PLASTIC WASTE MANAGEMENT FOR LANDFILL SPACE SAVINGS AND GHG EMISSION REDUCTION IN THE GARDEN ROUTE DISTRICT MUNICIPALITY

KISSOON S* , TROIS C**

*South African Research Chair Waste and Climate Change, University of KwaZulu-Natal, PhD Researcher sameerakissoon@gmail.com 082 3657642

**South African Research Chair Waste and Climate Change, University of KwaZulu-Natal, troisc@ukzn..ac.za 031 260 1070

ABSTRACT

The recycling of plastic packaging materials has expanded rapidly over the years. This is due to an increase in technological advancements and the awareness of materials widely available for recycling. Through combined efforts from government, industry and the general public, larger amounts of plastic waste have the potential to be removed from the municipal solid waste stream and has the ability to further enhance the recycling market in South Africa, thereby contributing to landfill airspace savings. The aim of this study is to determine the potential landfill diversion rates and landfill airspace savings that can be achieved through the extraction of low density polyethylene (LDPE)and polyethylene terephthalate (PET) plastic polymer fractions from the municipal solid waste stream over a 50-year period using the Garden Route District Municipality as a case study. In addition, the GHG emissions and emission reduction will also be included. The study employs the Waste Resource Optimization and Scenario Evaluation (WROSE) model as a methodology to select the scenarios that will be assessed. The scenarios identified were, the collection and disposal of unsorted untreated MSW as the business-as-usual scenario. The second scenario was the collection of unsorted, untreated MSW to a mechanical pre-treatment facility and ultimately recycling. The outcome of the study derived a 1.5% diversion rate from landfill when considering the extraction of the PET and LDPE fractions as a whole from the total waste generated. Landfill space savings are seen to increase as larger amounts of PET and LDPE are extracted from landfills. GHG emissions are low in the business as usual scenario due to emissions from the disposal of LDPE and PET to landfill being contributed to from the transportation of plastic waste. However, GHG emission reductions are seen when PET and LDPE fractions are extracted.

INTRODUCTION

The management of municipal solid waste (MSW) continues to pose an important environmental challenge. The collection and disposal of MSW to landfill contributes to greenhouse gas (GHG) emissions and subsequently the overall impact on global warming.

Constantly increasing amounts of MSW combined with limited landfill airspace in South Africa has led to the need of the consideration of alternative waste management mechanisms to reduce the burden on landfills. According to the State of Waste Report, 2018, of the total plastic waste generated in South Africa, only 43.7% was extracted for recycling while the remaining 56.3% was disposed of into landfill. As per the WWF plastics report in 2020 the average plastic consumption in 36kg per capita per year in South Africa. Consequentially the consideration of alternative waste management contributes to the potential reduction of GHG emissions from the collection and disposal of plastic waste.

The strategies identified in this study contribute to the diversion of waste from landfill as well as landfill space savings. This is for the purpose of the production of new products which has the potential to activate better waste to resource management and contribute to the circular economy.

The aim of this study is to conduct simulations of the diversion of LDPE and PET plastic waste fractions from landfill to determine potential landfill space savings in the Garden Route District Municipality over a 50-year period. Thereafter simulating the impact of interventions such as recycling on the reduction of GHG emissions. This will be achieved through illustrative scenarios of the diversion of PET and LDPE plastic from landfill at various rates, thereby establishing the potential landfill space saving and GHG emission reductions that can be achieved.

Due to a lack of reliable, available data, specific boundary conditions needed to be assigned in order to achieve the aim of the study.

1. Historical Integrated Wate Management Plan (IWMP) and Integrated Development Plan (IDP) data was extracted and utilized for the forecasting of total population and waste generation figures.
2. Population growth was established at 2% per annum based on the projections conducted by the Department of Social Development in the Garden Route District Municipality in line with the district.
3. Average waste characterisation percentages were extracted from the 3rd generation IWMP for determining waste fractions in tons.
4. National average recycling figures were employed to determine the amount of plastics that were extracted for recycling and what would be sent to landfill.
5. Only LDPE and PET fractions of plastics were considered for the purpose of this study as they are statistically the most recycled plastic polymer fractions in South Africa.

