CENTRE FOR RENEWABLE & SUSTAINABLE ENERGY STUDIES

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# Overview of key strategies for mitigating methane emissions from waste

**Prof. Cristina Trois**

PRESIDENTIAL
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TOWARDS A JUST TRANSITION

Webinar Series

The Role of Methane Abatement in South Africa's Climate and Development Pathway

10 Nov 2025

# Acknowledgments

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WORLD BANK GROUP Sustainable Development

IIASA International Institute for Applied Systems Analysis

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**The WROSE I-Map:**
BLACK BOX


**Alignment/Resources**

***Waste RDI Roadmap Grant #51*** *– "A comprehensive waste management model for promoting effective decision-making and sustained climate change stabilisation for South Africa" (2022-2024)*

forestry, fisheries & the environment
Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

CSIR our future through science

NRF National Research Foundation | RISA Research and Innovation Support and Advancement

technology innovation AGENCY Innovating Tomorrow Together

UNIVERSITY OF KWAZULU-NATAL INYUVESI YAKWAZULU-NATALI | UKZN INQUBATE

iwwg international waste working group SOUTHERN AFRICAN REGIONAL BRANCH

sanedi South African National Energy Development Institute


Waste management in an emerging economy is a complex social, technical, and environmental challenge

# The Challenge in SA

**>100M**

tonnes of waste disposed yearly

**80%**

waste to landfill/dumps

**6.5%**

carbon emissions from waste

# ….. and Globally

**>2b**

tonnes of waste generated

**>30%**

Ends up in dumps

**3%**

carbon emissions from waste

# Landfill space – DAY ZERO


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)

**31M**

**Waste: ~76% of all waste generated in SA is disposed of to landfill**

(DEFF, 2018 - State of Waste Report)

**Solid waste disposal** contributing 18,253 Gg $CO_2e$ (79.2%) of the total Waste sector emissions.

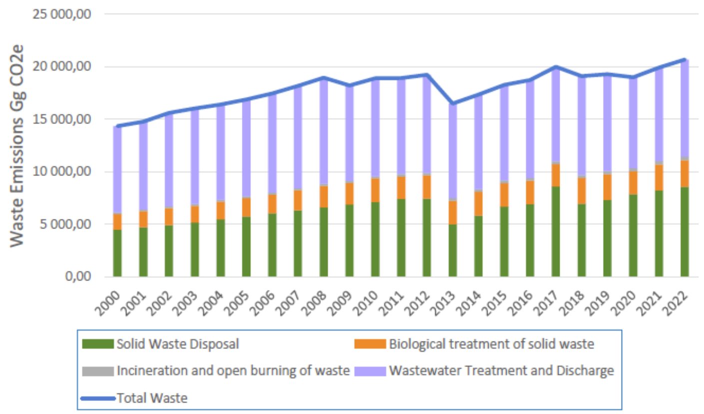
**Wastewater treatment and discharge** contributed a further 4,458 Gg CO2e (19.3%) of waste emissions.

**Open burning of waste** contributed 335 Gg CO2e (1.5%). Emissions from the **biological treatment of solid waste** were estimated to be insignificant (0.0019 Gg CO2e).

**Solid waste disposal** increased its contribution to the total Waste sector emissions by 4.5% (from 74.6% to 79.2%) since 2000.

**Incineration and open burning** of waste increased its contribution since 2000 by 0.5% (1.0% to 1.5%)

**Wastewater treatment and discharge** declined from 24.4% to 19.3% by 2020. This is largely driven by a 54.2% decline in Industrial wastewater treatment and discharge.




$CH_4$ has increased of **36.5% in 2020** and GHG emissions have increased of almost **56.7%** (**2.7%** year by year) from waste sector in SA in past 20 years (2000-2020).
*(7th NIR, 2017 and 8th NIR, 2022)*

4.8/5.3%

The waste sector in South Africa contributes to **4.8%** of GHG emissions and **36.5%** of total $CH_4$ Waste sector emissions have increased by 26,5% in 2020(DFFE, 2022*)

**GHG Emissions: 23,046 Gg$CO_2$e = 23.046 Mt $CO_2$e (2020)**


Waste management technologies
Waste data
wrose
Best solution
Indicators


Our Solution
Sound decision-making
Zero waste to landfill
Circular economy $1T
Energy recovery
Job creation 13%
wrose

# Key drivers

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**DRIVERS**

- ❑ **Strengthen the MPA process** to fill gaps/uncertainties in data and emissions factors for the waste sector
- ❑ **Align the WROSE model** to the MPA process for municipalities and provinces

- ❑ **Progressively migrate from a Tier 1** methodology for the assessment of GHG emissions to **Tier 3** promoting the adoption of the WROSE model as a country-specific model for the waste sector

- Tier 1 methods apply IPCC default emission factors and use IPCC default models
- Tier 2 methods apply country-specific emission factors and use IPCC default models
- **Tier 3 methods apply country-specific emission factors and use country-specific models.**

- ❑ **Understand the contribution of the metros** with respect to the national GHG emissions from the waste sector
- ❑ **Need to harmonize the MPA process** at national level **with the** use of the WROSE Decision-support tool at **municipal level**

| 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<br>• Reporting on climate change / standards<br>• Development of GHG indicators | • **Technologies** to **achieve stabilisation**<br>• **Localisation** of appropriate technologies<br>• **Low-carbon** economy | • Low carbon economy / best scenario<br>• De-carbonization of South Africa | • Transitioning from resilient to smart, wise, and sustainable<br>• Indicators of sustainability |


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# Application of WROSE as Tier 3 – Country Specific Model

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- To **map GHG emissions** from landfill sites in the eight Metro Municipalities
- To **collect and project critical indicators/data** (socio-economic factors, waste stream analysis, waste composition and generation rates)
- To **calculate and forecast** from 2020 to 2050, **carbon emissions** from the scenarios, **waste diversion rate**, and **landfill airspace savings** from all scenarios
- To apply the WROSE model to **develop** and **evaluate the scenarios** that can achieve **maximum waste minimisation** and **climate stabilisation** in the next 30 years
- To use the **WROSE model** and the results of the study to **inform** a **climate change mitigation strategy** in the eight metros

# WROSE as Country-Specific Tier 3 model

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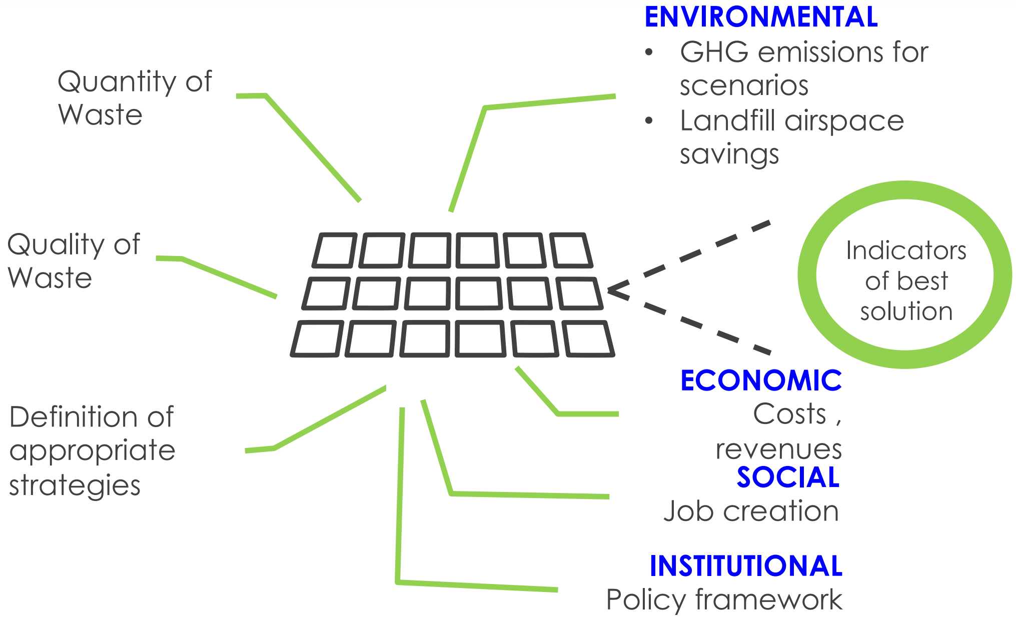
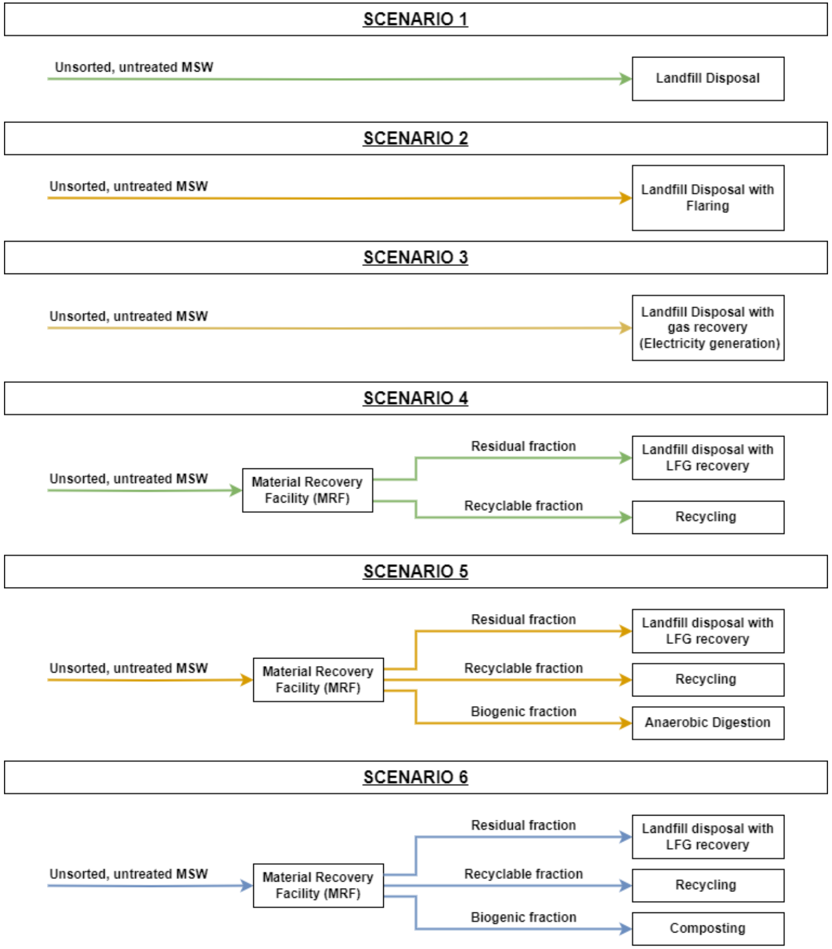
## Key features of the model

