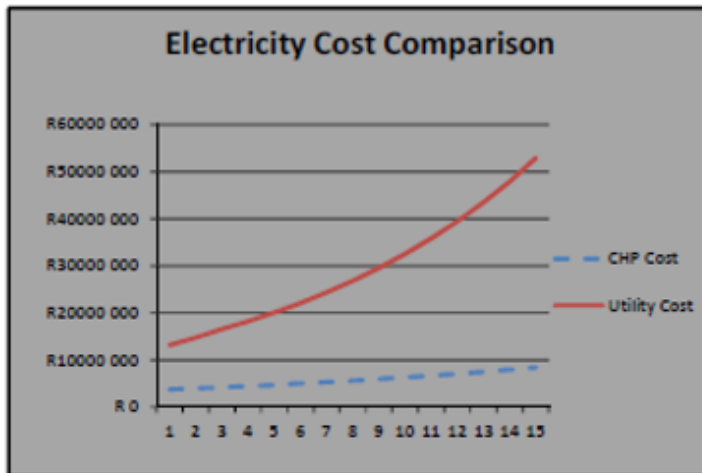


ANNEXURE 5: EXAMPLE OF SAQA UNIT STANDARD ON THE OPERATION OF AN ANAEROBIC DIGESTER



Job
well
done!

SALGA-GIZ-WEC Tool financial feasibility


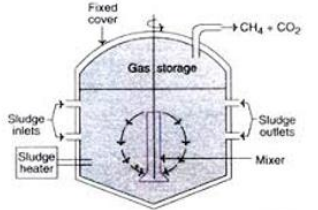



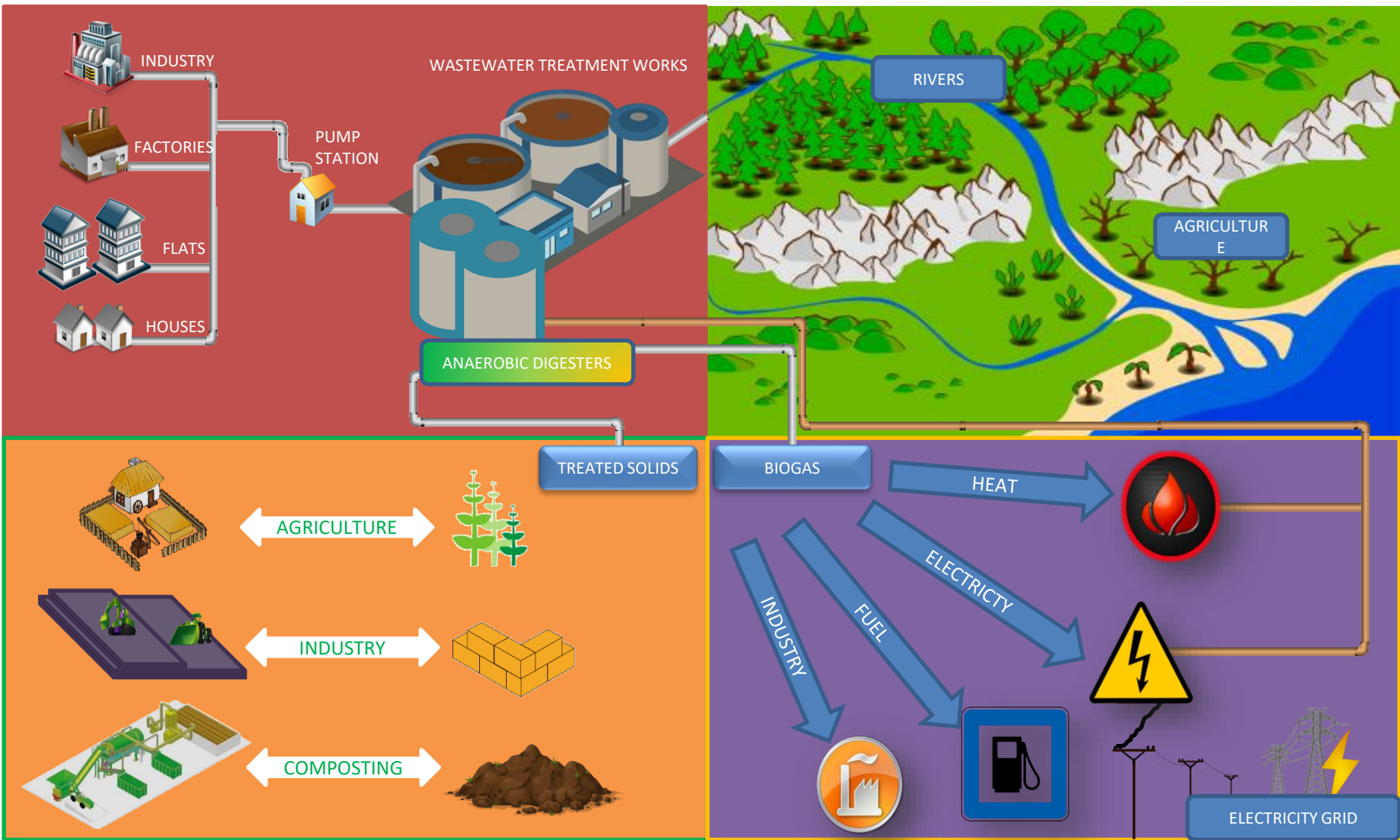
Inspection Guide

The Checklist addresses the following disciplines:

[Legend: Initial = I; Daily = D; Weekly = W; Monthly = M; Quarterly = Q; 6-monthly = S; Annually = A]

Discipline	I	D	W	M	Q	S	A
1. Digester capacity and loading	I	-	-	M	-	-	-
2. Digester performance	I	D	W	M	-	-	-
3. Maintenance Civil	I	-	-	M	-	-	-
4. Maintenance Mechanical and Electrical	I	D	W	M	Q	S	A
5. Safety and housekeeping	I	-	-	-	Q	-	-

Description	Assessment Criteria	Assessment/remarks	Score
1(a) Digester capacity and loading	Frequency: Initial and after every AD extension		-3 to +3
	Quantify the total volume of anaerobic digesters. This needs to be done once and then after every AD extension. The number and size of each type or group <u>must be known</u> , if not score -3 for each type/group. If all information is available, score 0.	Assessment baseline: Type 1 Mixed.....YES/NO Type 1 Heated.....YES/NO Type 1 rate assessment....HIGH/MED/LOW Type 1 number.....no Type 1 volume each.....m ³ Type 1 total volume.....m ³ Type 1 max flow.....m ³ /d Type 1 max VSkgVS/d	
	AD rate classification HIGH: heated and mixed MED: unheated and mixed LOW: unheated and un-mixed	Assessment baseline: Type 2 Mixed.....YES/NO Type 2 Heated.....YES/NO Type 2 rate assessment....HIGH/MED/LOW Type 2 number.....no Type 2 volume each.....m ³ Type 2 total volume.....m ³ Type 2 max flow.....m ³ /d Type 2 max VSkgVS/d	
	Hydraulic loading capacity: HIGH: Tot Vol/15 m ³ /d MED: Tot Vol/30 m ³ /d LOW: Tot Vol/30 m ³ /d	Assessment baseline: Type 3 Mixed.....YES/NO Type 3 Heated.....YES/NO Type 3 rate assessment....HIGH/MED/LOW Type 3 number.....no Type 3 volume each.....m ³ Type 3 total volume.....m ³ Type 3 max flow.....m ³ /d Type 3 max VSkgVS/d	



Way Forward



marlene@watergroup.co.za