LITERATURE REVIEW

According to the State of Waste Report 2018, plastic waste accounts for 2% of the total general waste stream generated in 2017. In 2019, 503 600 tons of plastic waste was collected for the purpose of recycling this includes packaging and imported recyclables from neighbouring countries (SAPRO, 2019). South Africa has an input recycling rate of 46.3% for all plastics in 2018. More than 70% of the recyclable plastics collected were sourced from landfills and post consumer waste. Furthermore, the plastics recycling sector contributes 2.3% to the South African GDP and up to 18.5% of the manufacturing GDP (SAPRO, 2019). According to the South African Plastics recycling survey conducted in 2019 by Plastics SA, 244 300 tons of CO_2 were saved.

Global production of plastics grew from 2Mt to 390Mt between 1950 and 2015 (Zheng, 2019) Globally 58% of plastic waste is discarded of into landfill and 18% was recycled in 2015.

Although there are concerns globally of the impact of plastics on the environment as well as human health, very little research is done on the contributions of plastic waste on climate change and GHG emissions (Zheng, 2019). One of the explored strategies for the reduction of GHG's from plastic waste is recycling which partially reduced the carbon intensive virgin polymer production (Zheng, 2019).

MSW management as a whole contributes significantly to GHG emissions (Calabrò., 2009). Plastics as a material contributes to environmental impacts in multiple ways, the production of plastics contributes to GHG emissions. The wide use of plastic materials contributes to a growing waste management problem (Sevigné-Itoiz *et al.*, 2015). In order to reduce emissions and increase the lifespan of landfill facilities an integrated approach must be used (Calabrò., 2009). According to Plastics SA, the most widely recycled plastic material in South Africa are low density polyethylene (LDPE) and polyethylene terephthalate (PET). Therefore, for the purpose of this study the LSS and GHG emissions and emissions reductions will be illustrated for the LDPE and PET polymer fractions.

STUDY AREA

The Garden Route District Municipality (GRDM) is located in the Western Cape Province, South Africa. The GRDM is at present the third largest District in the Western Cape and is home to 7 local municipalities. These are, George, Knysna, Bitou, Mossel Bay, Kannaland, Hessequa and Oudtshoorn. The total surface coverage of the GRDM is approximately 23 332km^2 (GRDM IDP, 2019). Around 80% of the population within the GRDM resides in Urban Areas. According to the Department of Social Developments Projections the GRDM total population was at 635 600 in 2019 with a provincial population growth of 2% per annum (GRDM IDP, 2019).

In 2019 the GRDM conducted a waste characterisation study of the MSW at household level. The outcome of the waste characterisation study is outlined in the figure below. Food waste comprised 25% of the total waste profile whereas recyclables accounted for 40.3% of the total domestic waste profile, this includes hard and soft plastics, glass, metals, paper and cardboard (Gibb, 2020). The combined plastic waste fraction accounts for 16% of the total waste profile which is the second highest waste stream to food waste.