- waste data and emission factors
- LCA integrated with MCDA
- Context specific solution

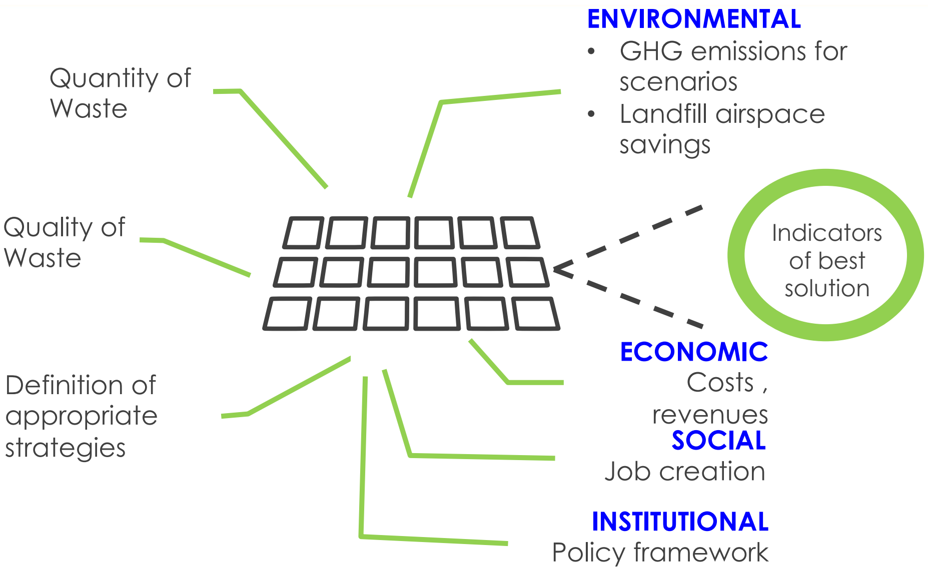
Developed since 2009 by the South African Research Chair (SARCHI) in Waste and Climate Change Group

Initial goal: to identify and evaluate **zero-waste strategies** using a dry-wet waste diversion model to prevent the disposal of recoverable or biodegradable waste fractions into landfills





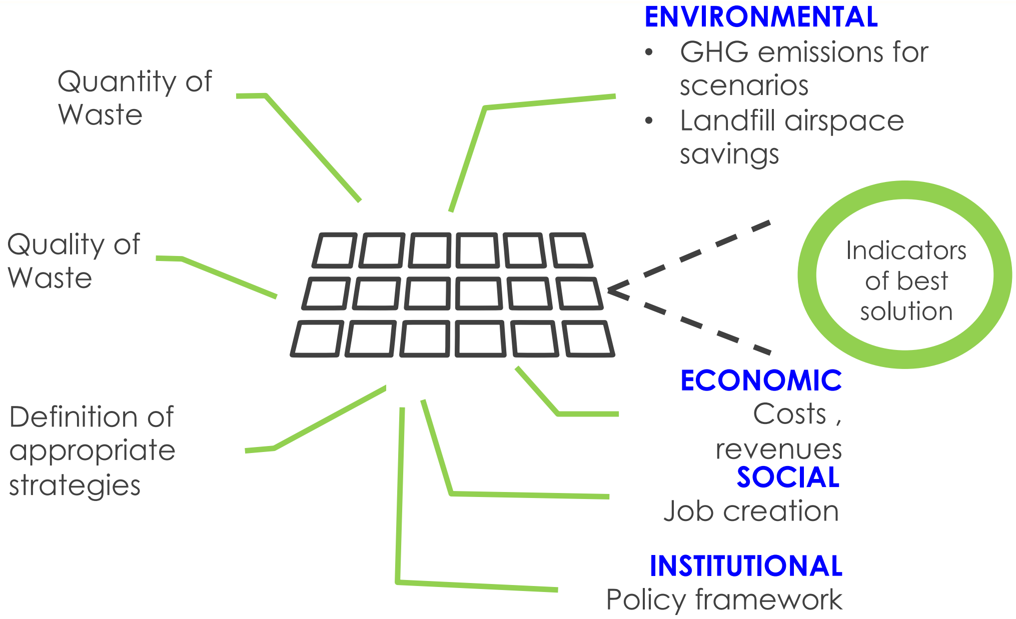

waste resource optimisation scenario evaluation



wrose
waste resource optimisation scenario evaluation

## Waste categories

- Paper
- Glass
- Metals (mixed)
- Polyethylene-terephthalate (PET)
- High-density polyethylene (HDPE)
- Low-density polyethylene (LDPE)
- Other Plastics
- Food waste
- Garden refuse
- Other waste

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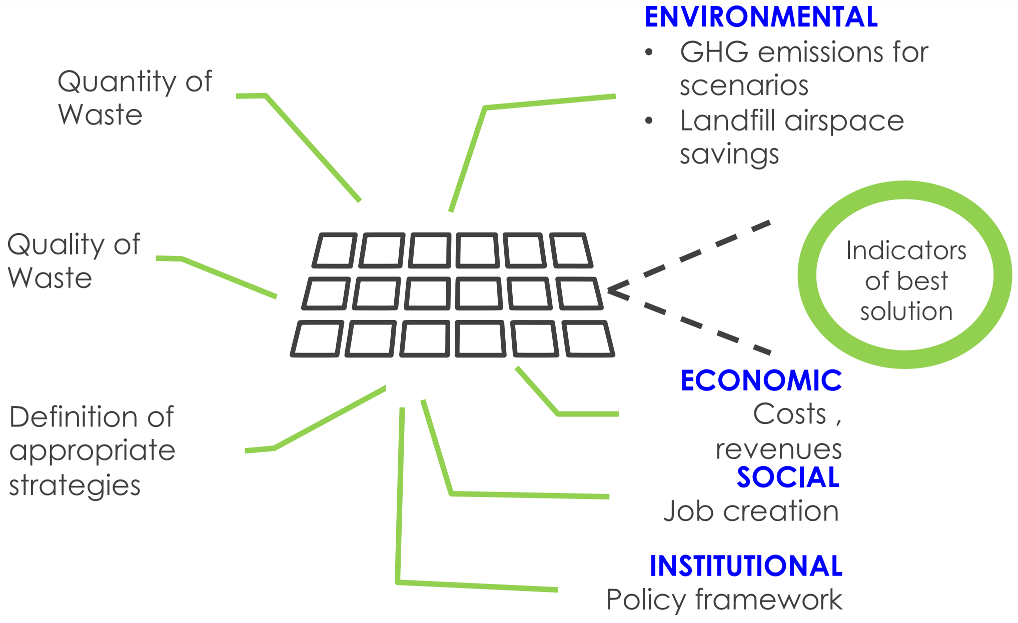
## Technologies included:

- Landfill disposal (LF)
- Landfill disposal with gas recovery and flaring (LFF)
- Landfill disposal with gas recovery and electricity generation (LFG)
- Material recovery facility (Dirty MRF)
- Recycling (Clean MRF)

- Composting
- Anaerobic digestion
- Incineration
- Pyrolysis
- Gasification
- Plasma gasification



**Indicators**

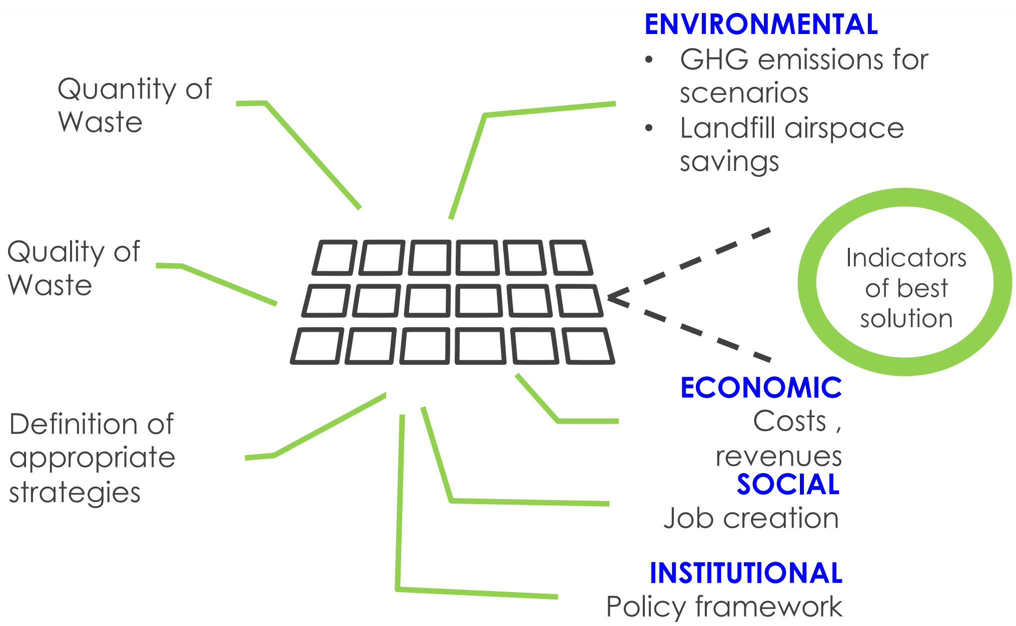
- Greenhouse gas emissions
- Landfill airspace savings
- Landfill monetary savings
- Waste diversion rate

