The WROSE Model: A Decision-Making Tool for Sustained Waste and Carbon Emissions Reduction

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WasteCon 2022

Acknowledgements

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NRF National Research Foundation
RISA Research and Innovation Support and Advancement

CSIR
our future through science

iwwg
international waste working group
SOUTHERN AFRICAN REGIONAL BRANCH

A WASTE RDI ROADMAP FOR SOUTH AFRICA

The importance of research, development and innovation (RDI) in transforming the South African waste sector

Prof. Cristina Trois is a Full Professor in Environmental Engineering, and **NRF/DSI/CSIR SARCHI Chair in Waste and Climate Change** at the University of kwaZulu-Natal, Durban, South Africa.

Since January 2022, she is the Acting Director of the **WASH R&D Centre** at UKZN.

Prof. Trois has over **20 years of experience** in waste and resources management and has been the principal investigator as well as the project coordinator of many R&D projects with municipalities in South Africa and Africa. Author of **over 100 peer-reviewed publications** in high-impact journals; she is a **C1 rated scientist with the NRF**. She developed and coordinates the first **Master Programme in Waste and Resources Management in South Africa, and graduated over 130 postgraduate students.**

SARCHI Chair
Waste and Climate Change

University of KwaZulu-Natal
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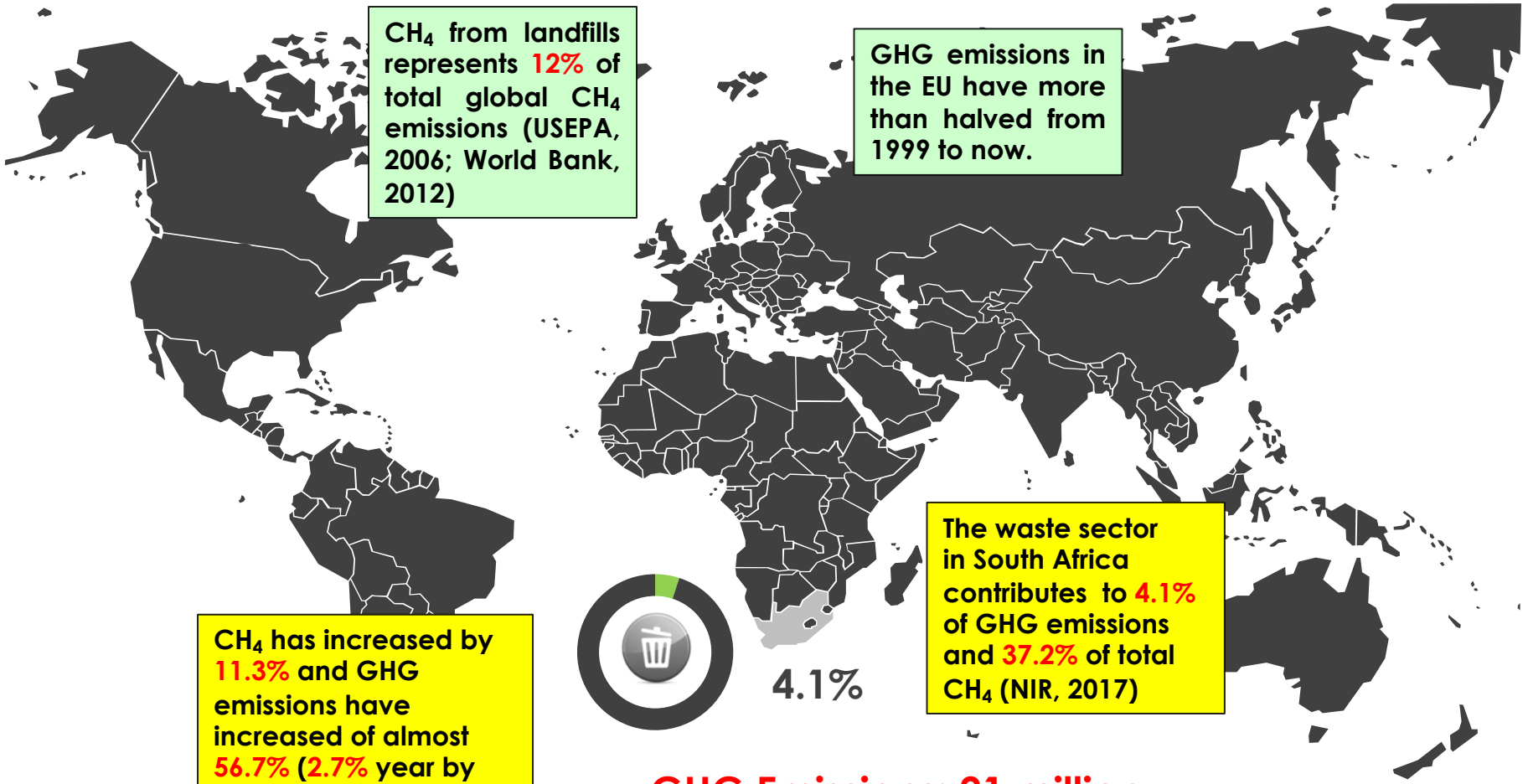
WASTE AND CLIMATE CHANGE

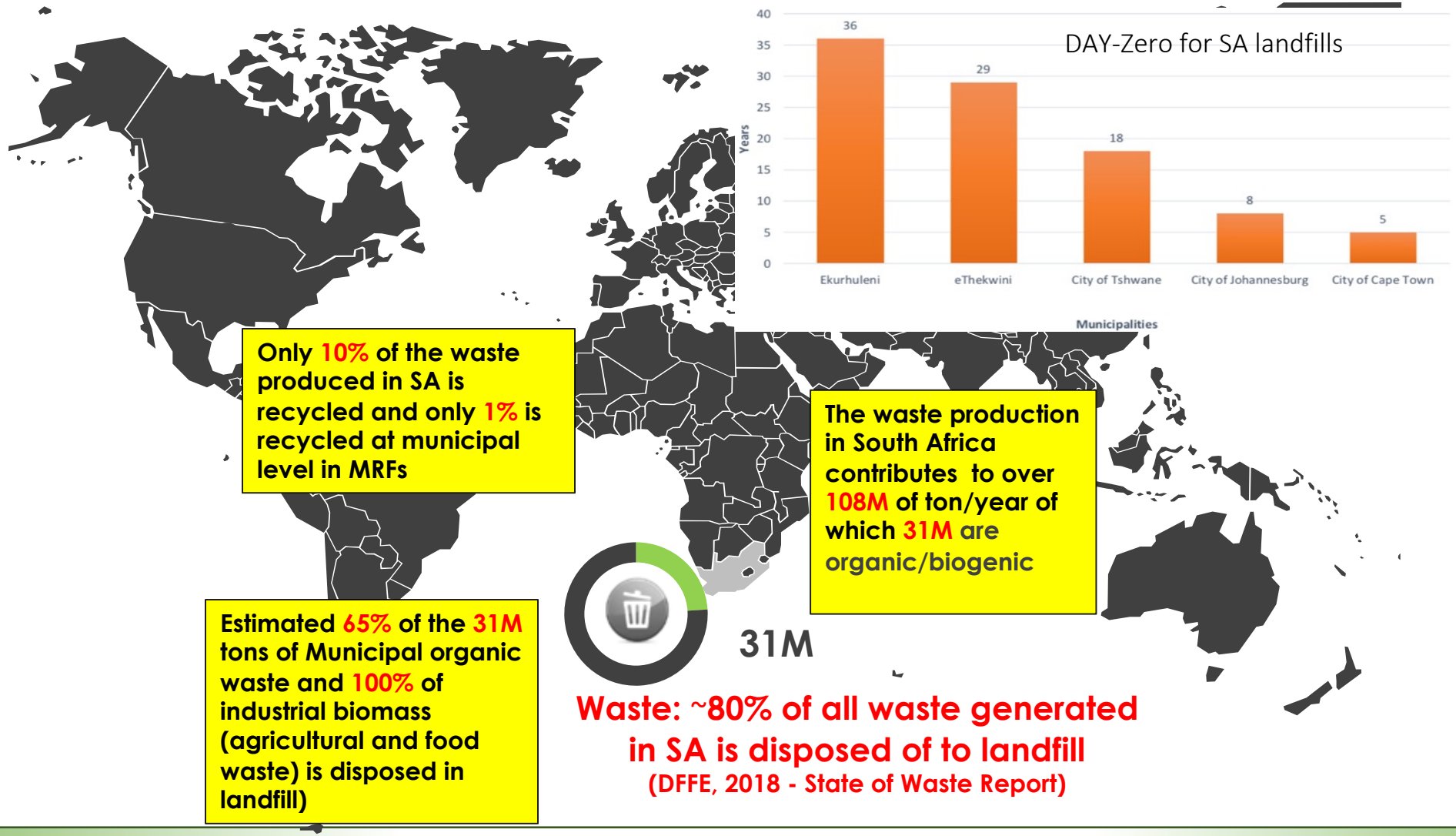
F1	F2	F3	F4
GHG	**WROSE**	**CLIMATE**	**AFRICAN CITY OF THE FUTURE**
ASSESS/MODEL	MITIGATE	ADAPT	RESILIENT → SUSTAINABLE
KEY THEME	KEY THEME	KEY THEME	KEY THEME
• Localisation of GHG generation hotspots • Reporting on climate change / standards • Development of GHG indicators	• **Technologies** to achieve **stabilisation** • **Localisation** of appropriate technologies • **Low-carbon** economy	• Low carbon economy / best scenario • De-carbonization of South Africa	• Transitioning from resilient to smart, wise, and sustainable • Indicators of sustainability

Waste and Climate Change in SA - GHG



GHG Emissions: 21 million tons of CO_2 equivalent (2017)

Waste and Climate Change in SA - WASTE



Only 10% of the waste produced in SA is recycled and only 1% is recycled at municipal level in MRFs

The waste production in South Africa contributes to over 108M of ton/year of which 31M are organic/biogenic

Estimated 65% of the 31M tons of Municipal organic waste and 100% of industrial biomass (agricultural and food waste) is disposed in landfill)

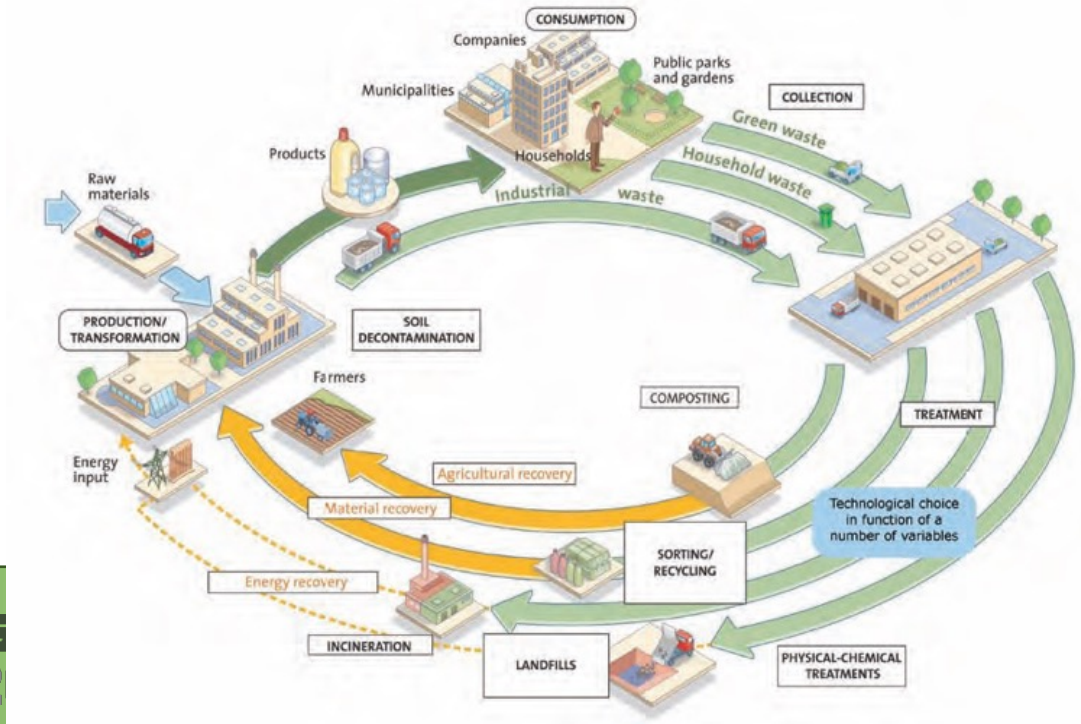
Waste: ~80% of all waste generated in SA is disposed of to landfill
(DFFE, 2018 - State of Waste Report)

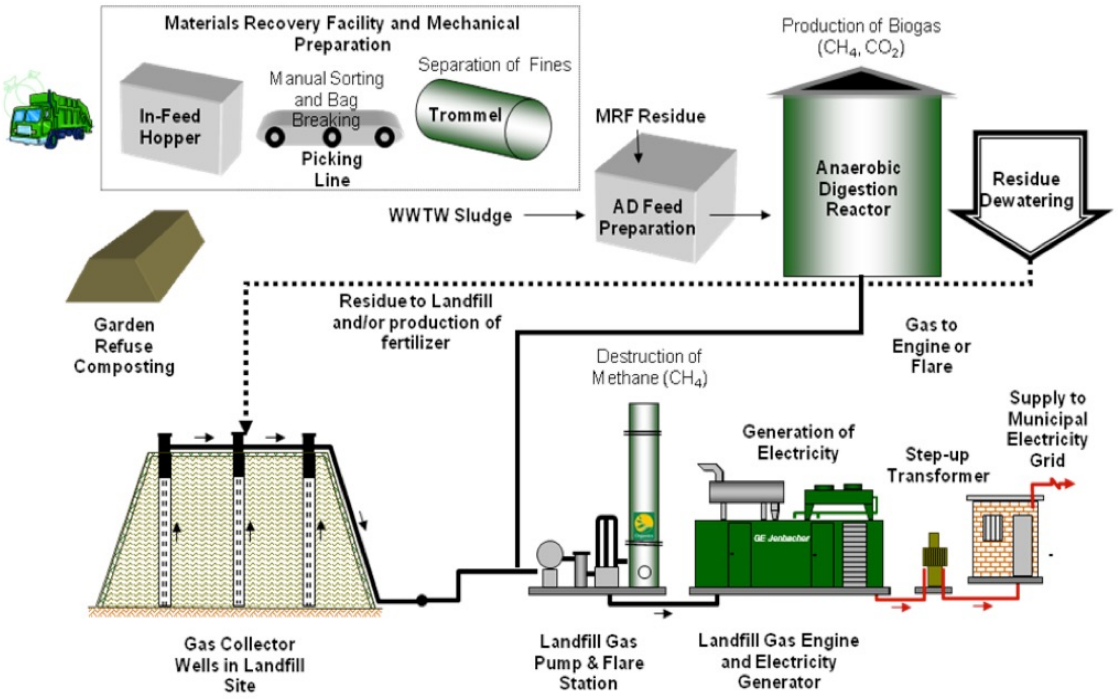
Waste Management in South Africa

- **Challenge of meeting high standards in service delivery with limited resources**
- Lack of environmental control systems and appropriate legislation
- **Limited know-how**, indiscriminate dumping
- **Lack of reliable data on waste streams and GHG emissions indicators**
- Poor environmental and waste awareness of the general public