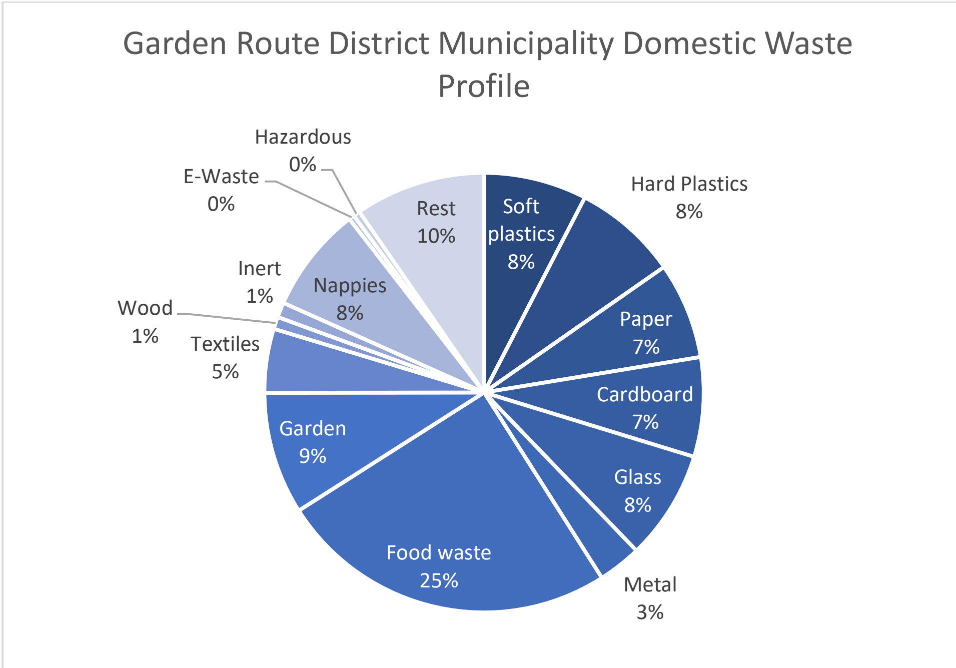

Figure 1: Garden Route District Municipality Domestic Waste Profile (Gibb, 2020).

METHODOLOGY

In order to achieve the objectives of the study, landfill density factors were used to were used to determine landfill airspace that could be saved by the extraction of PET and LDPE of plastics. Three types of calculations were conducted for this study. Firstly the landfill diversion rates were simulated for the extraction of the PET and LDPE fractions. Secondly the landfill space savings were established using the USEPA density factors. Lastly GHG emissions and emission reductions calculations were conducted to determine how much GHG emission reductions could be achieved through the extraction of LDPE and PET from landfill.

The Waste Resource Optimisation and Scenario Evaluation (WROSE) model is a methodology developed by the University of KwaZulu-Natal to aid municipalities in the decision-making process as a zero waste and GHG emissions reduction model. The WROSE model is used to assist municipalities in aligning with national legislative requirements and achieving sustained waste and emissions reduction through the evaluation of integrated waste management scenarios upon all levels of sustainability (environmental, economic, social and institutional).

A number of scenarios are embedded in the WROSE model, ranging from baseline (business as usual) to more complex optimised solutions. Figure 2 below outlines the scenarios of the WROSE model graphically. The WROSE model uses waste volumes of each waste fraction generated as input data, the outputs of the model are methane emissions productions or reductions. The outputs of the model are not limited to methane emissions but rather expand to a range of indicators such as landfill airspace savings (LSS), economic indicators, job creation potential, health risks associated with the jobs created, and institutional indicators.