Energy consumption

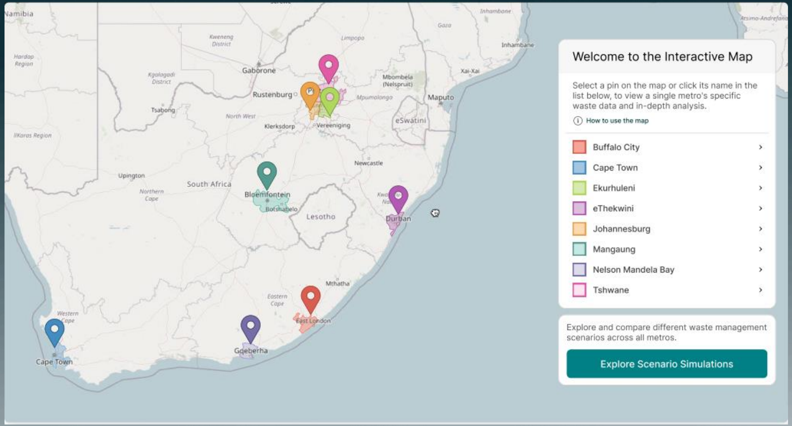
Economic indicators

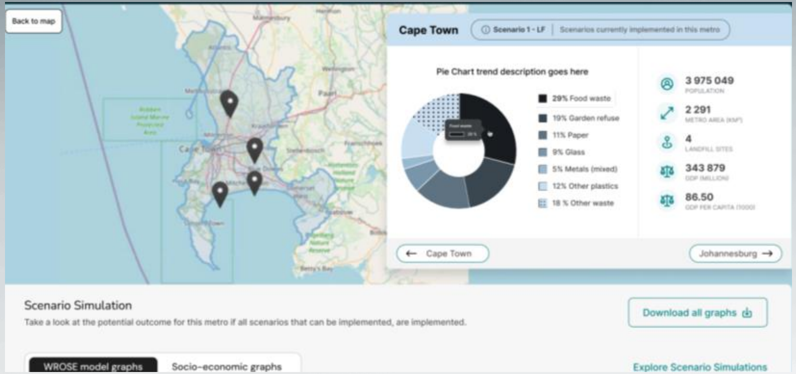
Social indicators

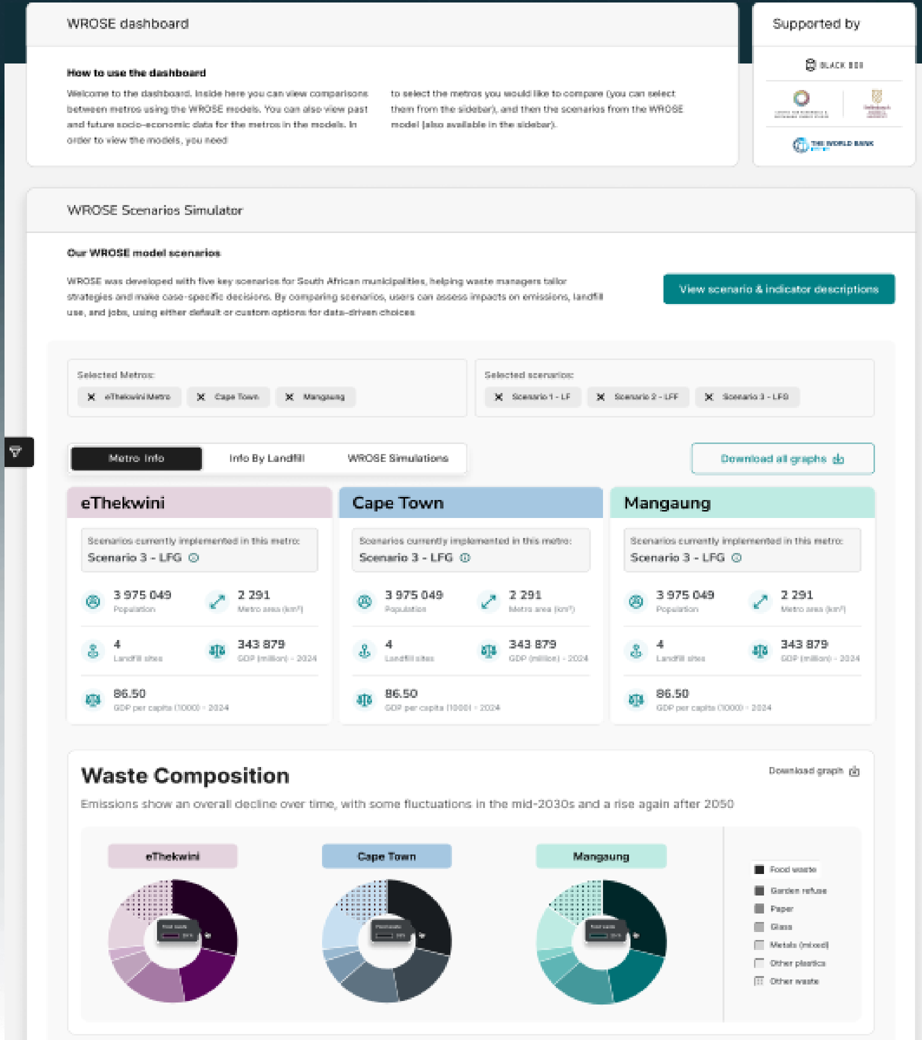
Institutional indicators

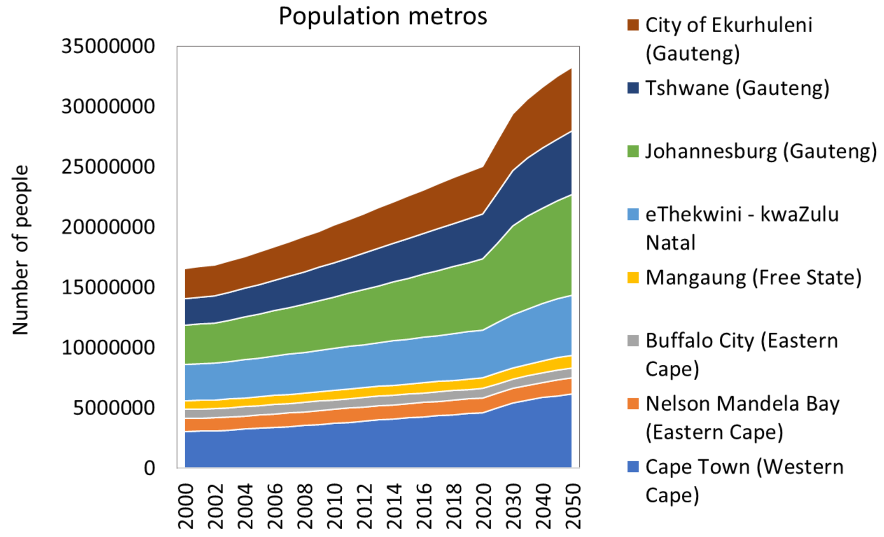


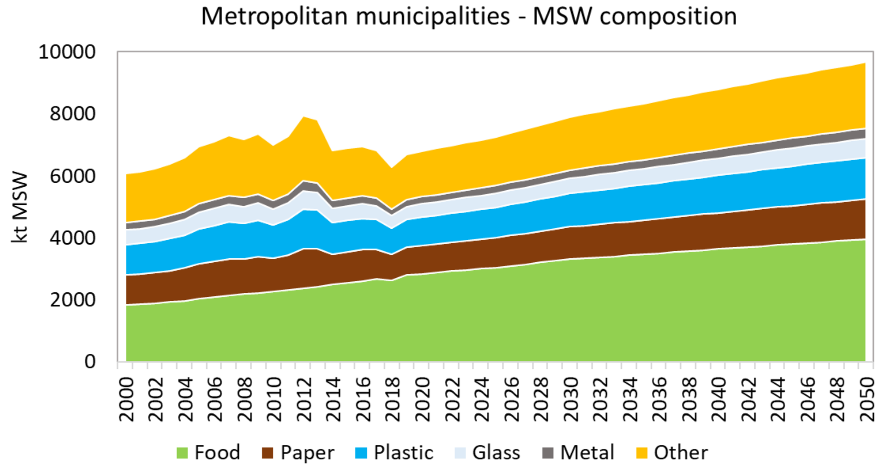
www.wrose.co.za

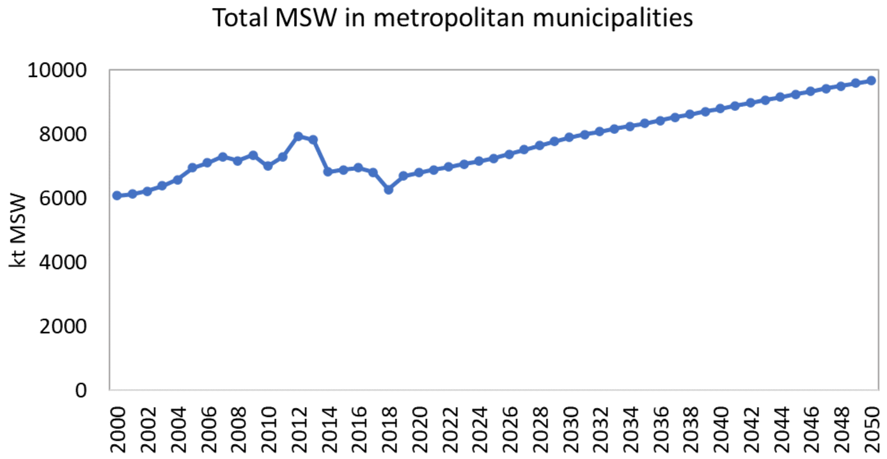


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# How wrose works



- Situational Analysis:
  - A "**With Existing Measures**" (**WEM/BAU**) projection, incorporating the impacts of climate change mitigation policies and measures implemented up to 2019
  - A "**With Additional Measures**" (**WAM**) projection, assuming that existing, pipeline and potential future climate change mitigation policies and measures are implemented

## Scenarios for the City of Cape Town

- Baseline scenario (WEM/BAU)
  3. Landfill disposal with gas recovery and electricity generation
- Alternative scenarios (WAM)
  4. MRF + material recovery
  5. MRF + material and energy recovery

<table>
<tr><th>Metropolitan Municipality</th><th>WEM (BAU)</th><th>WAM<br>(Low-hanging)</th><th>WAM<br>(fixed RR, 5%-40%)</th><th>WAM<br>(progressively increasing RR, 5% to 40%, every 5 years)</th></tr>
<tr><td>Buffalo City</td><td rowspan="5">Landfilling<br><u>(scenario 1)</u></td><td rowspan="5">Landfilling with gas recovery and flaring<br><u>(scenario 2)</u></td><td rowspan="8">Landfilling with gas recovery and electricity generation<br>+<br>recycling<br>+<br>composting<br>+<br>anaerobic digestion<br><u>(scenario 5)</u></td><td rowspan="8">Landfilling with gas recovery and electricity generation<br>+<br>recycling<br>+<br>composting<br>+<br>anaerobic digestion<br><u>(scenario 5)</u></td></tr>
<tr><td>Ekurhuleni</td></tr>
<tr><td>Mangaung</td></tr>
<tr><td>Nelson Mandela Bay</td></tr>
<tr><td>Tshwane</td></tr>
<tr><td>Cape Town</td><td rowspan="3">Landfilling with gas recovery and electricity generation<br><u>(scenario 3)</u></td><td rowspan="3">Landfilling with gas recovery and electricity generation + recycling<br><u>(scenario 4)</u></td></tr>
<tr><td>eThekwini</td></tr>
<tr><td>Johannesburg</td></tr>
</table>