Landfill, 1996

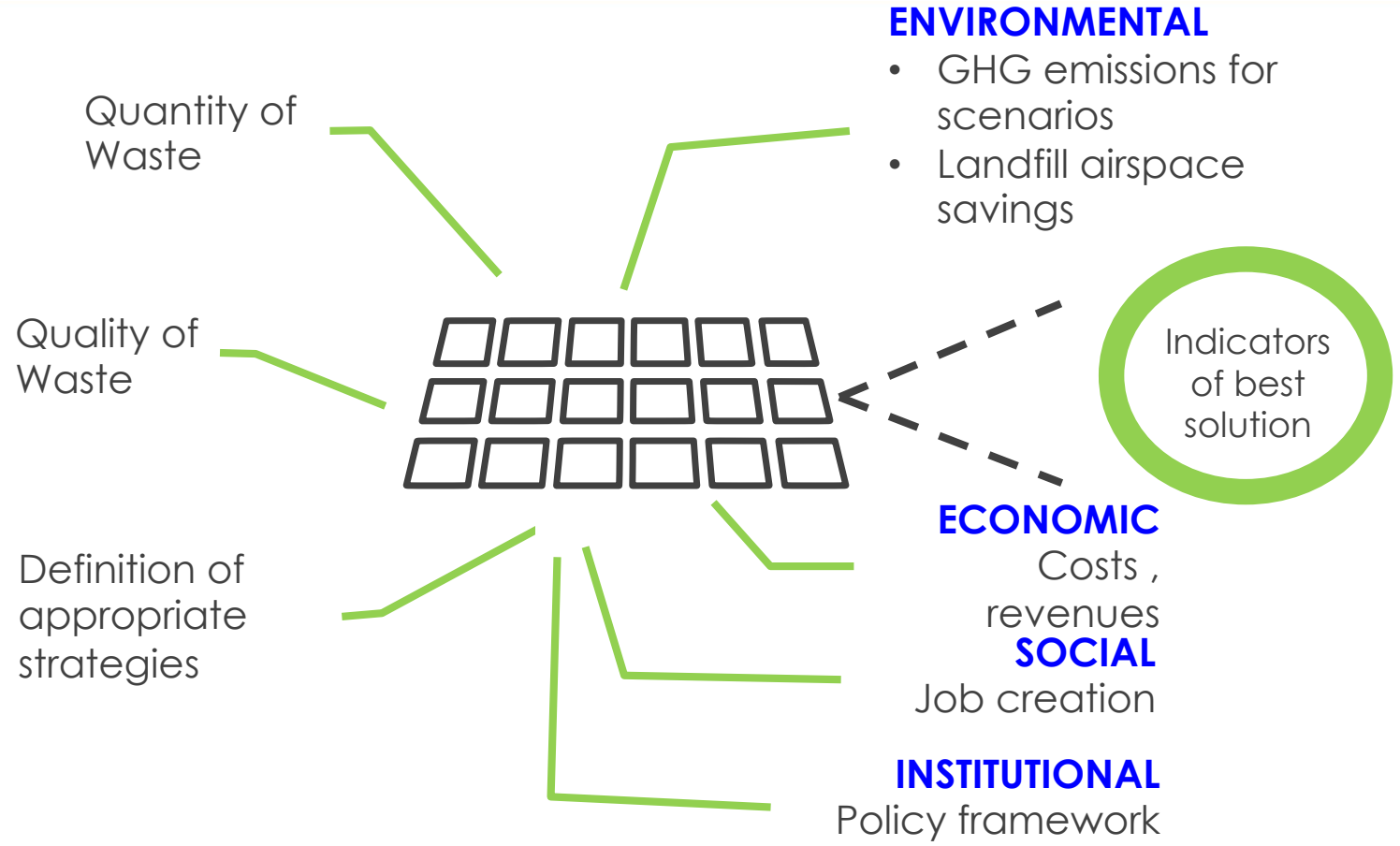

Landfill, 2006


CONSUMPTION
Companies
Public parks and gardens
Municipalities
Households
COLLECTION
Green waste
Household waste
Industrial waste
Products
Raw materials
PRODUCTION/ TRANSFORMATION
SOIL DECONTAMINATION
Farmers
COMPOSTING
TREATMENT
Energy input
Agricultural recovery
Material recovery
Technological choice in function of a number of variables
SORTING/ RECYCLING
Energy recovery
INCINERATION
LANDFILLS
PHYSICAL-CHEMICAL TREATMENTS


Materials Recovery Facility and Mechanical Preparation
In-Feed Hopper
Manual Sorting and Bag Breaking
Picking Line
Separation of Fines
Trommel
MRF Residue
Production of Biogas (CH_4, CO_2)
WWTW Sludge
AD Feed Preparation
Anaerobic Digestion Reactor
Residue Dewatering
Garden Refuse Composting
Residue to Landfill and/or production of fertilizer
Gas to Engine or Flare
Destruction of Methane (CH_4)
Generation of Electricity
Step-up Transformer
Supply to Municipal Electricity Grid
Gas Collector Wells in Landfill Site
Landfill Gas Pump & Flare Station
Landfill Gas Engine and Electricity Generator

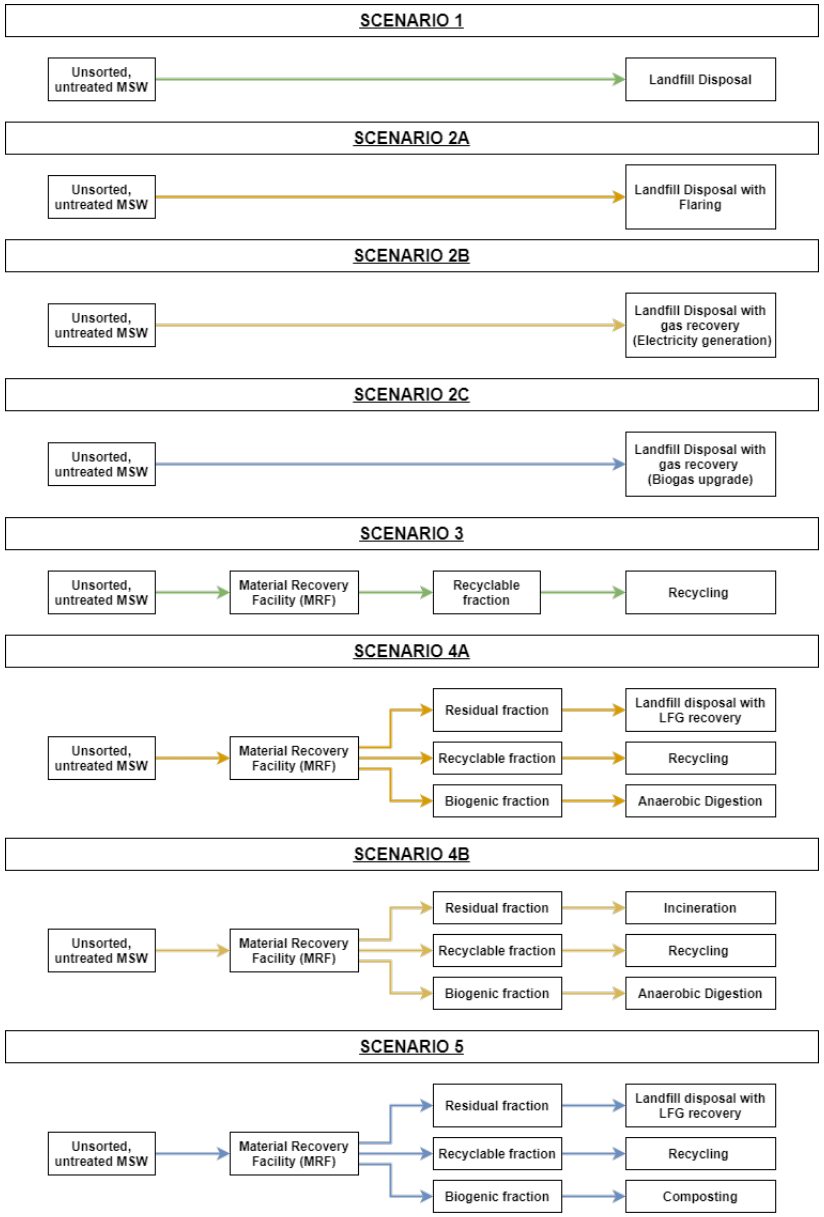
Simulation using the wrose™ model

WROSE™ (Waste to Resource Optimization & Scenario Evaluation)