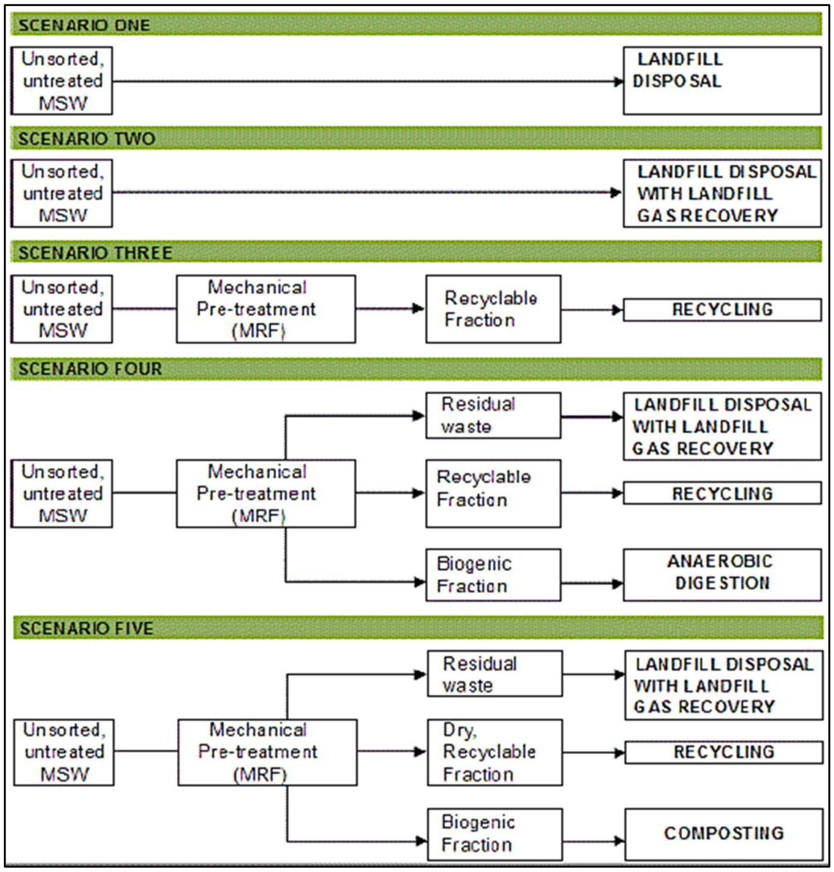

Figure 2. WROSE scenarios schematic (Jagath & Trois 2011)

For the purpose of this study, the WROSE model was utilised for the selection of the scenarios that were assessed. Due to plastics waste management forming the core focus area of the study, the scenarios identified as most applicable to this study are:

For this study 2 scenarios were considered:

1. SCENARIO 1: The disposal of unsorted, untreated MSW to landfill (BAU)
2. SCENARIO 3: Unsorted and untreated MSW undergo a mechanical pre-treatment with recovery of recyclable fraction through a Materials Recovery Facility (MRF)

Of the total plastic waste fraction established in tons, the amount of PET and LDPE were extrapolated based on the Plastics SA recycled figures as per the pie chart below.

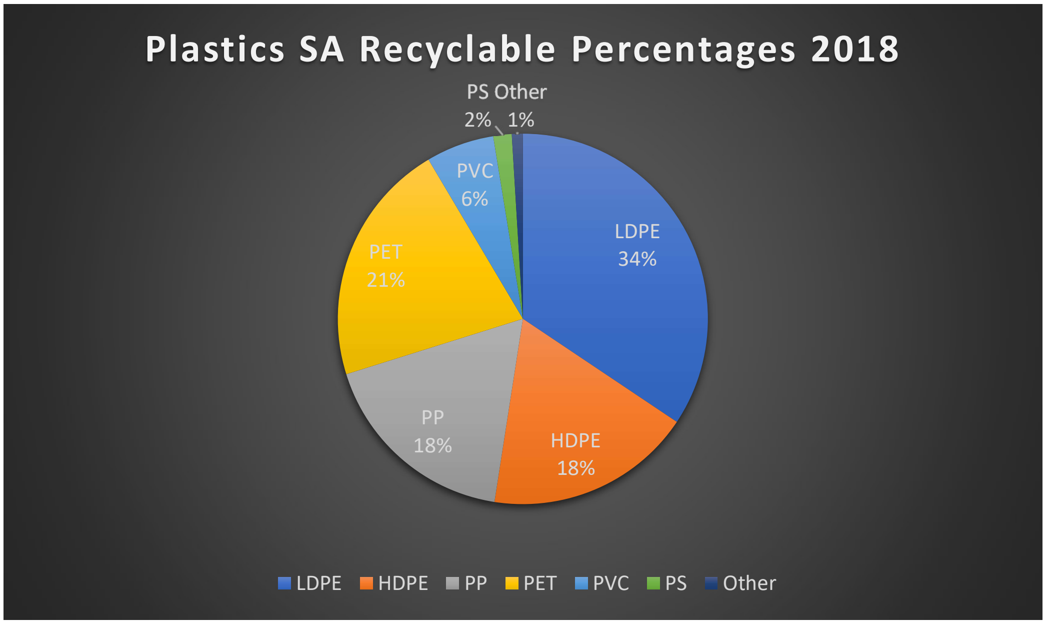

Figure 3. Plastics SA recyclables percentage per polymer fraction

Using the polymer fractions of PET at 21% of the total plastic waste fraction and LDPE at 34% of the total plastic polymer fraction, the tonnages were determined as input data for the LSS and waste diversion rates. Equation 1 below was used to simulate the landfill space saving potential that could be achieved through the extraction of PET and LDPE fractions.

$$Landfill\ Space\ Saving\ m3 = \frac{Total\ waste\ quantity\ diverted\ (tons)}{Average\ compacted\ denisty\ of\ mixed\ MSW}$$

Equation 1. Landfill space savings calculation

In order to determine the waste diversion rates the equation below was used.

$$Diversion\ rate = \frac{Waste\ diverted\ (tons)}{Total\ waste\ generated\ (tons\ )}\ X\ 100$$

Equation 2. Waste diversion rate calculation

In addition, methane emissions or emission reduction potential which were calculated in $MTCO_2eq$ using the IPCC derived USEPA 2016 emission factors.