# WEM/BAU 2030 estimations

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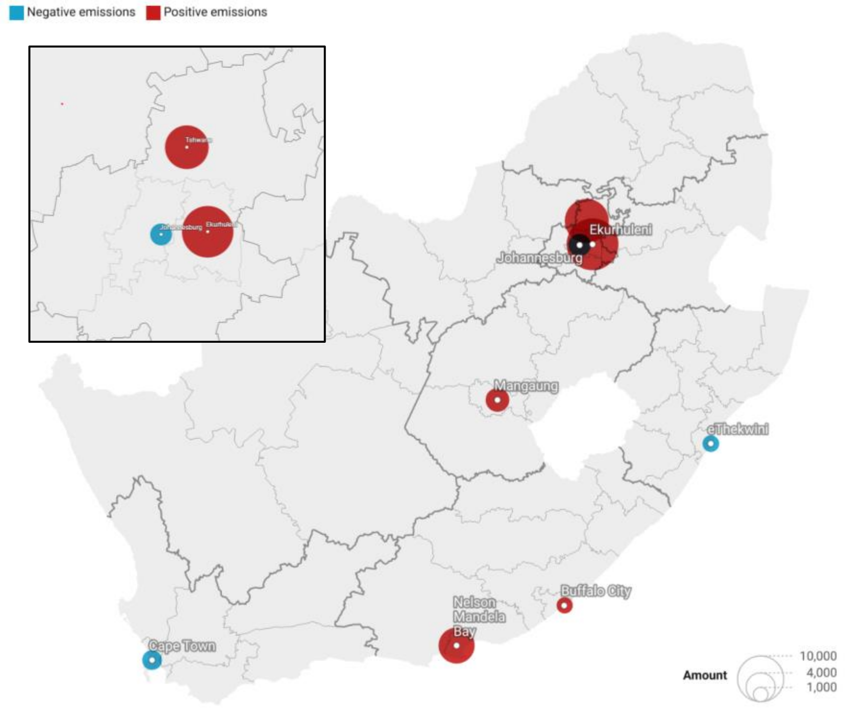
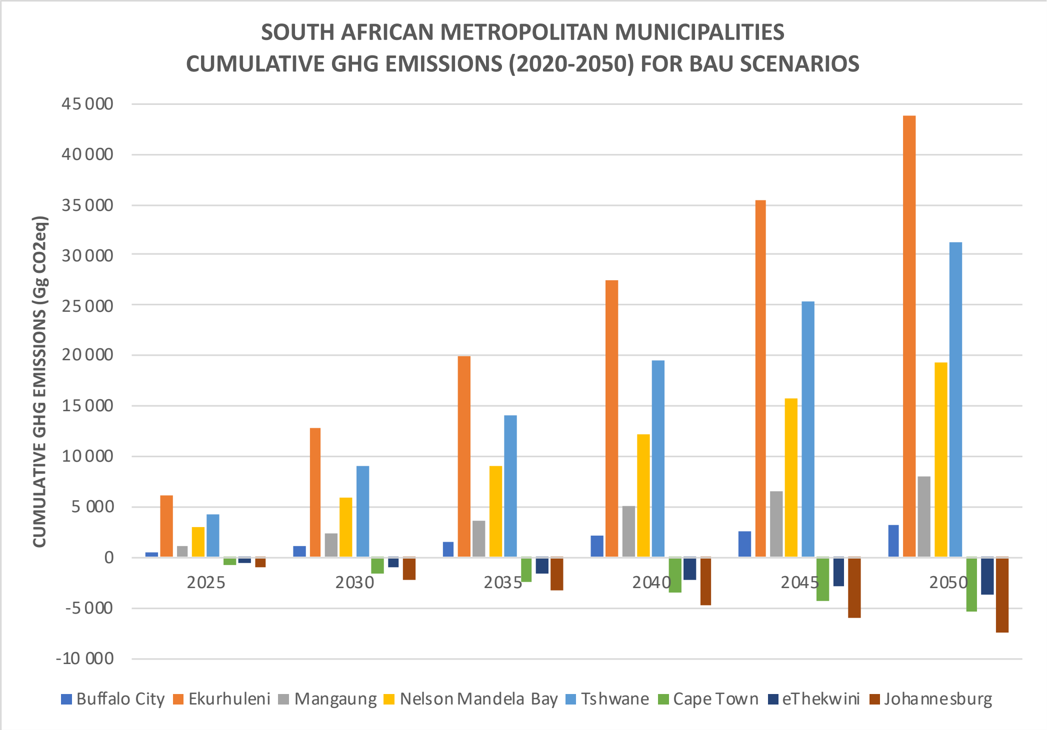
2020-2030 Projected Cumulative GHG Emissions (Gg CO2eq) for the business-as-usual (BAU) scenario




Map: SARChI Chair in Waste and Climate Change • Created with Datawrapper

| Metropolitan Municipality | Business-as-usual (BAU) scenario | Projected cumulative GHG Emissions since 2020 (Gg CO2eq) | Metro's contribution to the total GHG Emissions |
|---|---|---|---|
| Buffalo City | Landfilling | 1,024 | 4% |
| Ekurhuleni | | 12,737 | 48% |
| Mangaung | | 2,413 | 9% |
| Nelson Mandela Bay | | 5,946 | 23% |
| Tshwane | | 9,058 | 34% |
| Cape Town | Landfilling with gas recovery and electricity generation | -1,603 | -6% |
| eThekwini | | -1,093 | -4% |
| Johannesburg | | -2,159 | -8% |
| TOTAL | | 26,353 | 100% |

# WEM/BAU 2020-2050



# WEM vs WAM at FIXED 5%RR

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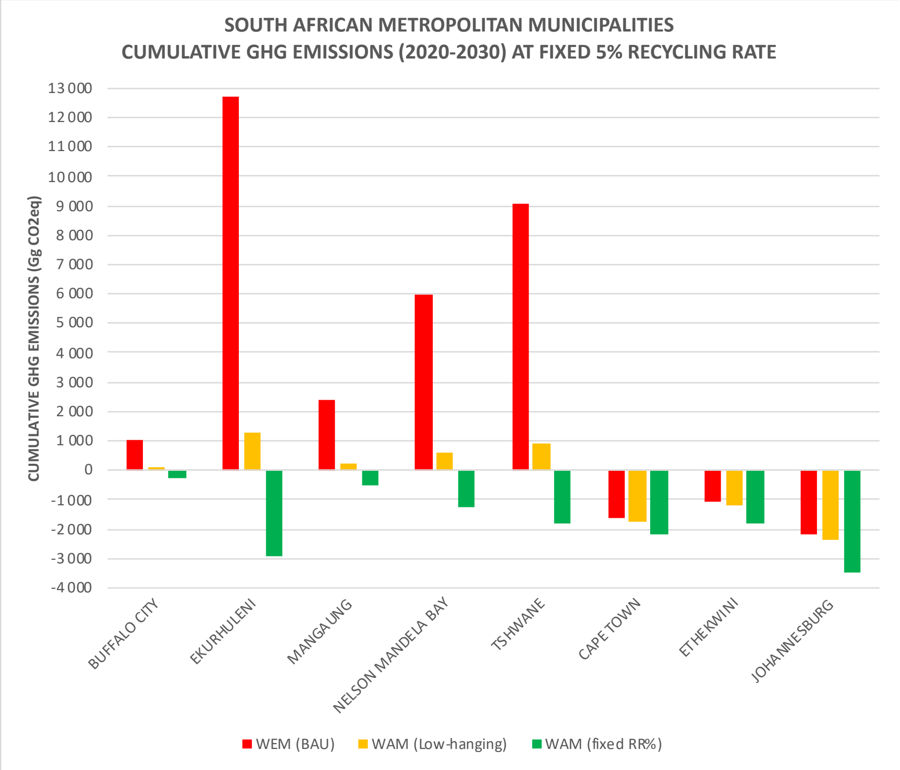


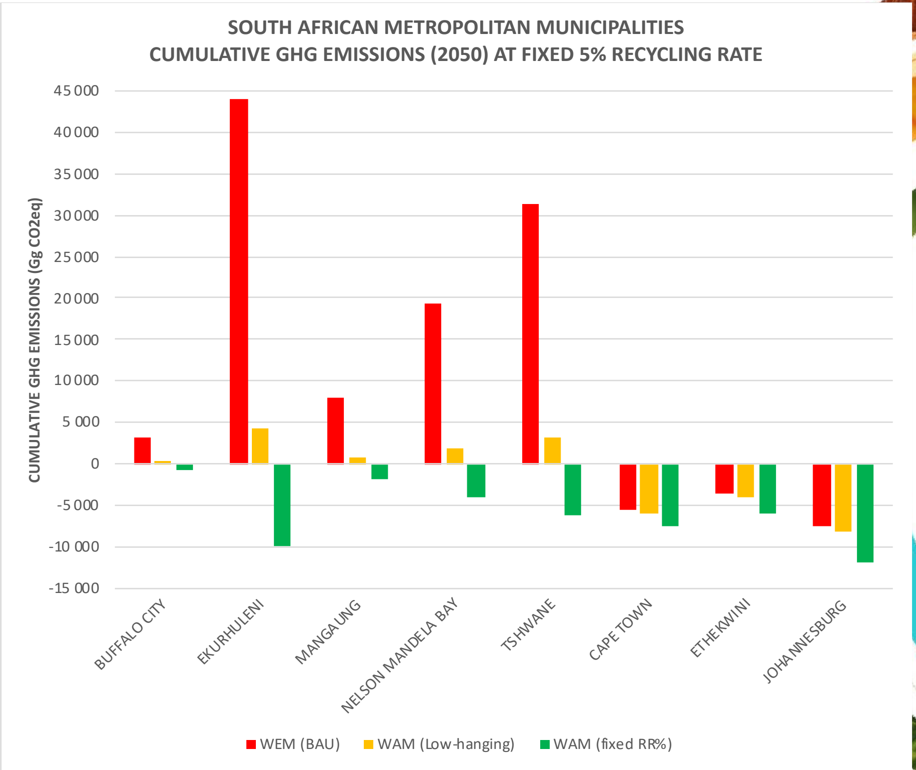

# Tshwane vs Johannesburg – increasing RR

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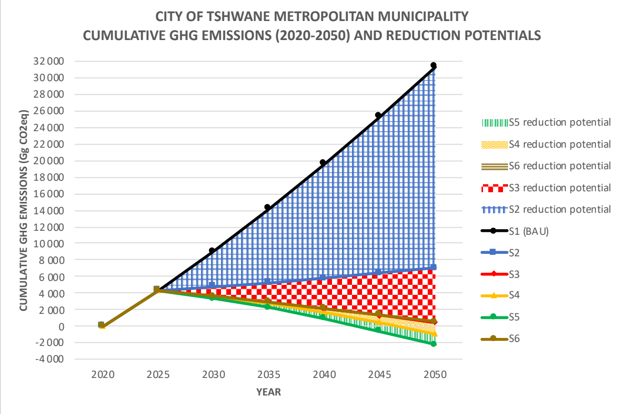