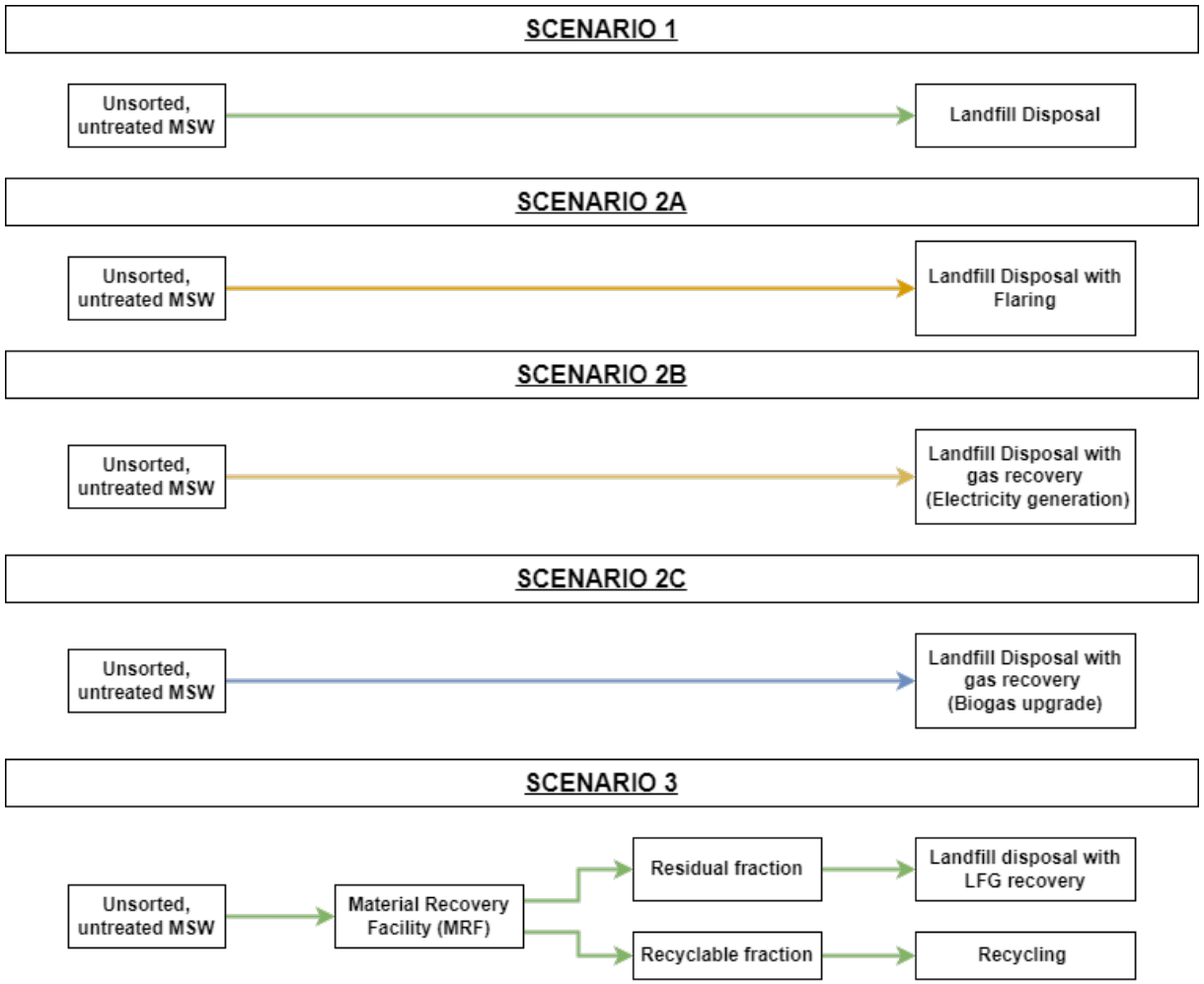


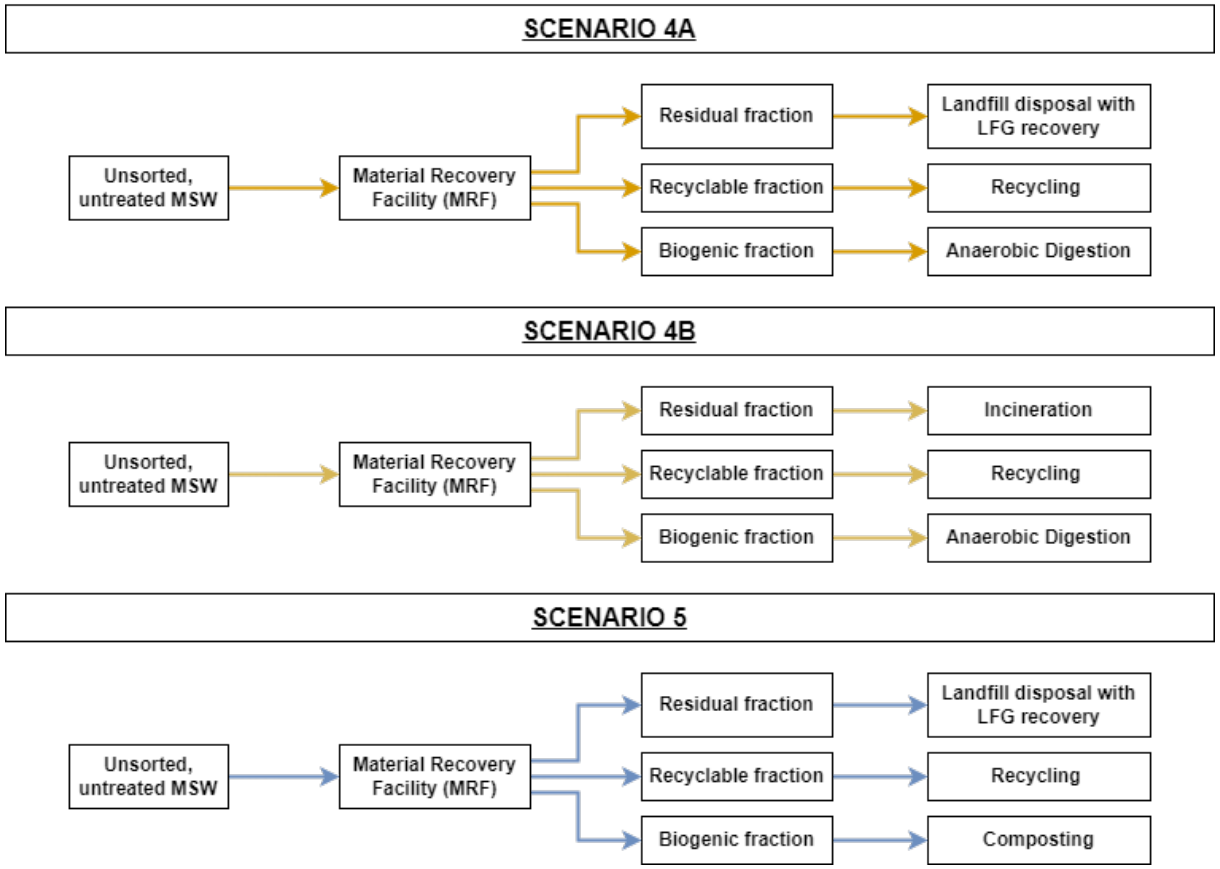
wrose™ scenarios

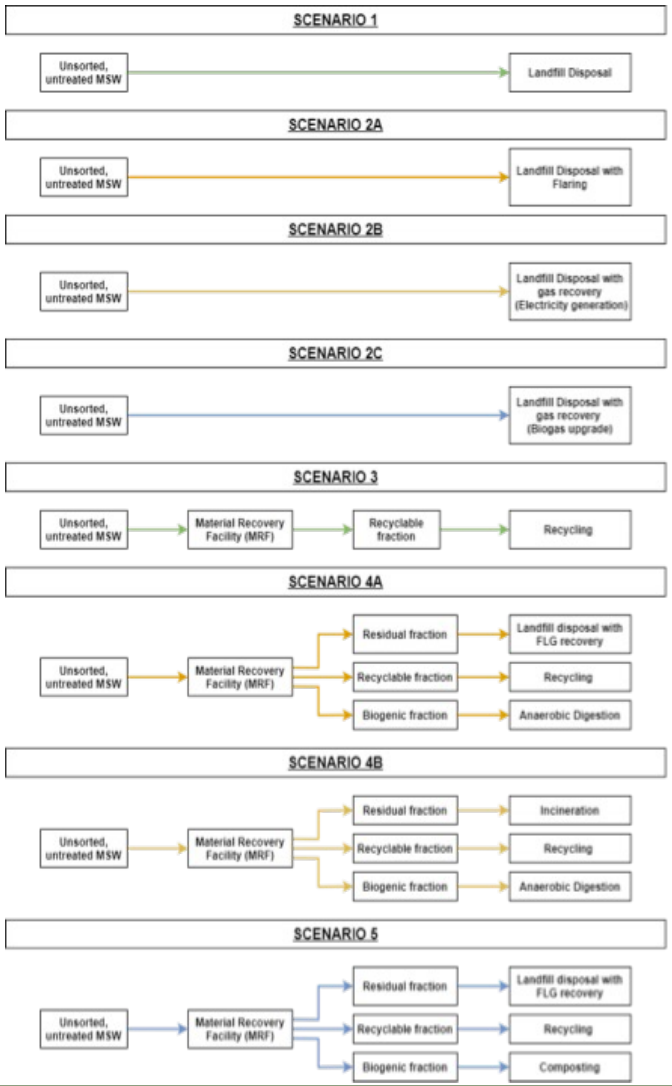
- Selection of case study
- Identification of waste stream
- Baseline scenarios
    1. Landfill disposal
    2. Landfill disposal with flaring / gas recovery
- Currently available scenarios
    3. MRF + material recovery
    4. MRF + material and energy recovery (AD and incineration / LFG)
    5. MRF + material and energy recovery (composting and LFG)

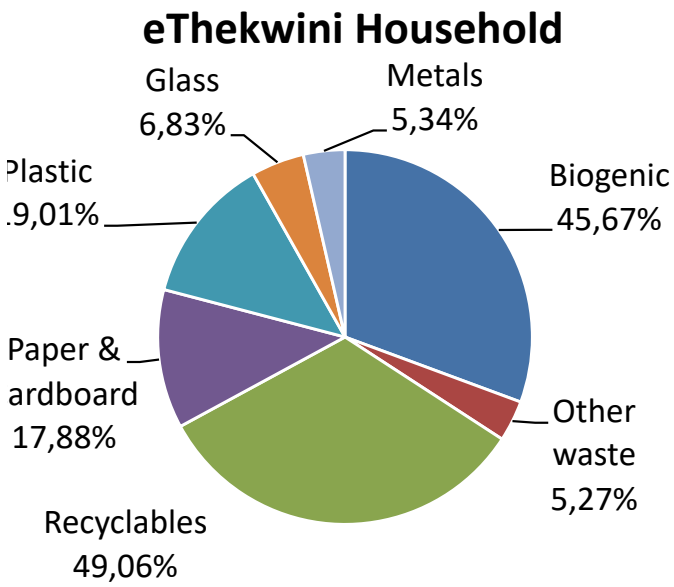


wrose™ scenarios

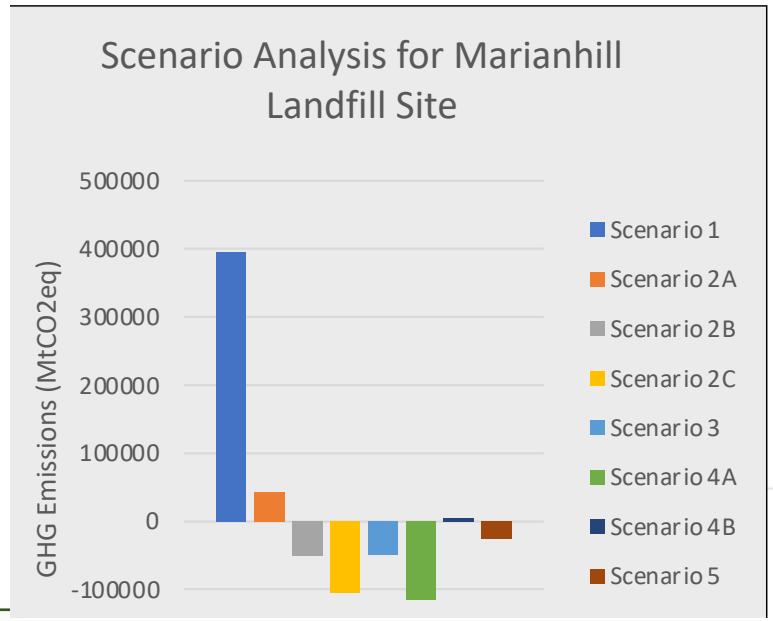


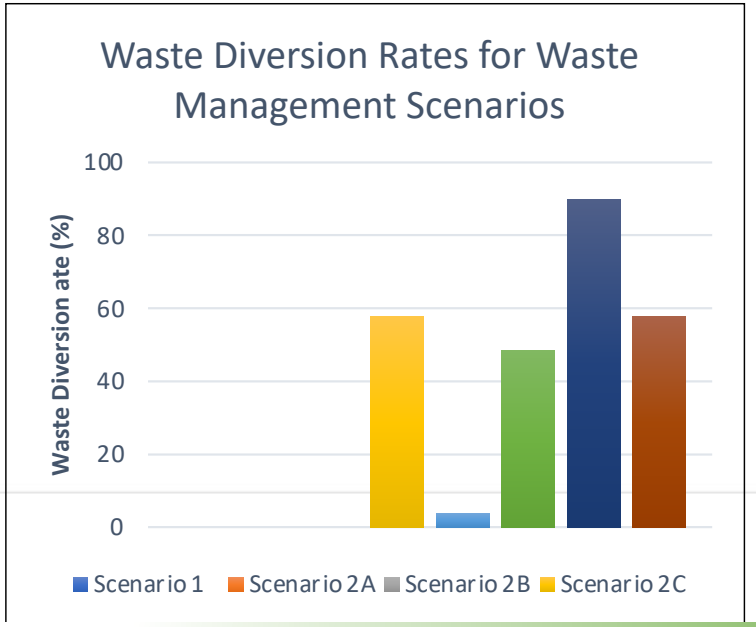






Strategy	Quantity Managed/ Produced	Rate	Capital Cost (R)	Operating Cost (R/annum)	Income/Savings (R/annum)
1. LANDFILL DISPOSAL & LFG RECOVERY					
Landfill Gas Recovery System	0.50 MW		1,100,000		
Landfill Disposal operations	122,514 tons	138 R/ton		16,906,932	
Landfill Gas Recovery operating costs	7,051,800 kWh	0.018$/kWh		866,758	
Sale of Electricity	7,051,800 kWh	0.047$/kWh			2,263,201
Certified Emission Reductions	5,758 $MTCO_2e$	14$/$MTCO_2e$			550,458
Total			**1,100,000**	**17,773,690**	**2,813,659**
2. MRF & RECYCLING					
Materials Recycling Facility Capital Cost	385 tpd	30,668$/tpd	33,848,875		
Materials Recycling Facility Operating Cost	385 tpd	2,815$/tpd		9,899,276	
Sale of Recyclables	21,549 tons	R/kg			19,598,660
Landfill airspace savings	47,122 m^3	62.5R/m^3			2,945,125
Total			**33,848,875**	**9,899,276**	**22,543,785**
3. ANAEROBIC DIGESTION					
Anaerobic Digestion Plant Capital Cost	49,153 tons	15.24$ million	104,066,340		
Anaerobic Digestion Plant Operating Cost	49,153 tons	28.2$/ton		9,465,084	
Sale of electricity	18,128,413 kWh	0.047$/kWh			5,818,124
Sale of Compost	29,492 tons	250R/ton			7,372,950
Certified Emissions Reductions	21,379 $MTCO_2e$	14$/$MTCO_2e$			2,043,797
Landfill airspace savings	45,872 m^3	62.5R/m^3			2,867,000
Total			**104,066,340**	**9,465,084**	**18,101,871**
4. AEROBIC COMPOSTING					
Composting Facility Capital Cost	57,847 tons	2E+06R/180tpd	3,066,667		
Composting Facility Operating Cost	57,847 tons	152.05R/ton		9,123,000	
Sale of compost	43,385 tons	250R/ton			10,846,313
Certified Emissions Reductions	12,753 $MTCO_2e$	14$/$MTCO_2$			1,219,182
Landfill airspace savings	54,799 m^3	62.5R/m^3			3,424,938
Total			**3,066,667**	**9,123,000**	**15,490,433**



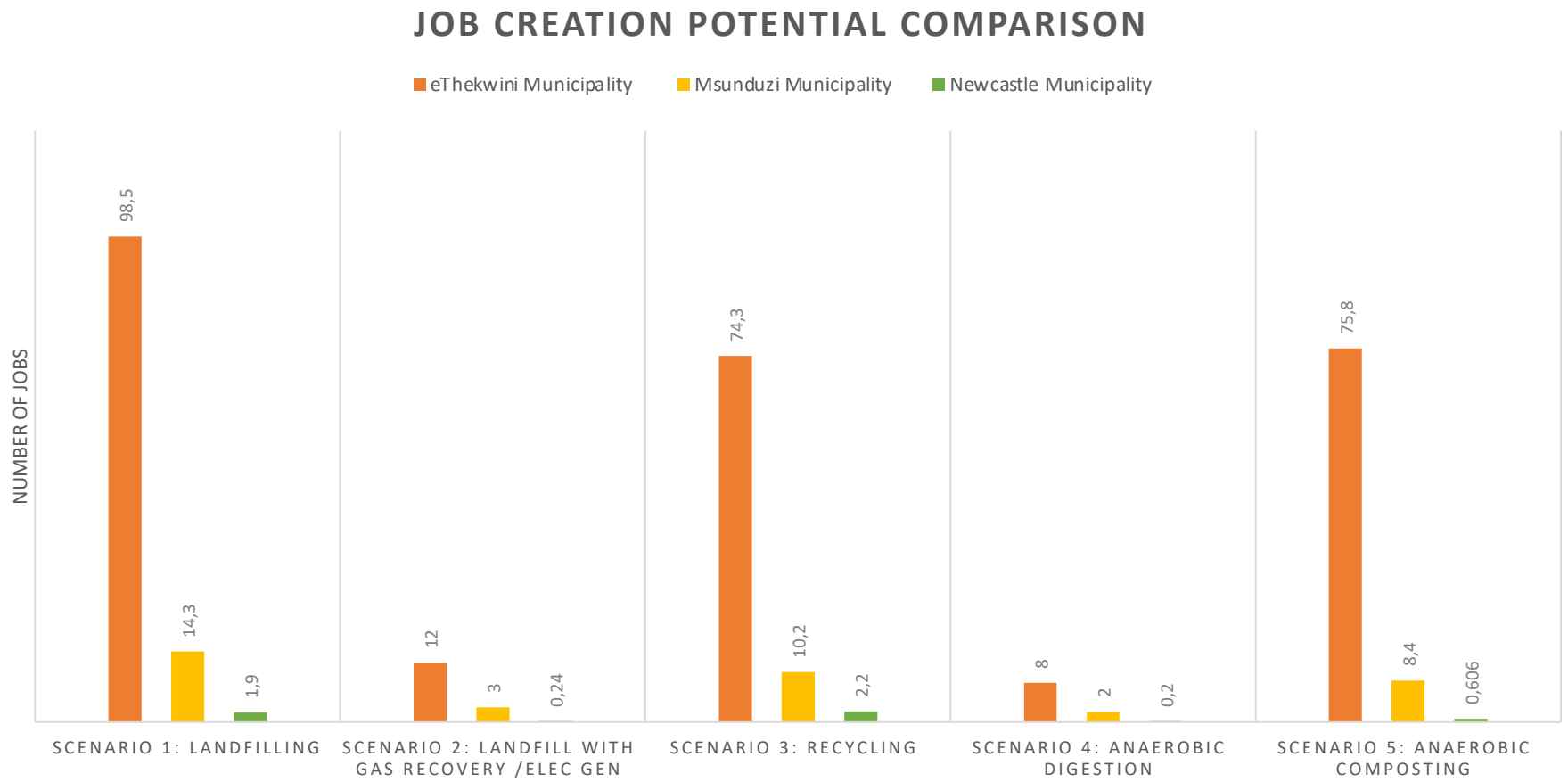


Social Indicators

WASTE RESOURCE OPTIMIZATION AND SCENARIO EVALUATION MODEL : SOCIO - ECONOMIC INDICATORS						
	WASTE QUANTITY (tons per day) /MW OF ELECTRICITY	NO. OF JOBS	DIRECT HEALTH RISKS	INDIRECT HEALTH RISKS	PUBLIC PARTICIPATION IN WASTE MANAGEMENT PROCESS	PUBLIC PARTICIPATION IN EIA PROCESS
SCENARIO 1: LANDFILLING	0	0.0	Respiratory Issues, , Fatigue, Headaches, Influenza type Symptoms	Cancer, Low Birth Weight, Birth Defects	No public participation necessary	Public participation process required
SCENARIO 2: LANDFILL WITH GAS RECOVERY /ELEC GEN	0	0	Wheezing, nausea, headaches	Asthma, respiratory issues	No public participation necessary	Public participation process required
SCENARIO 3: RECYCLING	0	0.0	Respiratory issues, influenza type symptoms, nausea, headache, tiredness	Asthma, respiratory issues	No public participation necessary due to separation at MRF	Public participation process required
SCENARIO 4: ANAEROBIC DIGESTION	0	0	Tiredness, headache, nausea	N/A	No public participation necessary due to separation at MRF	Public participation process required
SCENARIO 5: ANAEROBIC COMPOSTING	0	0	Fungal spores and bacteria causing Breathing problems, nausea	Fatigue and headaches	No public participation necessary due to separation at MRF	Public participation process required

Institutional Indicators

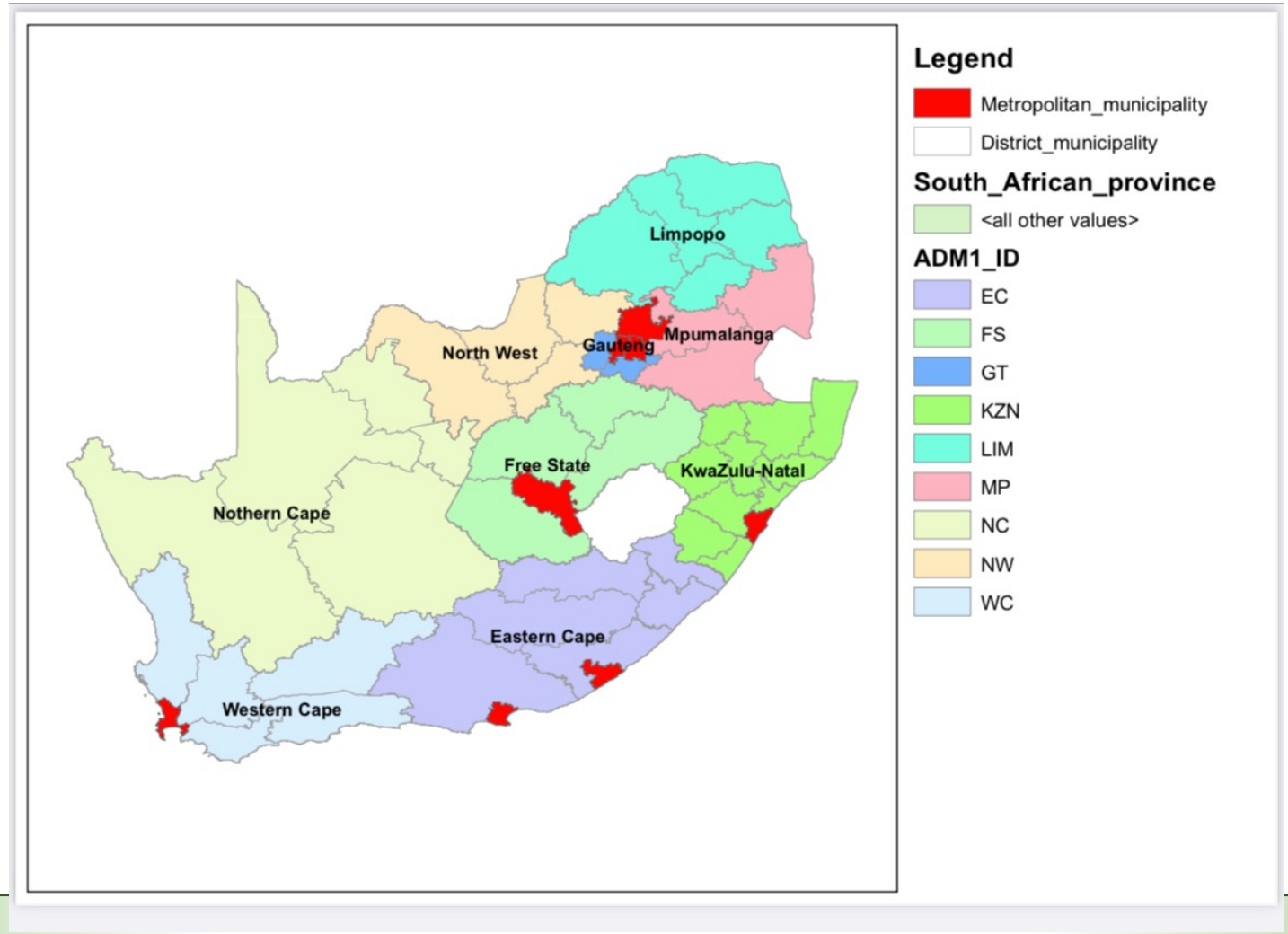
SCENARIOS	WASTE STREAMS	ENVIRONMENTAL LEGISLATION	ENERGY LEGISLATION	FINANCIAL & ADMINISTRATIVE REGULATION	LICENCE REQUIRED
SCENARIO 1: DISPOSAL OF UNSORTED UNTREATED MSW TO LANDFILL	General MSW	The Constitution	N/A	Occupational Health and Safety Act 1993	
		The Environmental Conservation Act	N/A	Municipal Systems Act 2000	
		National Environmental Management Act	N/A	Municipal Structures Act	
		National Environmental Management Waste Act	N/A	Municipal Finance Management Act	Atmospheric Emissions Licence
		National Environmental Management: Air Quality Act	N/A	Supply Chain Management	Waste Licence (For Storage, Treatment, Disposal and Processing of waste)
		Atmospheric Pollution Prevention Act	N/A	Asset Management	
		National Integrated Coastal Management Act	N/A	Generally Recognised Accounting Practices 17 & 19	



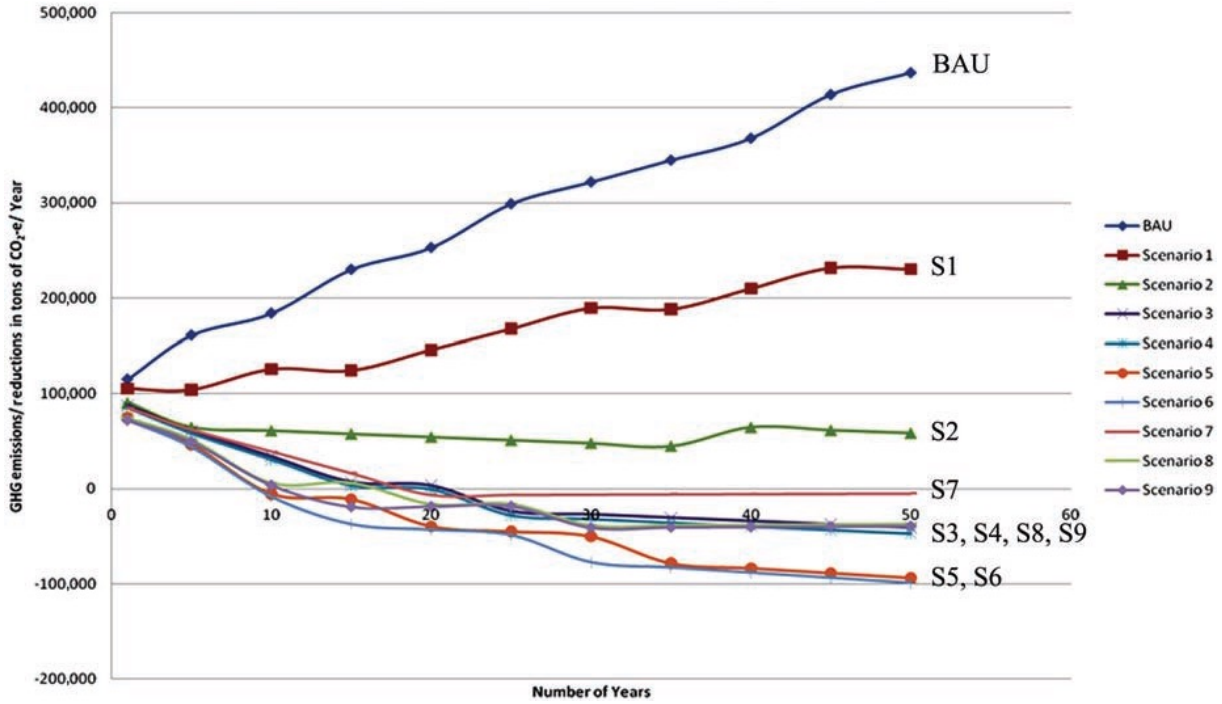
Scenarios 1, 3 and 5 are most preferable in terms of job creation potential as these scenarios are more labour intensive than scenarios 2 and 4

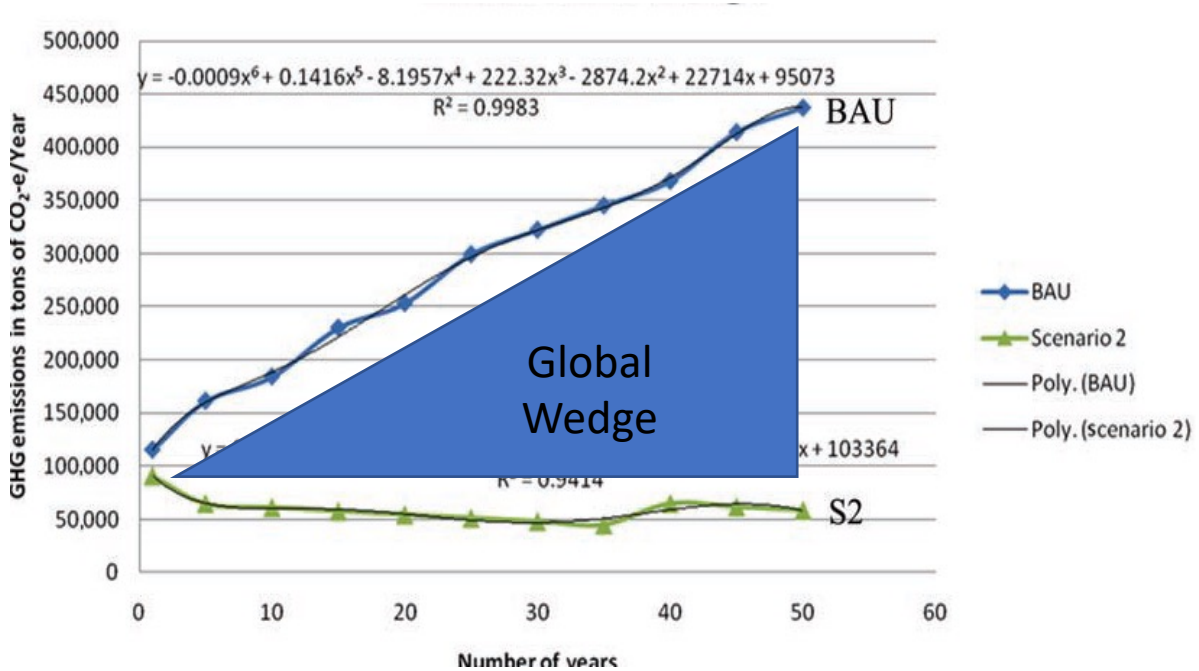
Development of a GHG emissions mitigation strategy for South Africa