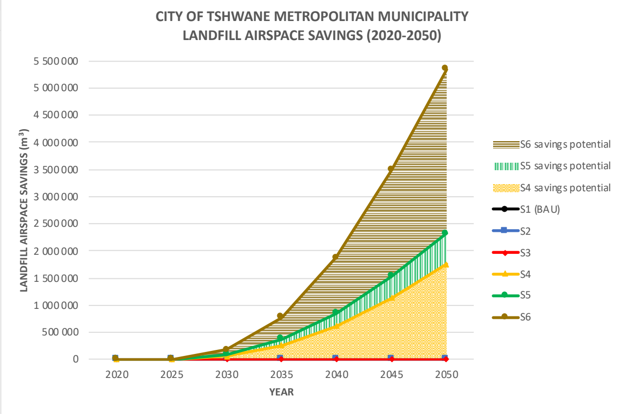


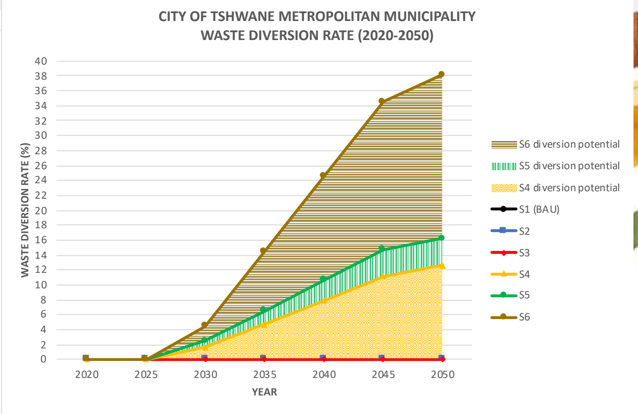


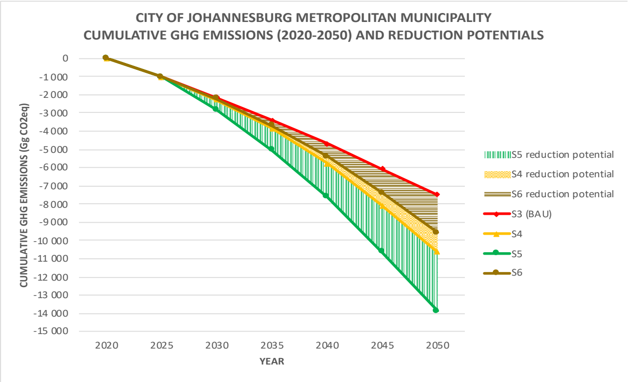


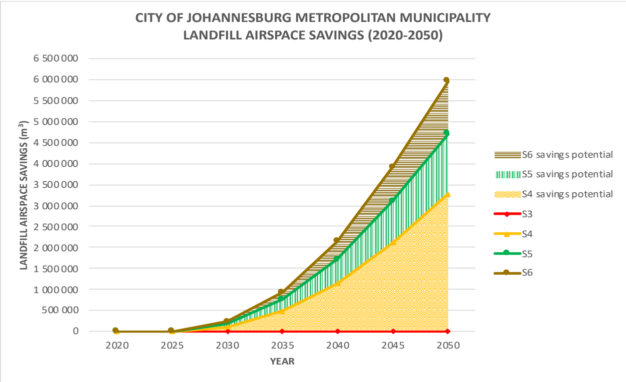


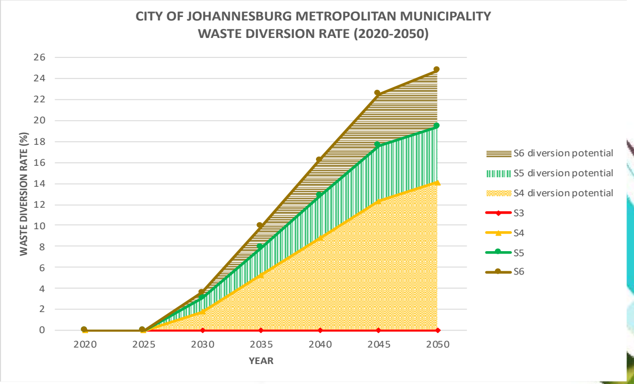

# The local context of a South African Metropolitan Municipality

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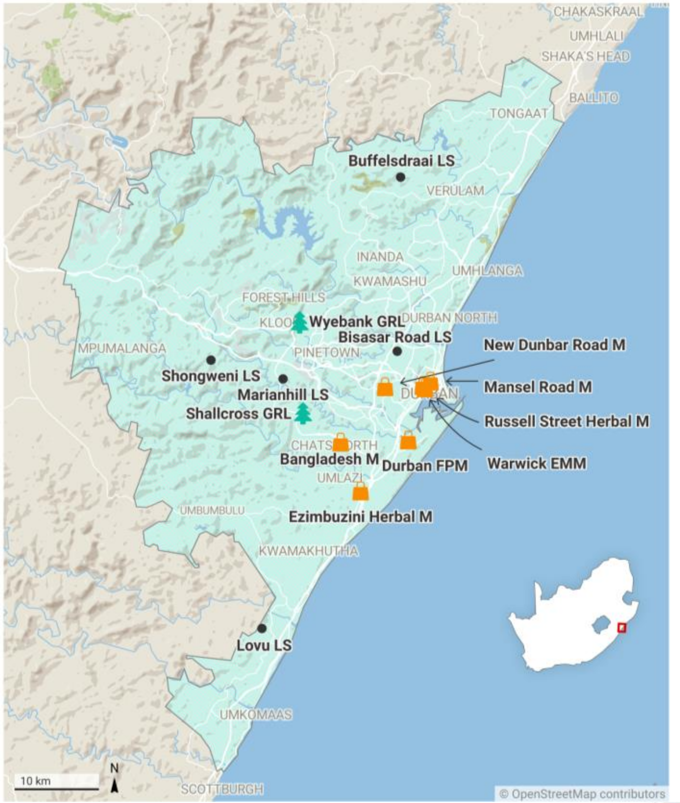
**Case study**: eThekwini Municipality (Durban, South Africa)

**Localisation** of organic waste sources and disposal sites in eThekwini

**Quantification** & **characterisation** of organic waste production

Simulation of **baseline vs. alternative** scenarios using WROSE



# A realistic source-separation scheme to collect clean feedstock

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**Pilot phase (2027-28)**

Fresh produce markets: 5,831 t/y (2.1%)

**Phase 1 (2029-30):**

Chatsworth: 11,549 t/y (4.0%)

**Phase 2 (2031-32):**

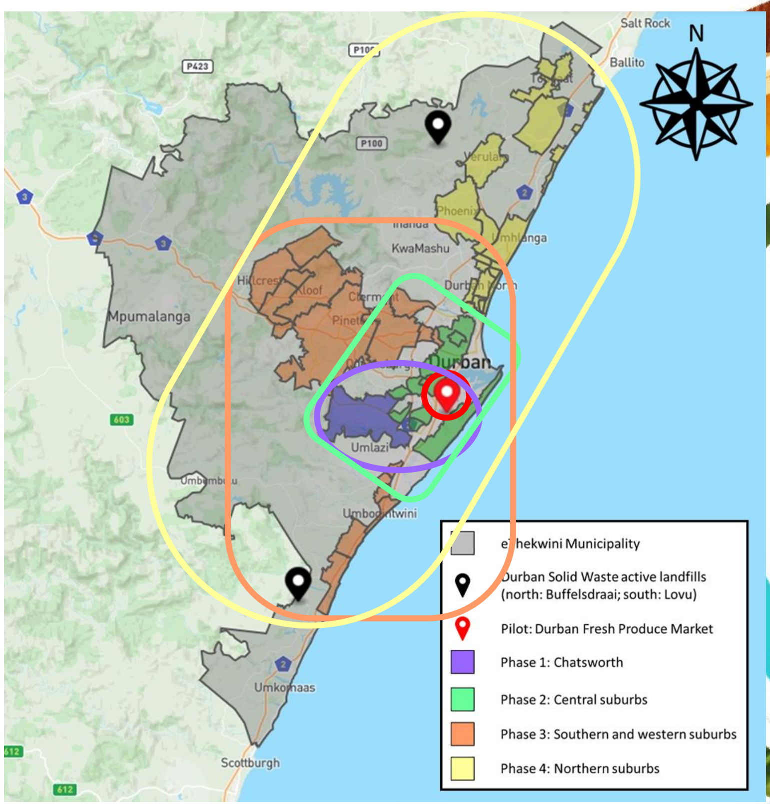
Central suburbs: 18,454 t/y (6.3%)

**Phase 3 (2033-34):**

Southeastern suburbs: 28,397 t/y (9.6%)

**Phase 4 (2035-50):**

Northern suburbs: 39,030 t/y (13.1%)



# Alternative scenarios can open new valorisation pathways

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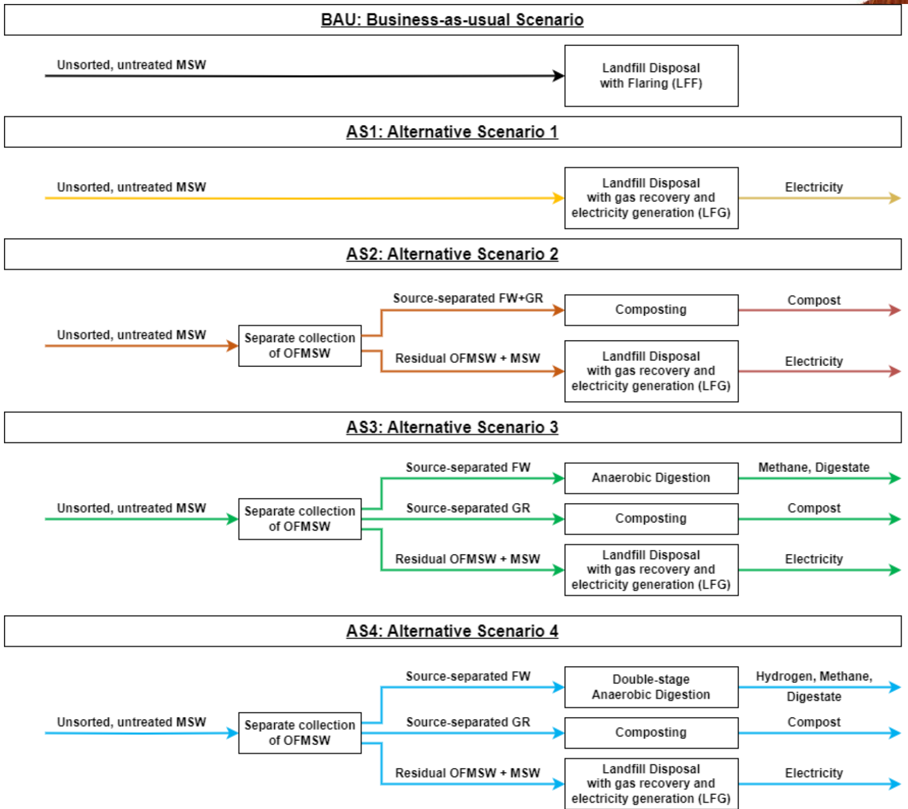
**BAU**: Landfill disposal with gas recovery and flaring (LFF)