Partners: DSI-RDI Waste Roadmap/IIASA/World Bank Group

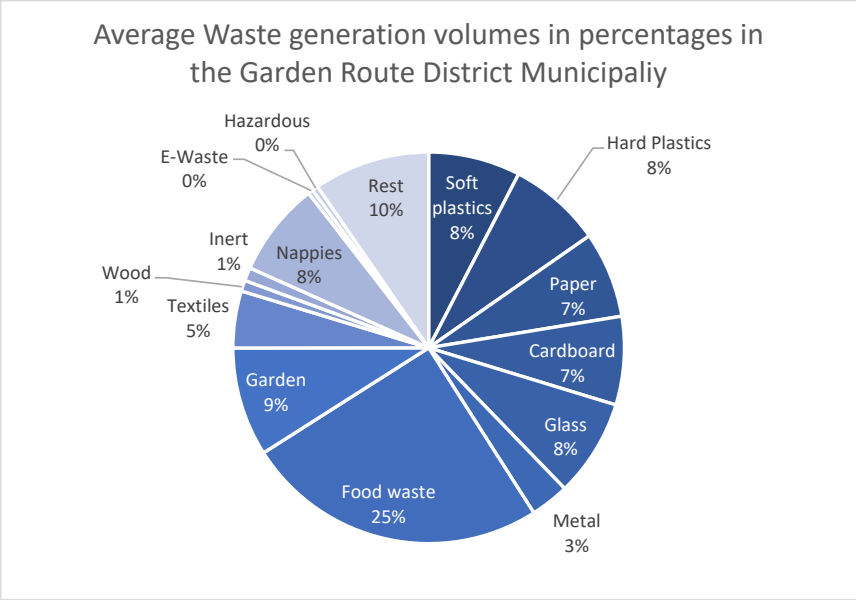


Building a mitigation strategy through optimised IWMS

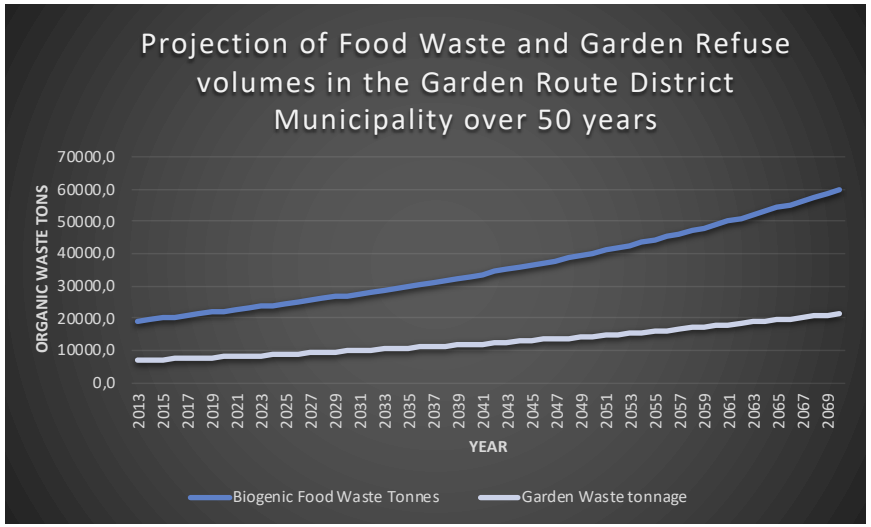


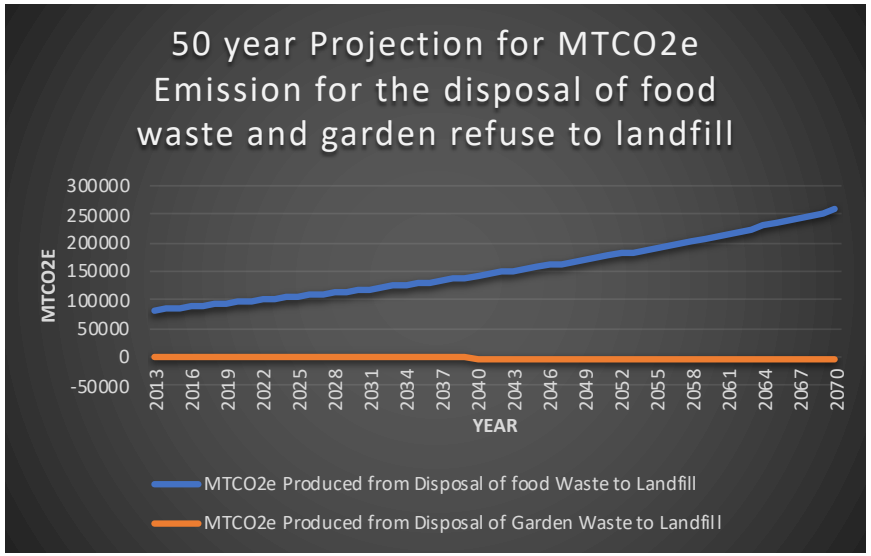


WASTE STREAM: Food waste/OFMSW
CASE STUDY: Garden Route District Municipality



The use of the WROSE model as a climate change stabilization wedge: A South African case study
PhD - Sameera Kissoon





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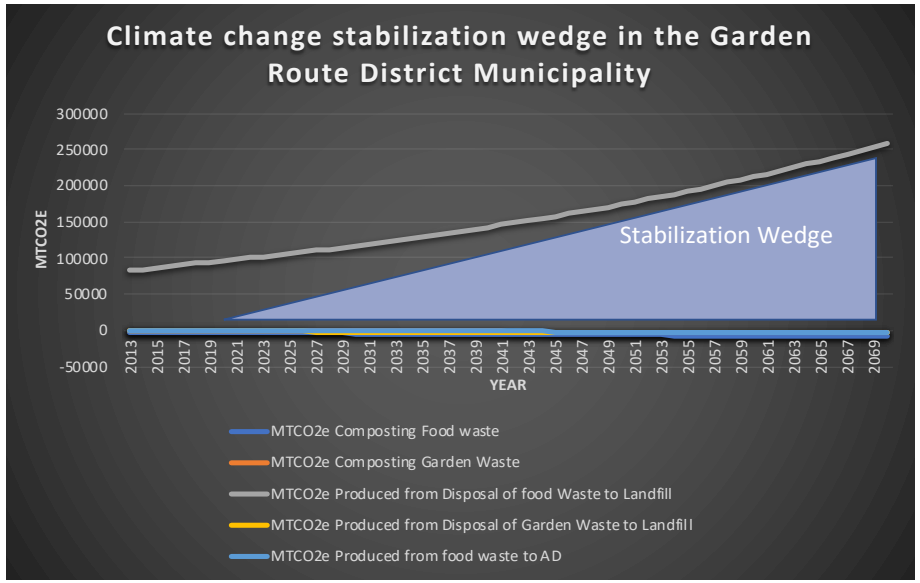

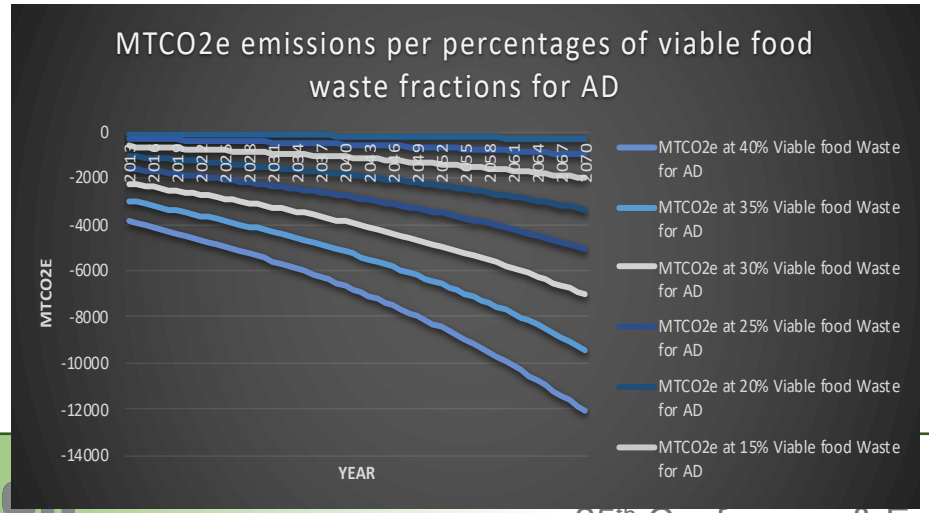

Based on Figures 3 and 4, as waste generation rates increase by more than triple in the next 50 years so do the GHG emissions from the organic waste fractions. Figure 5 below depicts the outcome of the comparison of the three selected scenarios:

- For Scenario 1, the model depicts the steady increase of GHG emissions for both organic waste and garden refuse. This rate of GHG emission is unsustainable for long term climate contributions due to the global warming potential of CH^4 being 25 times more harmful than that of CO^2 according to the USEPA.
- For Scenario 4, the introduction of AD facilities for the treatment of all organic food waste at 100% viability for digestion is shown to reduce the GHG emission levels to a stable state i.e no upward trajectory over the next 50 years.
- For Scenario 5, composting as a treatment method for garden refuse and biogenic food waste fractions is shown to reduce GHG emissions to a stable level for the next 50 years, similar to that of AD.

Should no interventions be put in place over the next 50 years, the impact of waste disposal to landfill grows exponentially. This is a direct result of the global warming potential of methane emissions from the decomposition of organic waste in landfill facilities.

WASTE STREAM: General MSW
CASE STUDY: eThekwini Municipality

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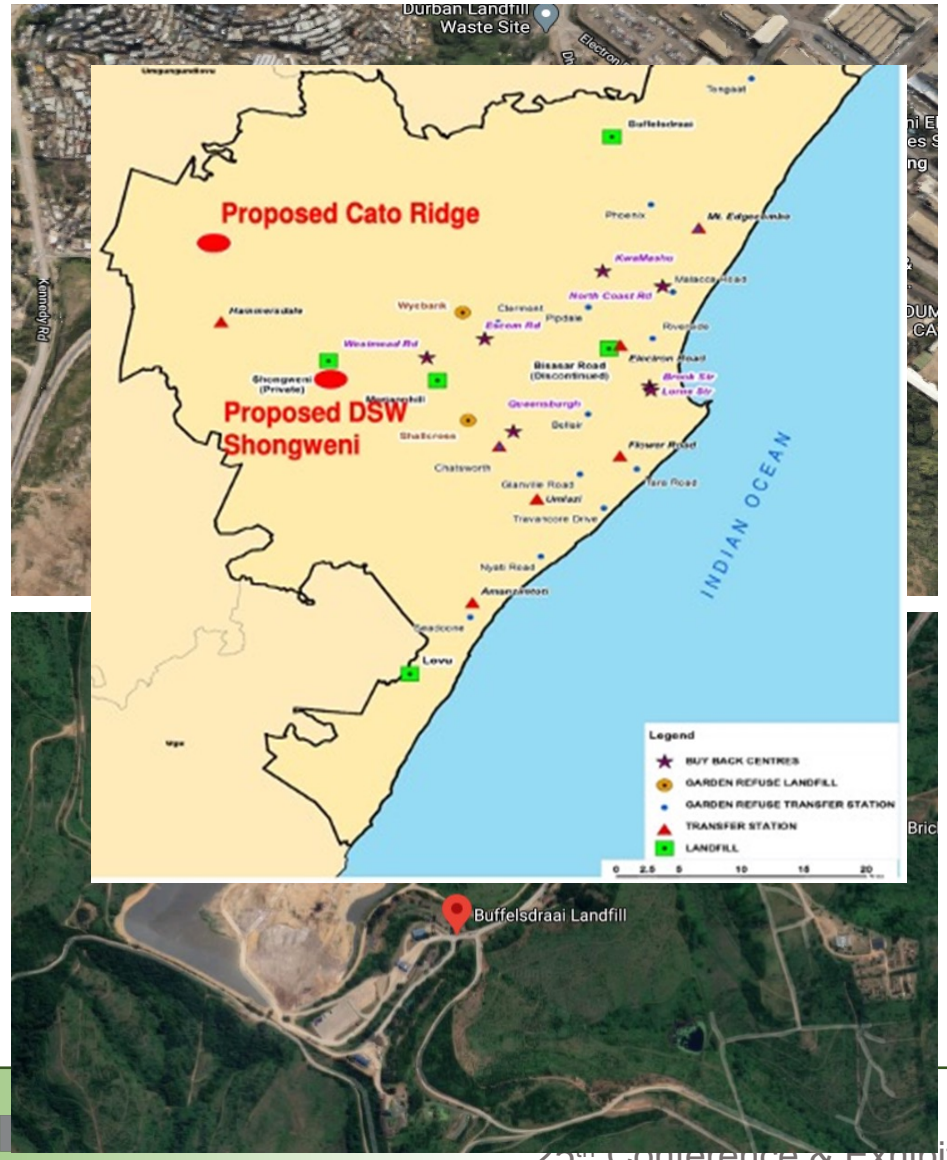
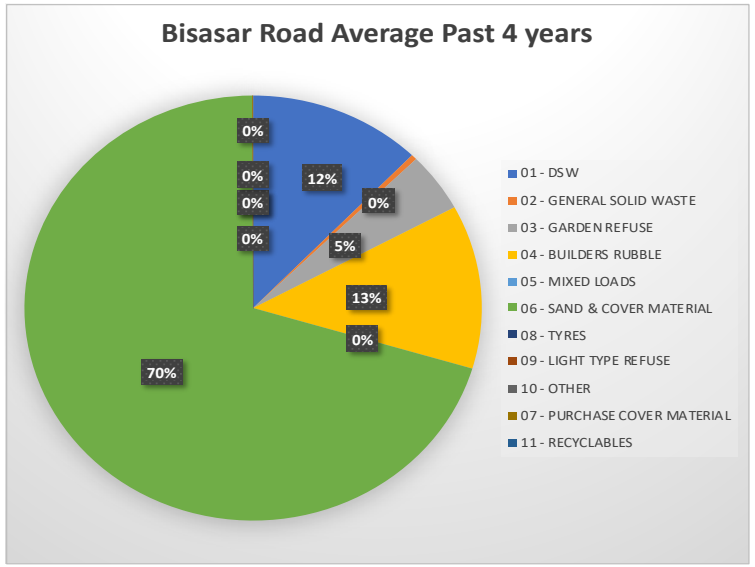
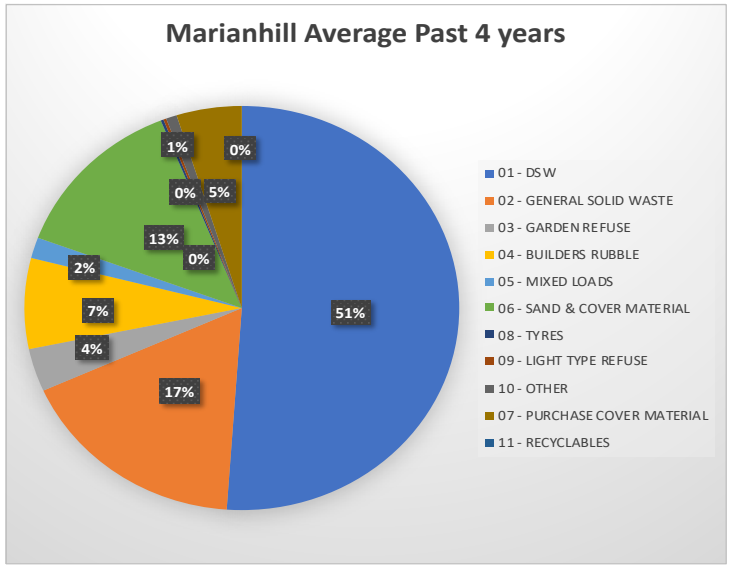
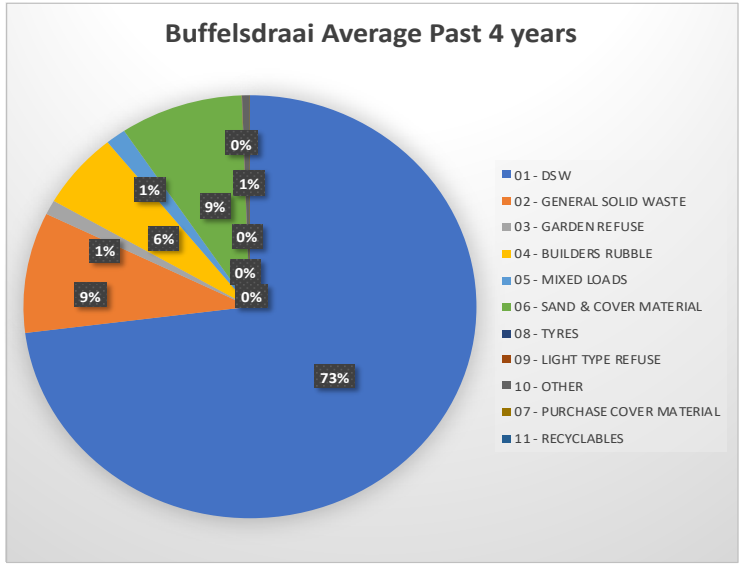