**AS1**: Landfill disposal with gas recovery and electricity generation (LFG)

**AS2**: LFG and composting

**AS3**: LFG, anaerobic digestion (AD) and composting

**AS4**: LFG, double-stage anaerobic digestion (2S-AD) and composting



# Indicators selected to measure impacts and benefits

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Greenhouse gas emissions

Landfill airspace/monetary savings

Waste diversion rate

Net present value (NPV),

Internal Rate of Return (IRR),

Payback Period (PBP),

Profitability Index (PI),

Levelised Cost of Energy (LCOE)

Levelised Cost of Waste (LCOW)

Levelised Cost of H2 (LCOH)

# 2S-AD is effective in reducing GHG emission, but is outperformed by AD

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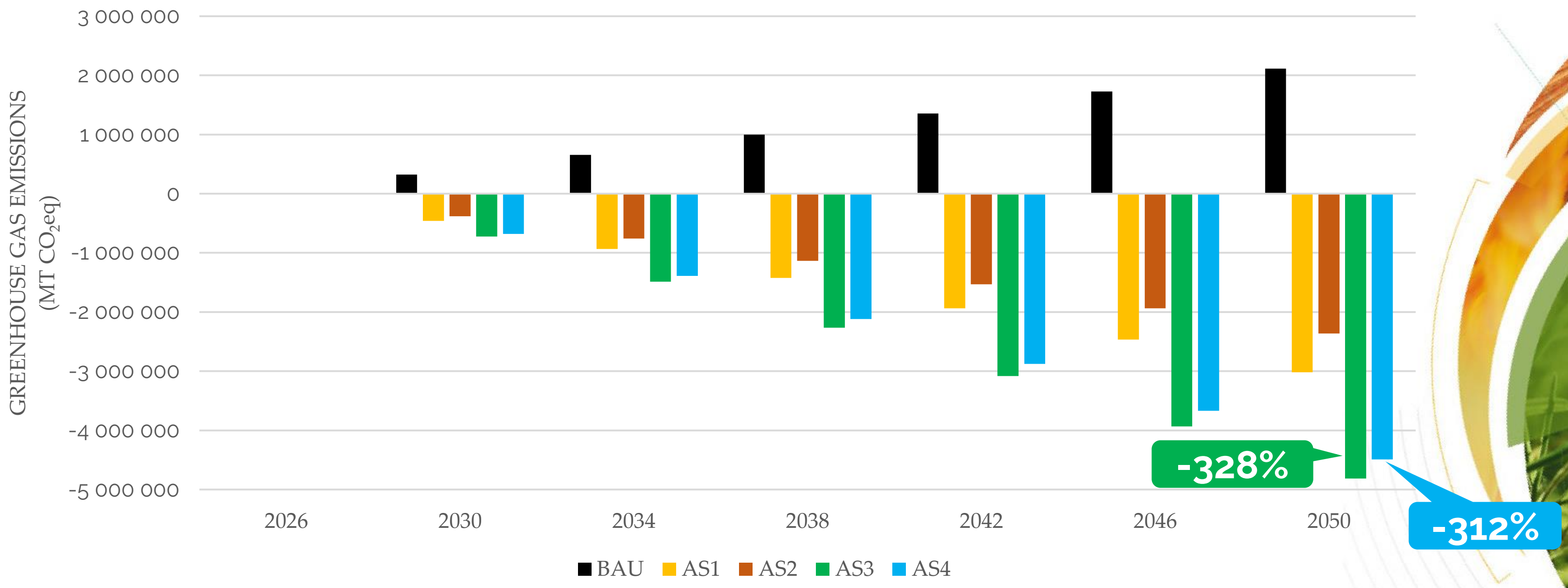

# Diverting FW and GR extends landfills' lifespan by 1.25 years

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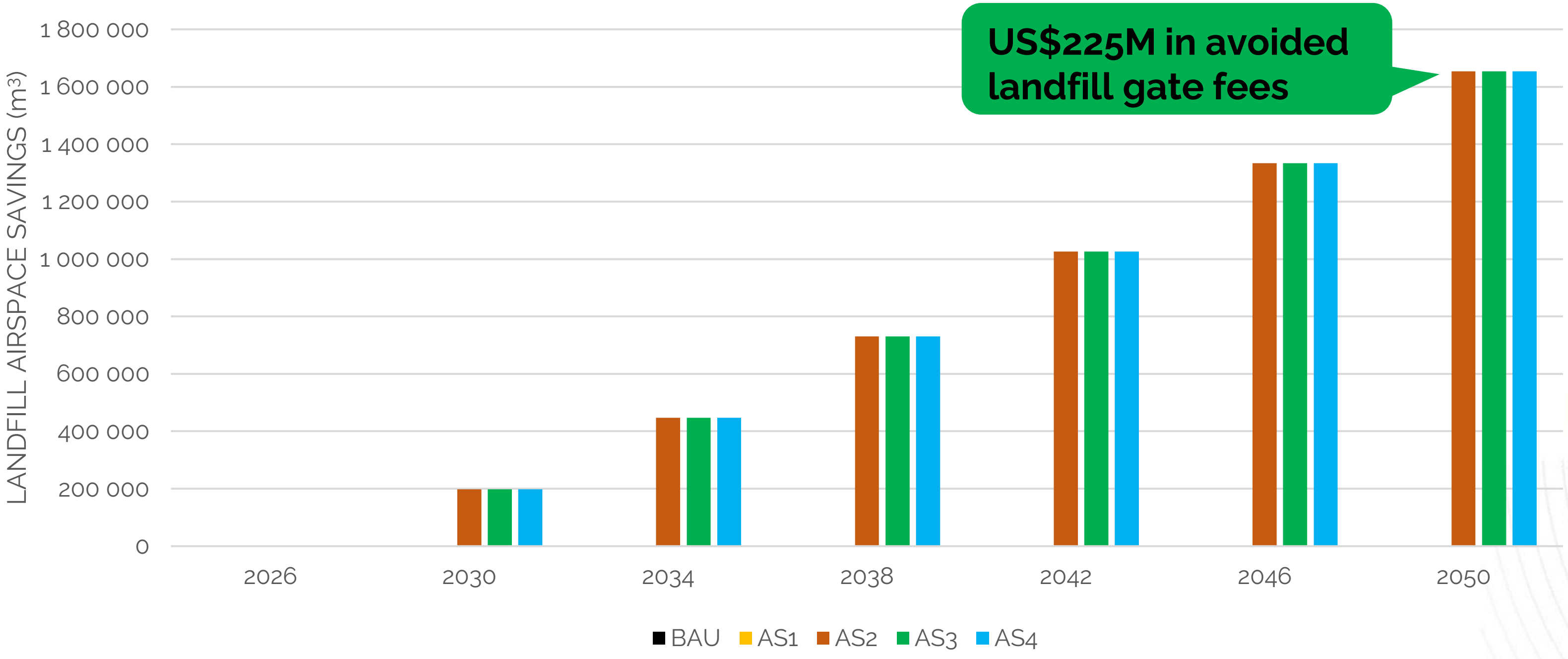

# Key strategies around Waste to Energy

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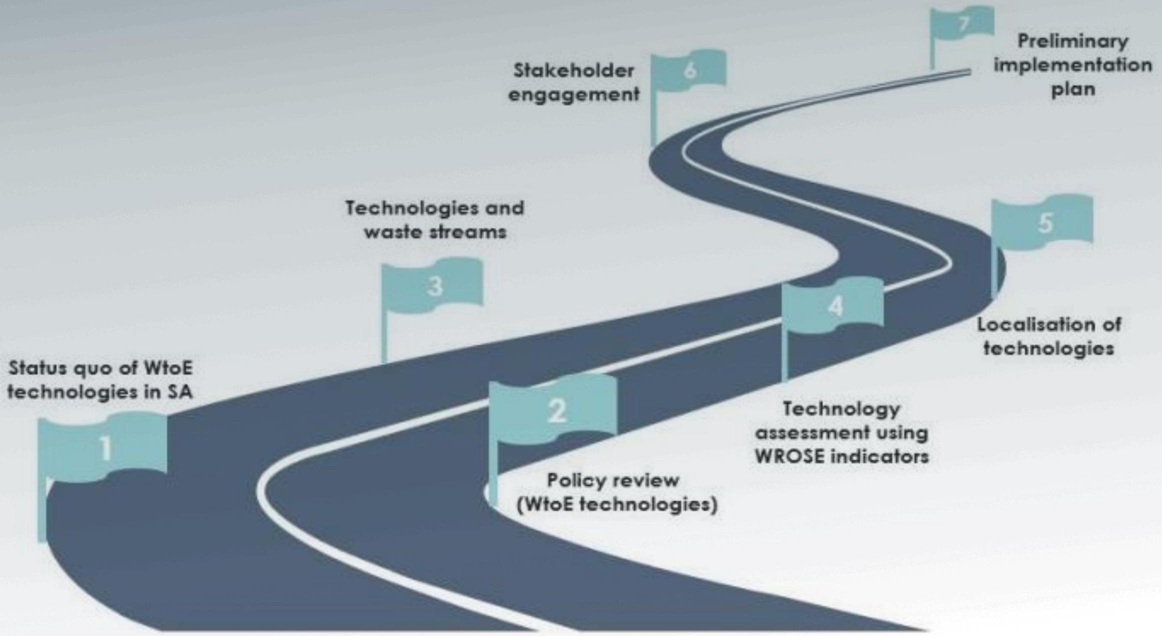
## South Africa's Waste-to-Energy Roadmap