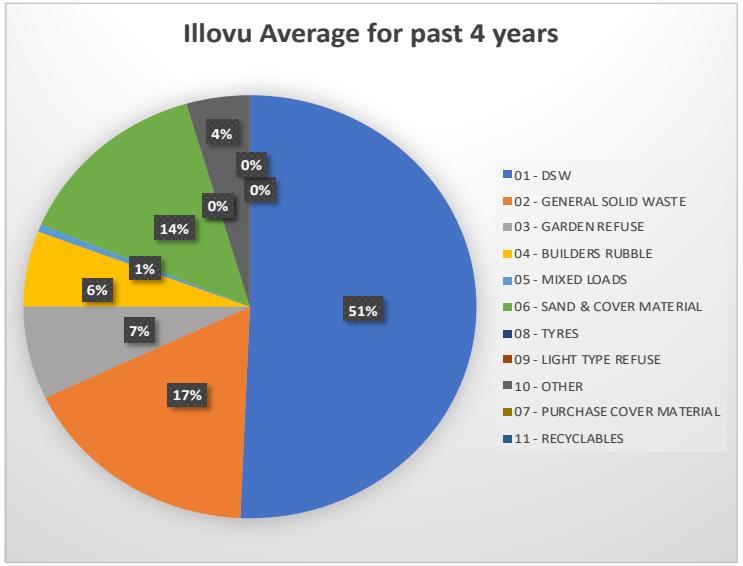
- Approximate area of 2297km^2
- 4 Municipal landfills
- 7 transfer stations
- 14 Garden waste transfer stations
- 2 garden waste landfill sites, Wyebank and Shallcross.

WASTE STREAM: General MSW
CASE STUDY: eThekwini Municipality









WASTE STREAM: General MSW
CASE STUDY: eThekwini Municipality

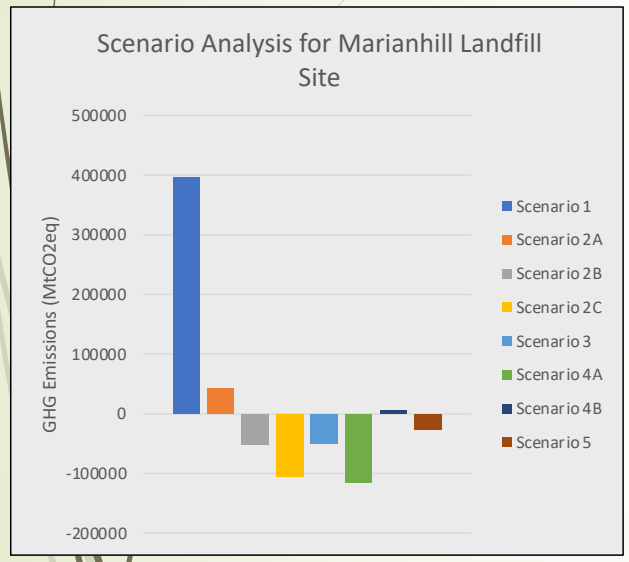


Figure 10: Scenario Analysis of MLS

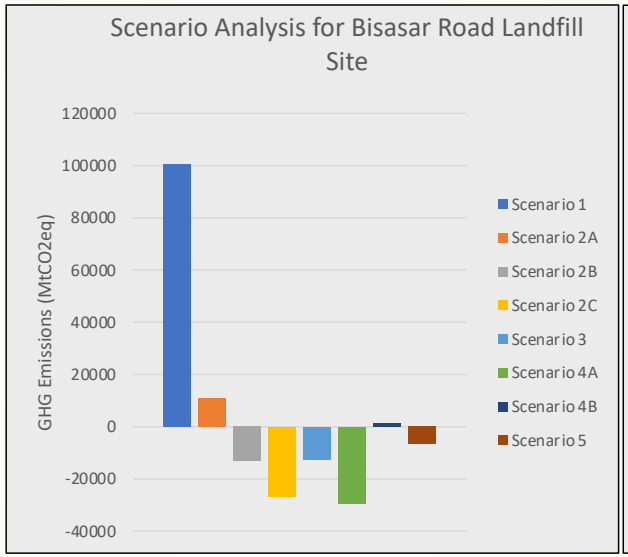


Figure 11: Scenario Analysis of BRL

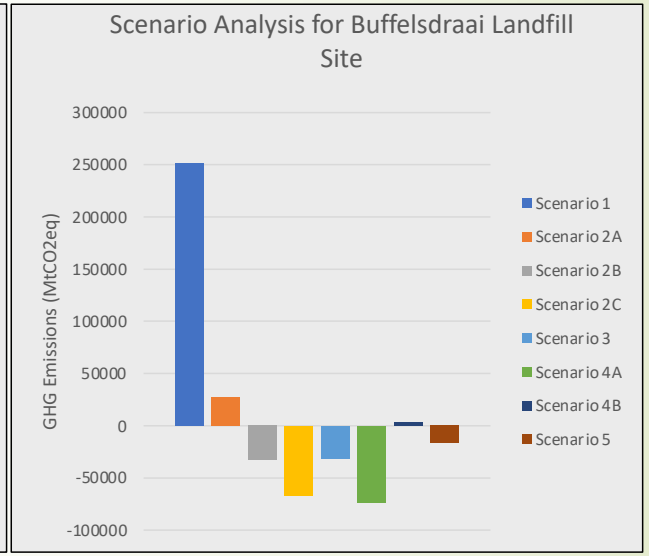
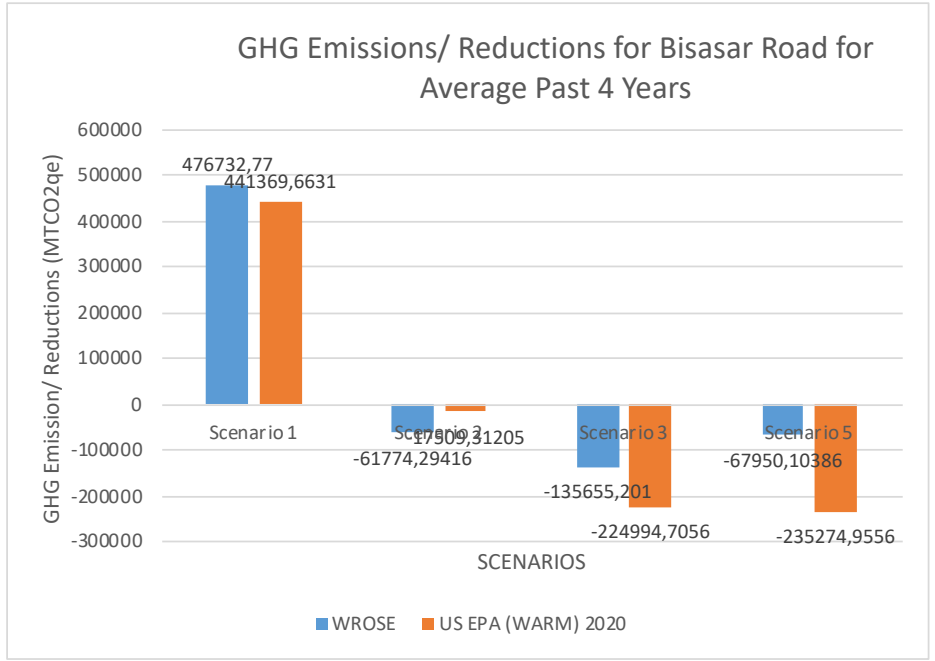
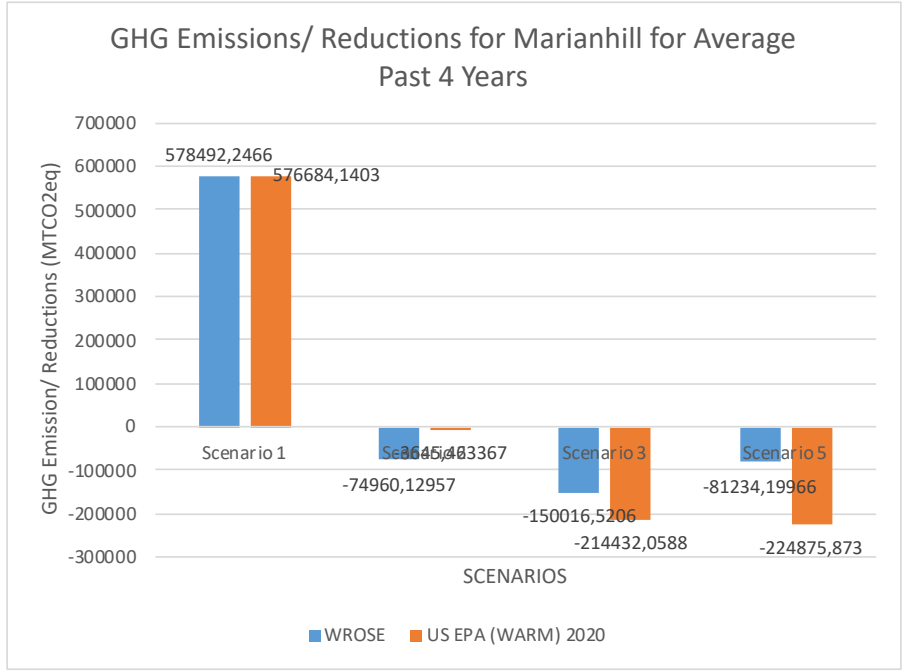
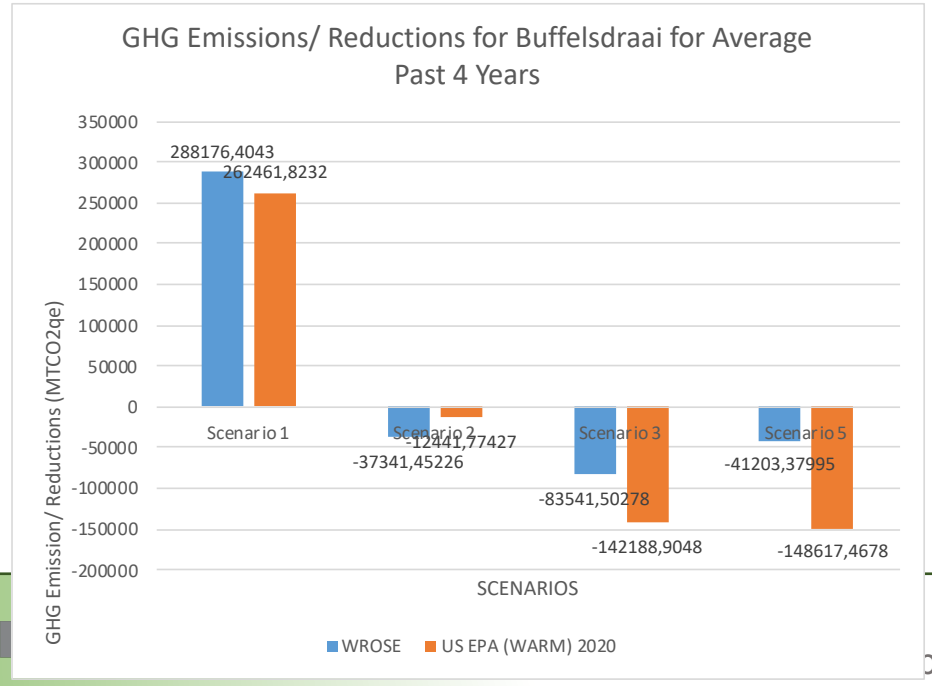
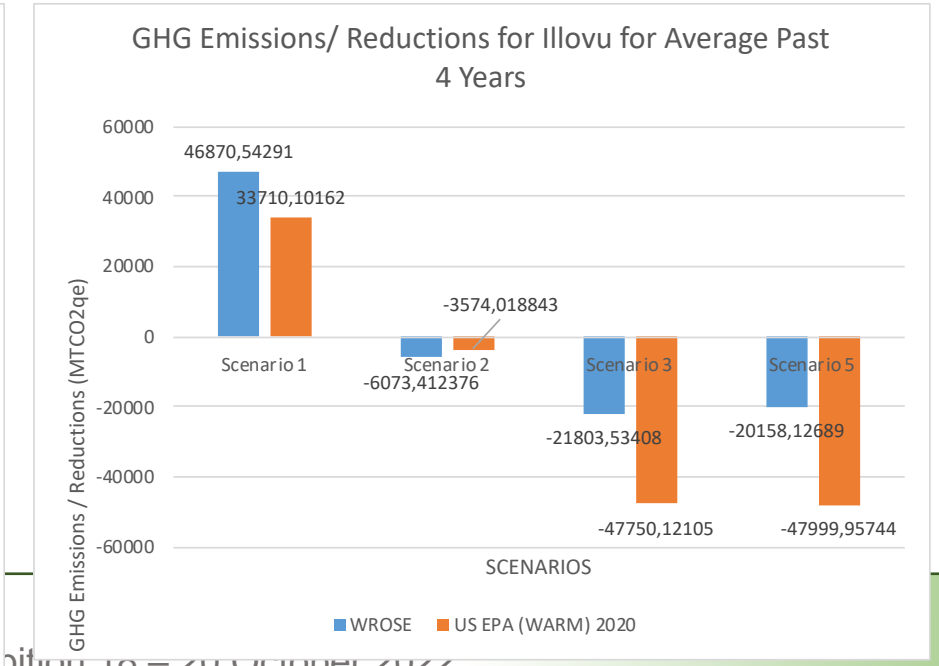