# Study Objective:

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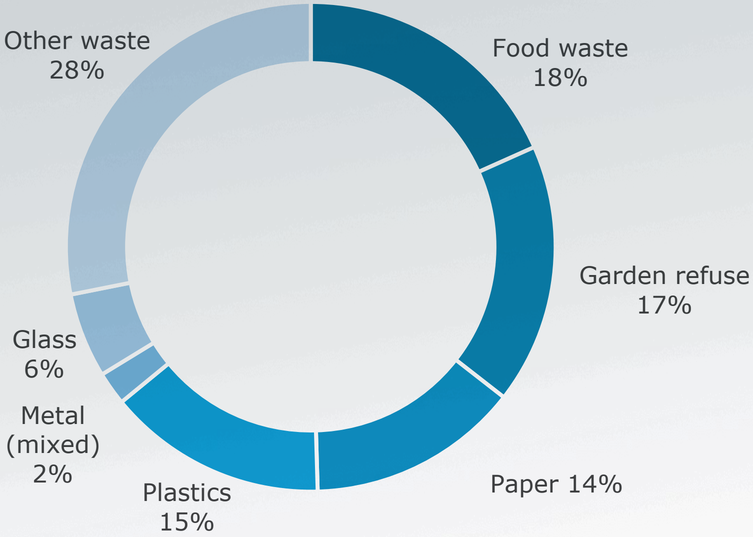
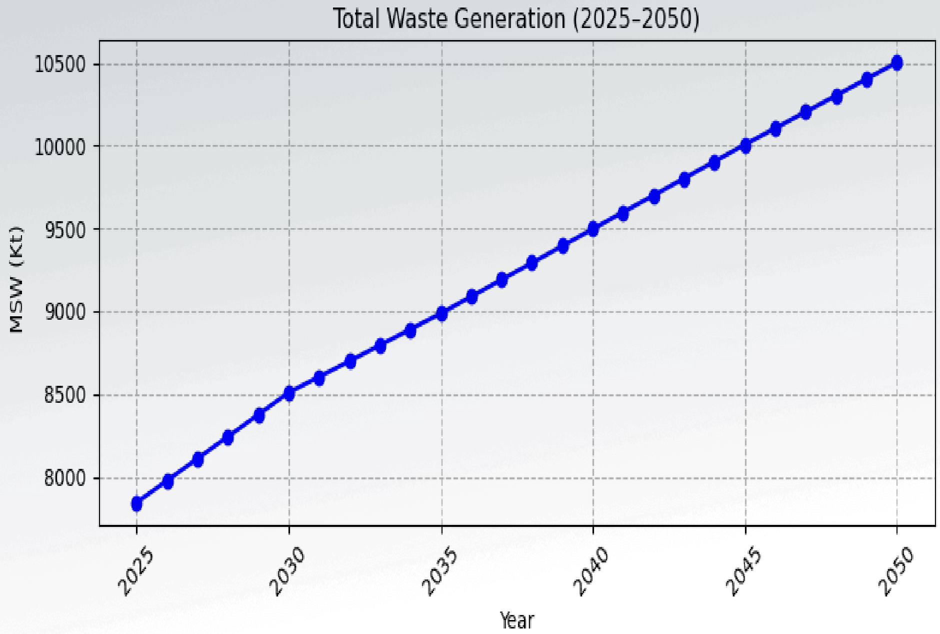
## Assessment of waste-to-energy (WtE) technologies in South African metropolitan municipalities

# Methodology

## Waste generation and composition




*Waste generation and composition in metropolitan municipalities Trois et al. (2023)*

# Scenarios definition

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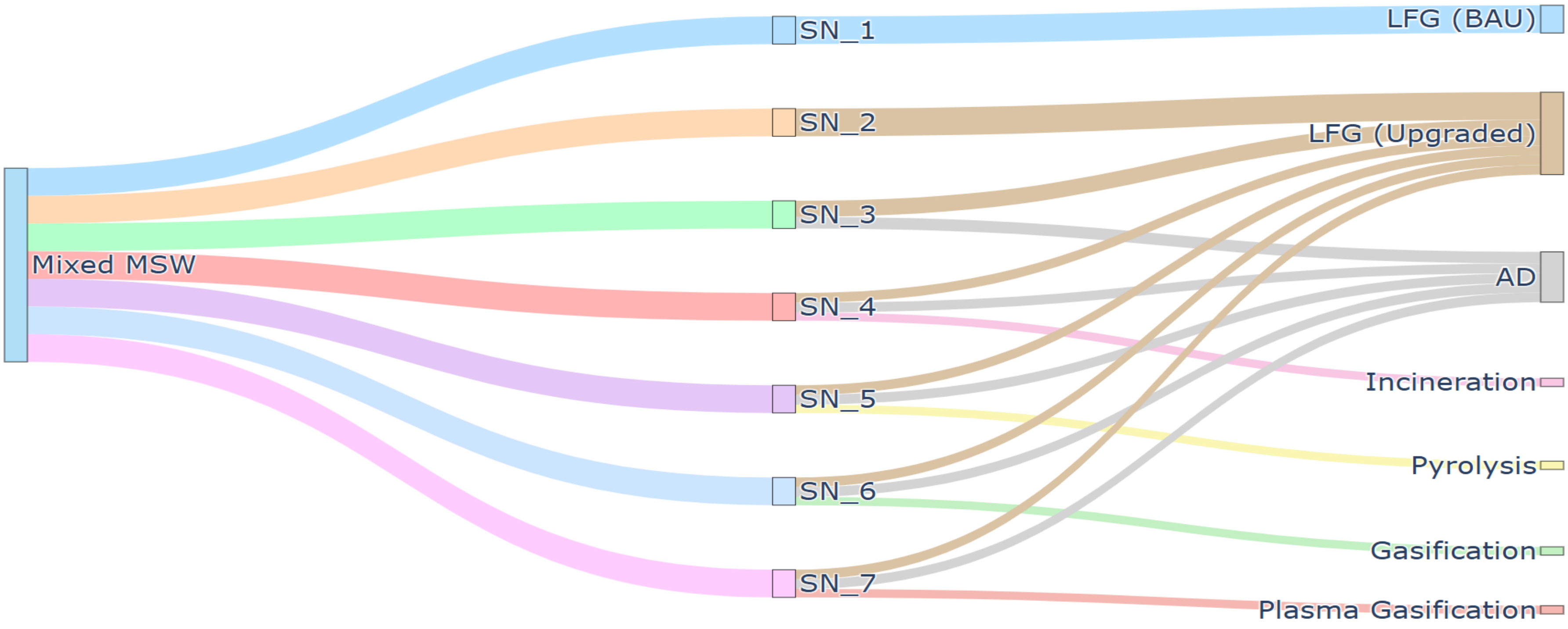
## Waste Management Scenarios



# Key assumptions



## KEY ASSUMPTIONS FOR WASTE-TO-ENERGY (Wte) SCENARIOS

### Defining the Baseline and Future Potential

**SCENARIO ONE (LFG BAU)**

Metropolitan Municipalties:

Combined Capacity: 38.1 MW

Source: CDM (2025); Mutungwazi at. (2018)

**SCENARIO TWO (LFG UPGRADED)**

- LFG Collection Efficiency: 75%
- Methane Content: 50%
- Conversion Efficiency: 40%

Optimized LFG to Electricity

**SCENARIOS THREE–SEVEN**

Waste Recovery rate (%)

AD

| 2027 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|
| 15% | 30% | 40% | 45% | 50% |

Waste to Energy

| 2027 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|
| 30% | 30% | 45% | 60% | 75% |

# Energy production

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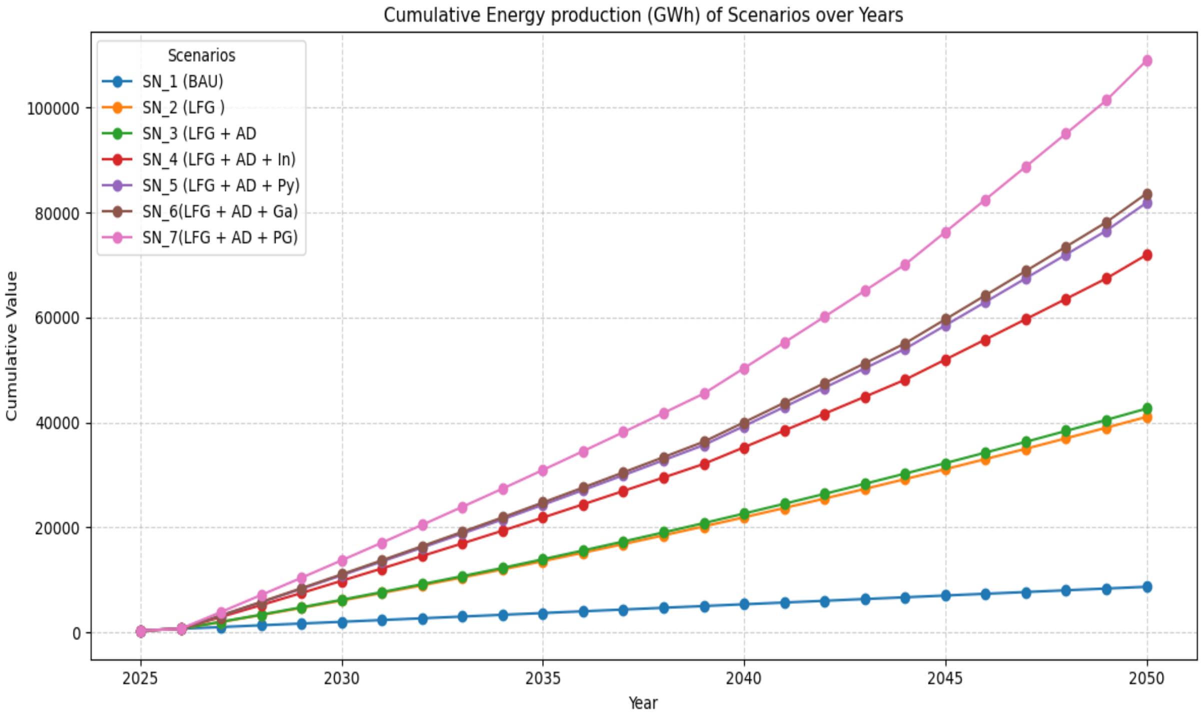


Figure 4 Energy production from waste-to-energy technologies

**Estimated households powered**

2,600 kWH/year (South Africa)

**128,462**
Scenario 1

**1,064,231**
Scenario 4

**1,619,231**
Scenario 7

# GHG emissions reduction

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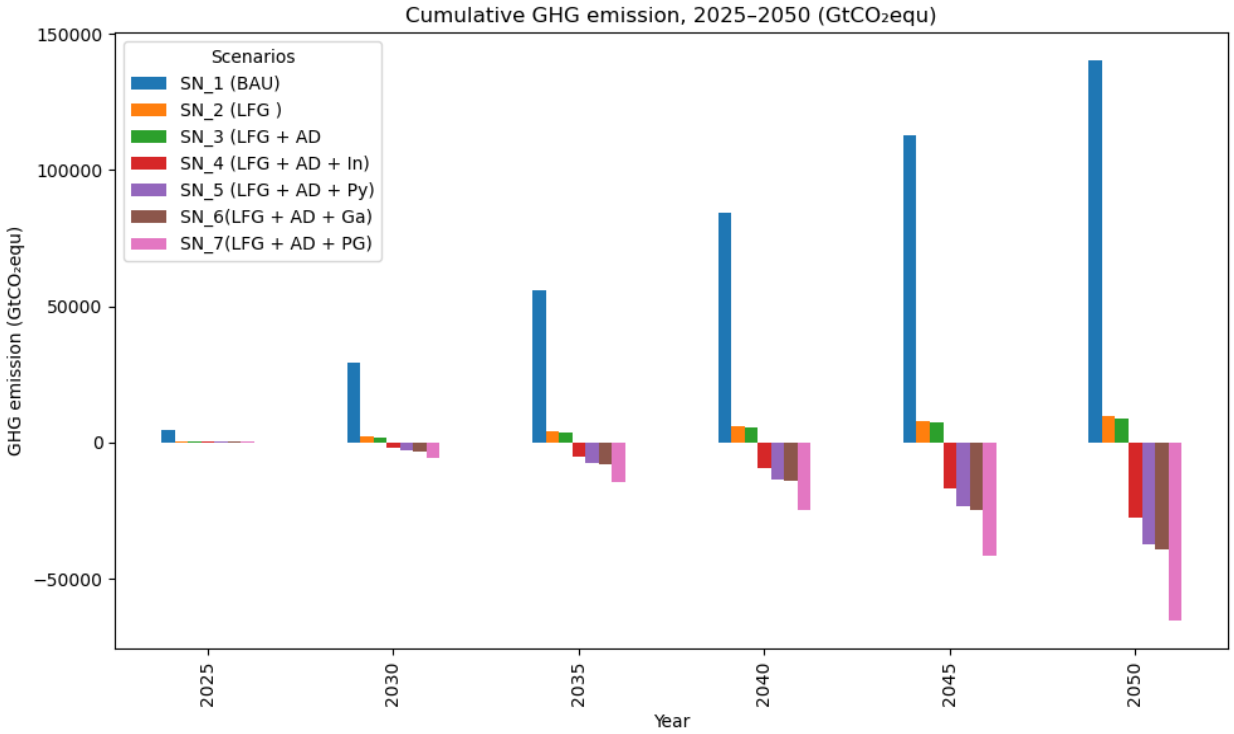