Figure 12: Scenario Analysis of BLS

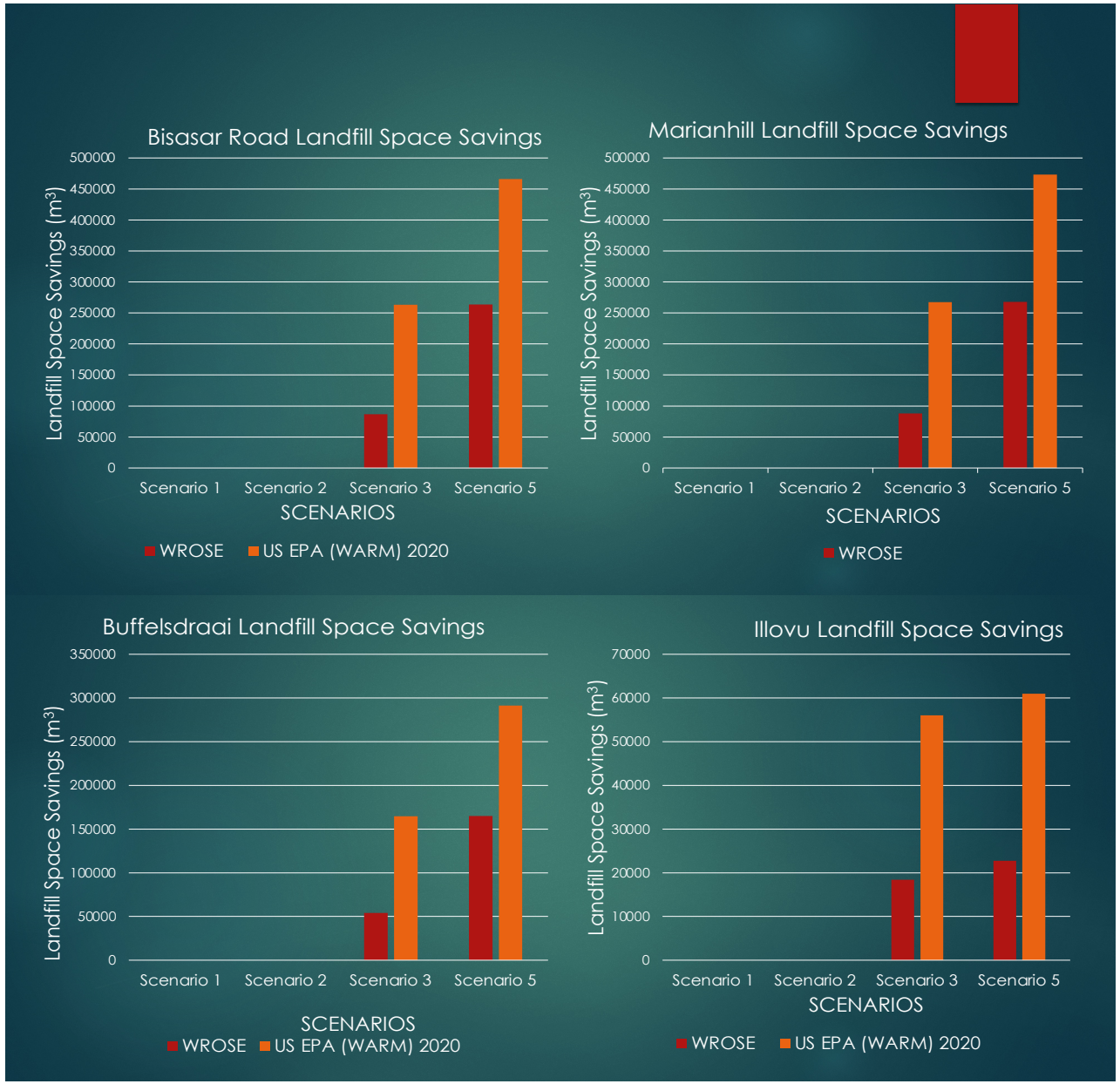

GHG Emissions/ Reductions for Bisasar Road for Average Past 4 Years
GHG Emission/ Reductions (MTCO2qe)
600000
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
476732,77
441369,6631
-17909,31205
-61774,29416
-135655,201
-224994,7056
-67950,10386
-235274,9556
Scenario 1
Scenario 2
Scenario 3
Scenario 5
SCENARIOS
WROSE
US EPA (WARM) 2020


GHG Emissions/ Reductions for Marianhill for Average Past 4 Years
GHG Emission/ Reductions (MTCO2eq)
700000
600000
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
578492,2466
576684,1403
-74960,12957
-150016,5206
-214432,0588
-81234,19966
-224875,873
Scenario 1
Scenario 3
Scenario 5
SCENARIOS
WROSE
US EPA (WARM) 2020

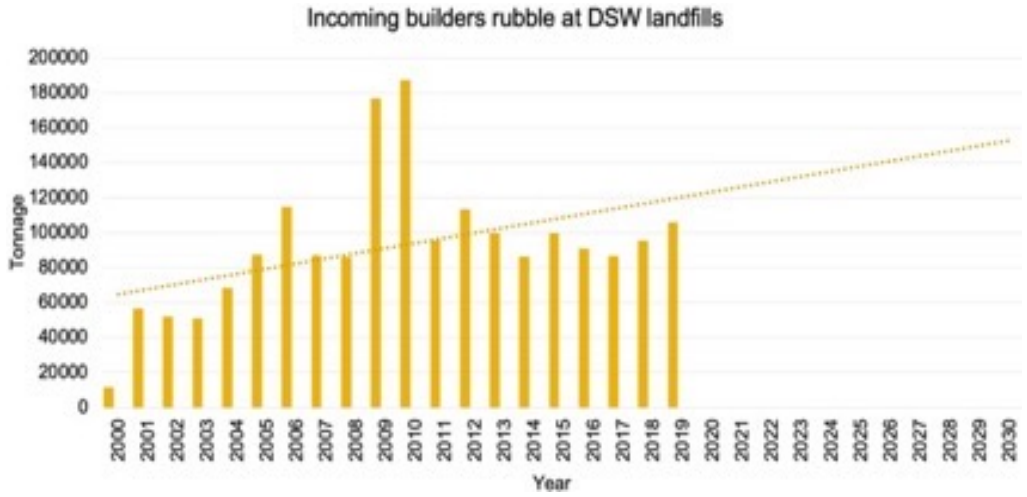

GHG Emissions/ Reductions for Buffelsdraai for Average Past 4 Years
GHG Emission/ Reductions (MTCO2qe)
350000
300000
250000
200000
150000
100000
50000
0
-50000
-100000
-150000
-200000
288176,4043
262461,8232
-12441,77427
-37341,45226
-83541,50278
-142188,9048
-41203,37995
-148617,4678
Scenario 1
Scenario 2
Scenario 3
Scenario 5
SCENARIOS
WROSE
US EPA (WARM) 2020

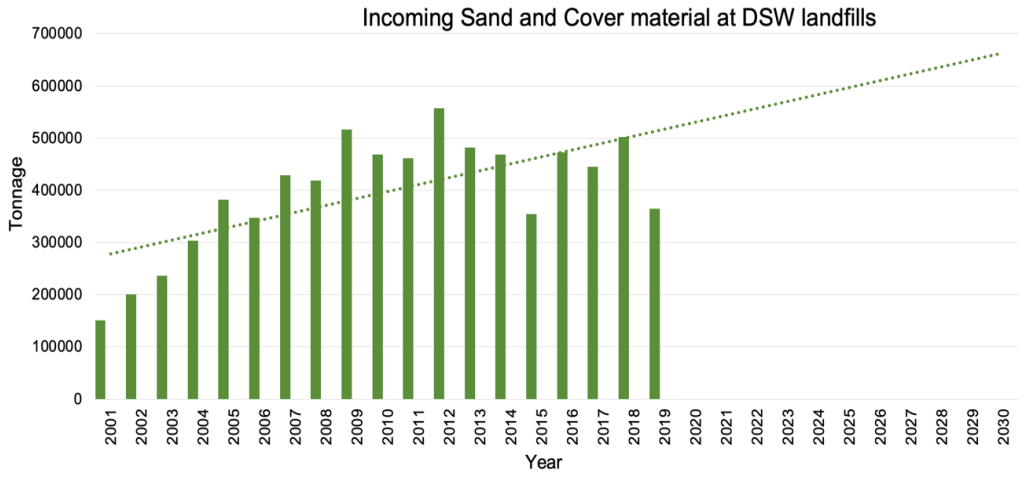

GHG Emissions/ Reductions for Illovu for Average Past 4 Years
GHG Emissions / Reductions (MTCO2qe)
60000
40000
20000
0
-20000
-40000
-60000
46870,54291
33710,10162
-3574,018843
-6073,412376
-21803,53408
-47750,12105
-20158,12689
-47999,95744
Scenario 1
Scenario 2
Scenario 3
Scenario 5
SCENARIOS
WROSE
US EPA (WARM) 2020

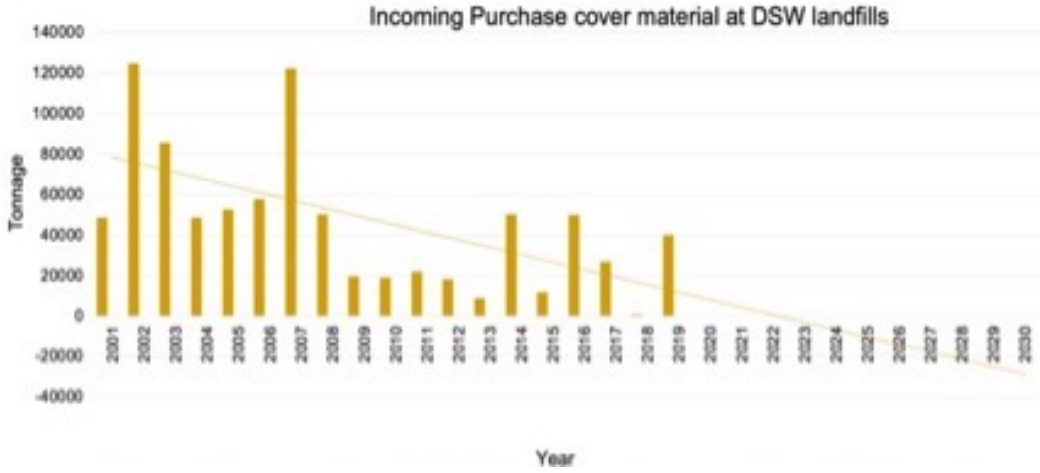
WASTE STREAM: General MSW
CASE STUDY: eThekwini Municipality



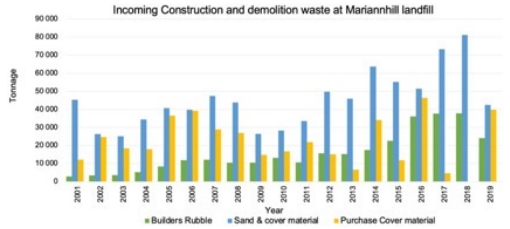
WASTE STREAM: C&D waste
CASE STUDY: eThekwini Municipality