Figure 5 Energy production from waste –to-energy technologies

# Landfill Space-Savings

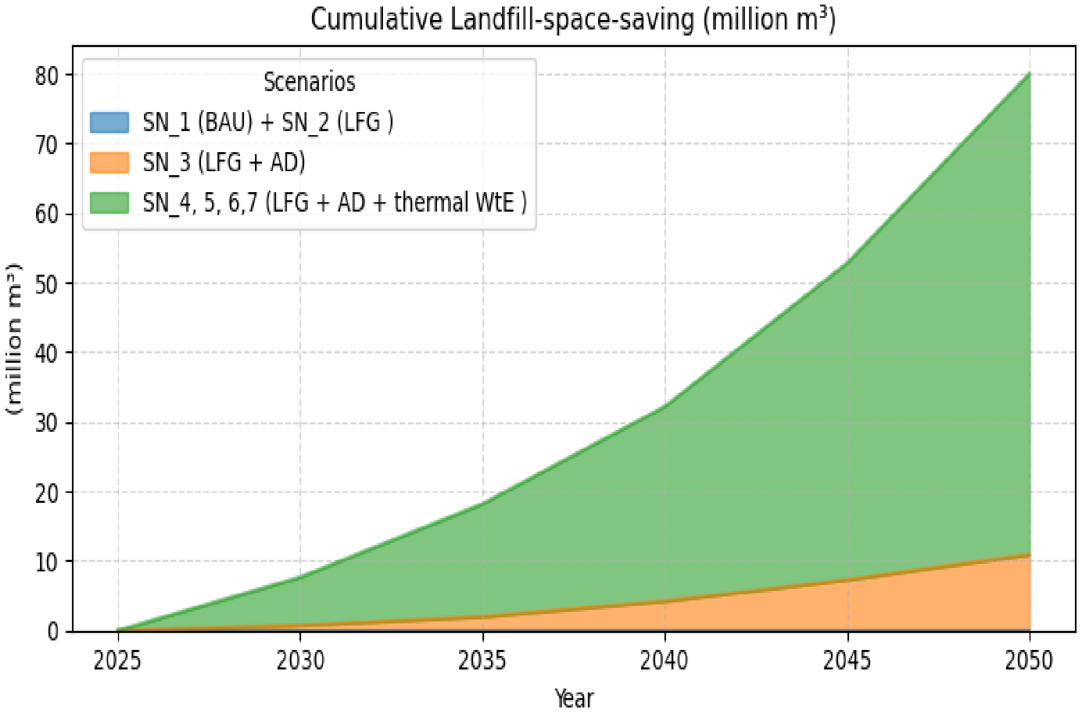
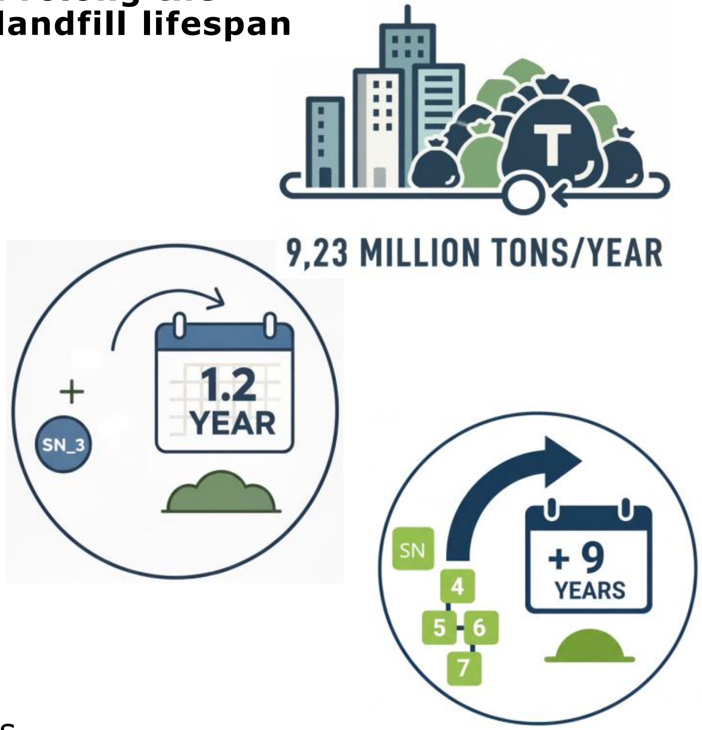



Figure 6 Landfill Space-Savings from waste–to-energy technologies

**Prolong the landfill lifespan**



# Waste Diversion Rate

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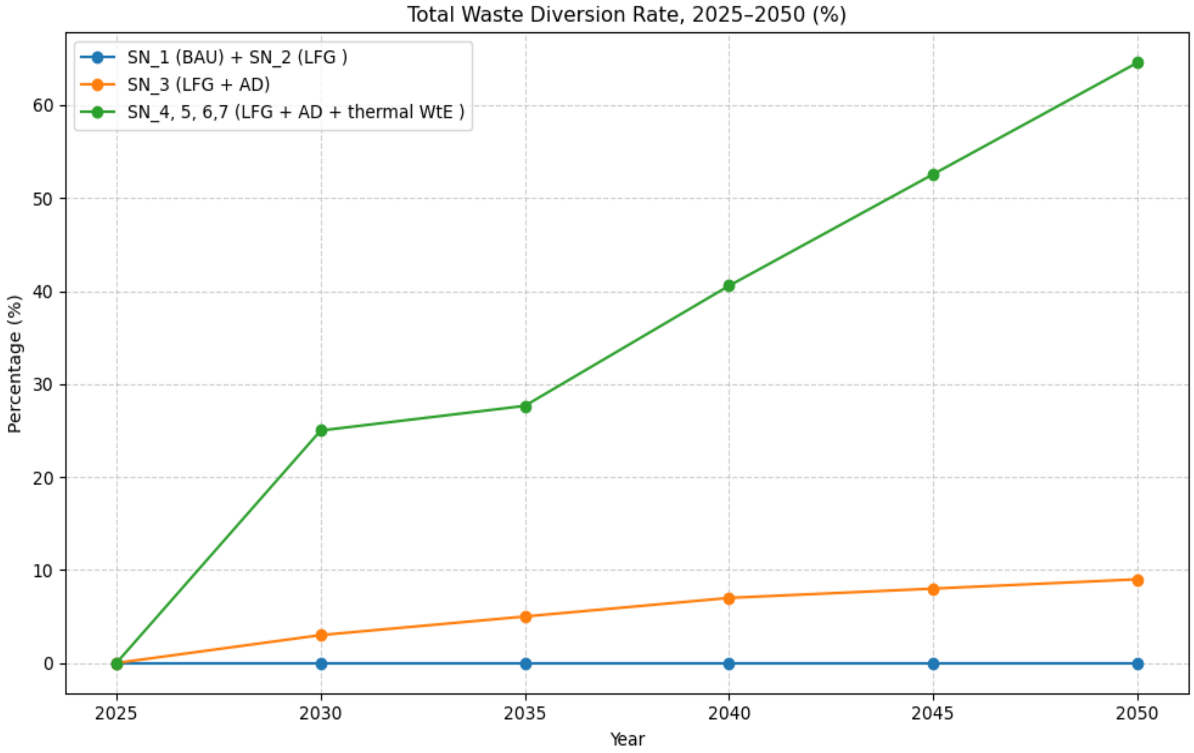
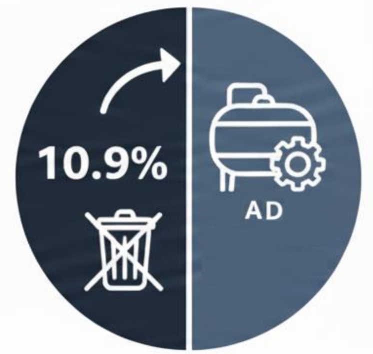
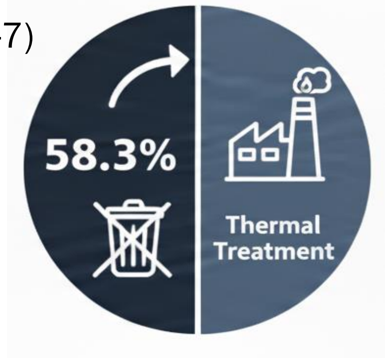



Figure 7 Waste Diversion potential from waste-to-energy technologies

SN_3




SN_(4-7)



# Conclusion and Recommendation

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- The analysis (2025–2050) using **WROSE® model** shows clear differences in GHG reduction, energy recovery, and landfill savings across WtE scenarios.
- **BAU (LFG only)** High GHG emissions, minimal energy recovery, and zero landfill savings.
- **Enhanced LFG & AD** Over 93% emission reduction and up to 5× more energy recovery than BAU.
- **Scenario 3 (AD inclusion)** Moderate landfill savings, lower than thermal technologies.

# Conclusion and Recommendation

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- **Thermal technologies (Scenarios 4–7)** Highest landfill space savings.
  - Highest waste diversion rates.
  - Net-negative GHG emissions and maximum cumulative energy recovery.
- **Plasma gasification** stands out for deep decarbonization and sustainable WtE conversion.
- Technology selection should consider economic feasibility in analyses.
- Gradually **transition from landfill** to integrated **waste management systems**.

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# QUESTIONS?

Thank You For Your Attention