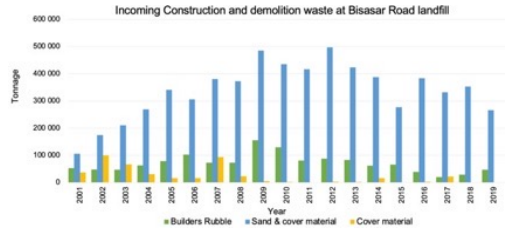


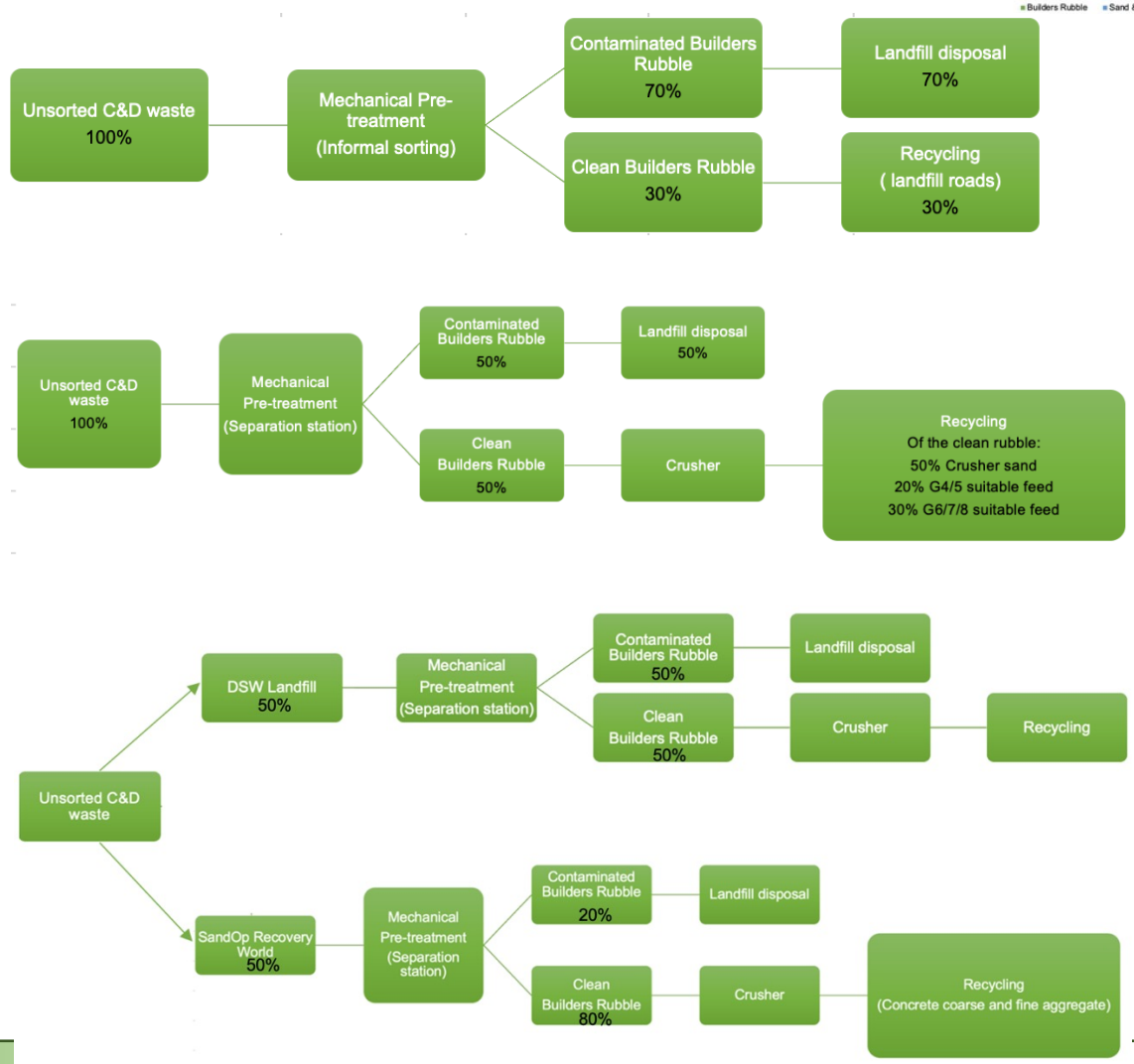




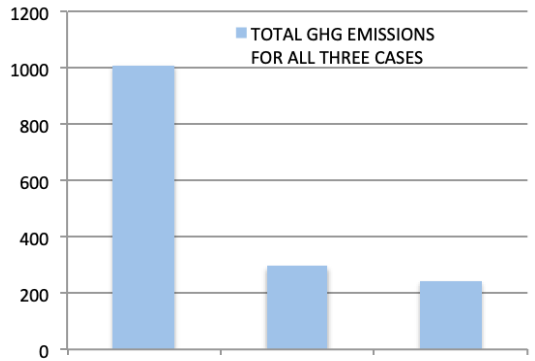
WASTE STREAM: C&D waste
CASE STUDY: eThekwini Municipality



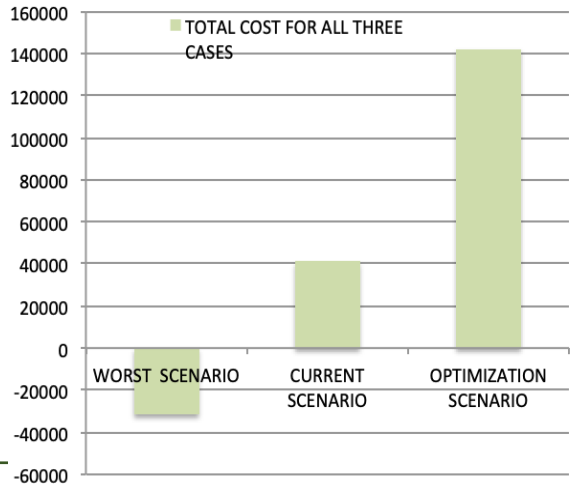




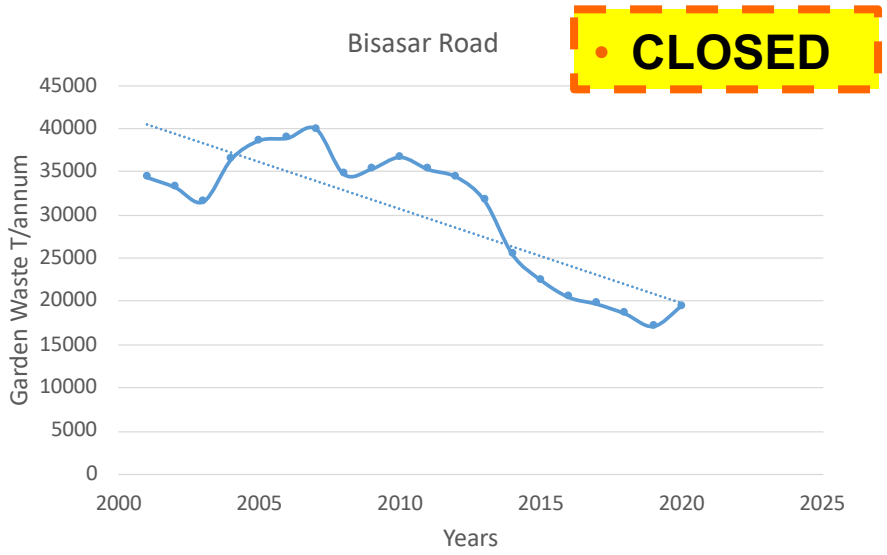
TOTAL GHG EMISSIONS FOR ALL THREE SCENARIOS

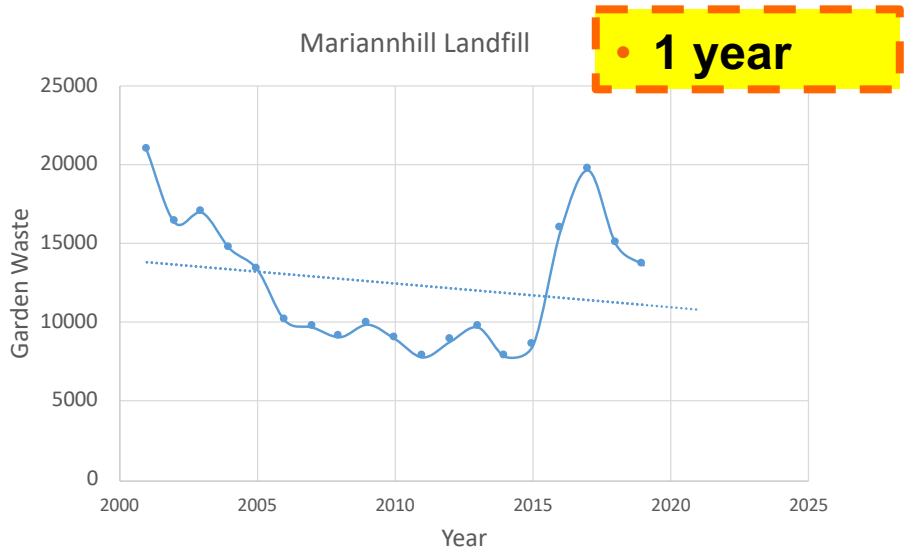


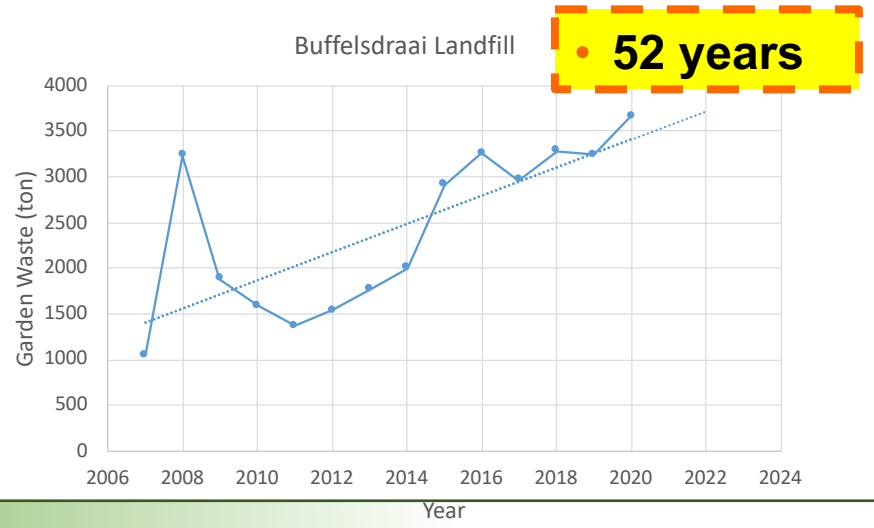
TOTAL COST FOR ALL THREE SCENARIOS

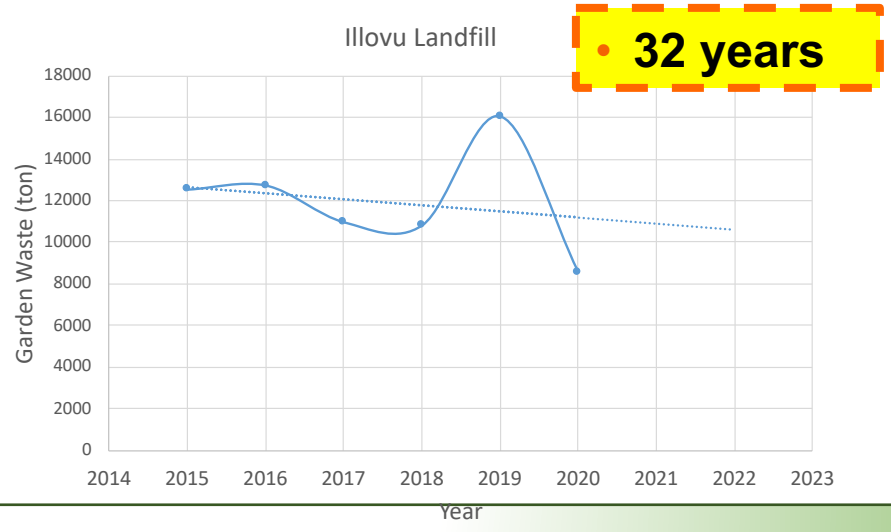


WASTE STREAM: Garden Refuse
CASE STUDY: eThekwini Municipality









WASTE STREAM: Garden Refuse
CASE STUDY: eThekwini Municipality

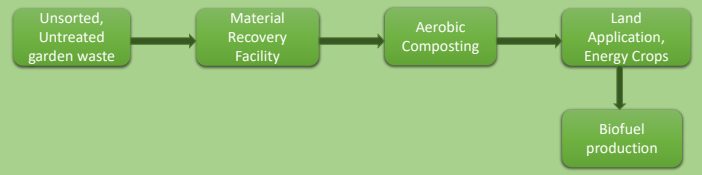
Scenarios Analysed

Scenario 1 – Status quo

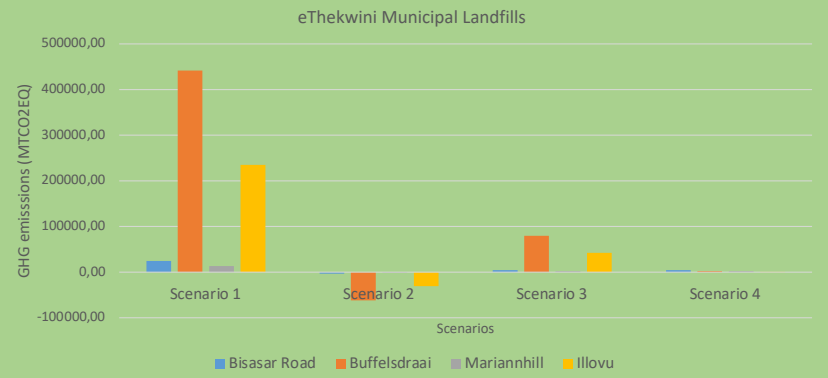
Scenario 2

Scenario 3

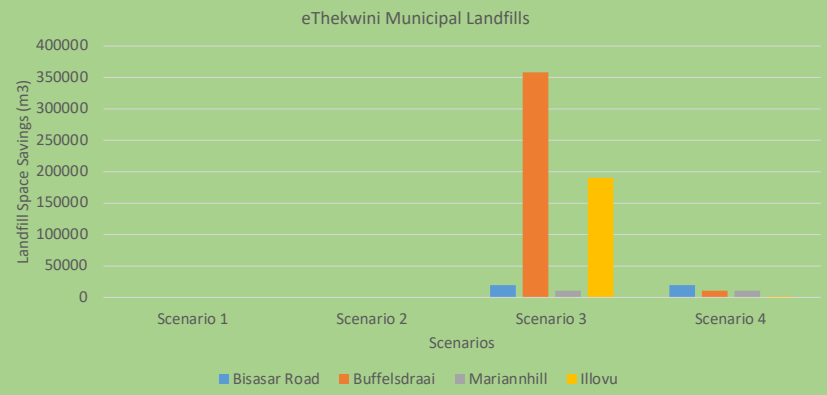
Scenario 4 – Implemented at closure



Total Projected GHG emissions



Total Projected Landfill Space Savings



Thank you

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