The equation below was used to determine the methane emissions or emission reduction potential in $MTCO_2eq$:

$$Waste\ volume\ in\ tons\ \times\ emission\ factor = MTCO2eq$$

Equation 3. Emissions from waste management scenarios in metric tons of CO_2eq

These emissions/emission reductions and landfill space savings were calculated for a 50-year period for each of the defined scenarios selected using the appropriate emission and density factors. Taking into consideration that the total amount of LDPE and PET tons may not be viable for recycling due to contaminants in the waste stream, assumptions were made for determining viability of LDPE and PET fractions for recycling. Simulations were conducted at 10% intervals up to 40% assuming that due to contamination only a portion of the LDPE and PET streams are viable. The results for which are discussed in the section below.

RESULTS AND DISCUSSION

Plastic waste accounts for 16% of the total waste generated for consideration in the study. LDPE and PET account for 55% of the total plastic waste stream. Using the calculation above the waste diversion rate was established at 1.5% of the total waste stream should the entire LDPE and PET fractions be extracted.

Figure 4 below depicts the landfill space saving that can be achieved through the diversion of PET from landfill at various achievable intervals by the year 2070. The potential recycling rates were simulated based on the volume of PET plastics that are viable for recycling. These were at 10%, 20%, 30% and 40% of the total PET fraction. The higher the percentage of PET extracted for recycling, the greater landfill space saving potential.

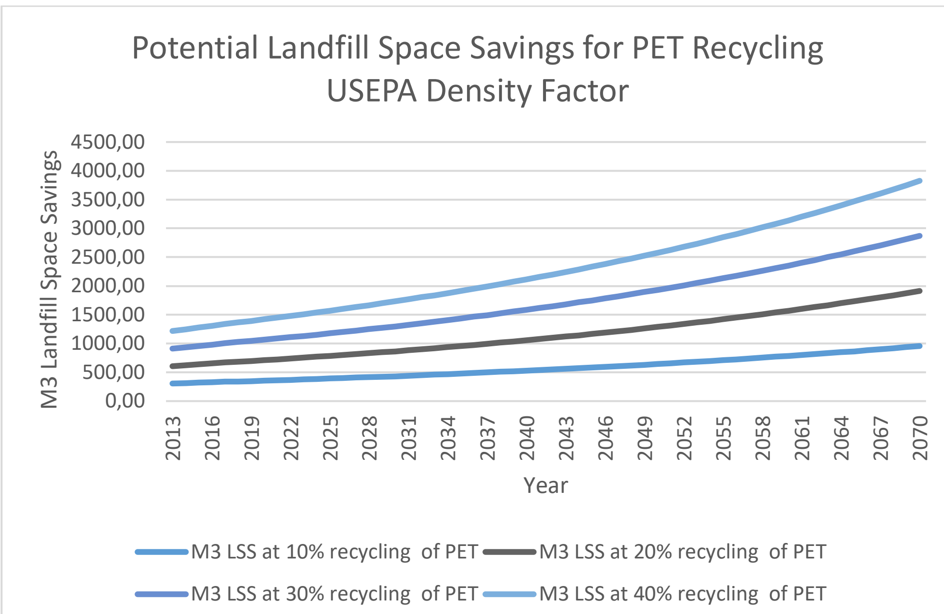

Figure 4. Potential landfill space savings for PET recycling over 50 Years in the Garden Route District Municipality

The figure below illustrates the BAU scenario as increasing GHG emissions over the next 50 years from 55.29 $MTCO_2eq$ in 2013 to 173.96 $MTCO_2eq$ in 2070. The disposal of PET does not contribute directly to GHG emissions as there is no degradation of organic matter. However, the GHG emitted and accounted for is due to the transportation of plastic waste. The extraction of the PET fraction for recycling through Scenario 3 at various intervals, depicts the reduction of GHG emissions.

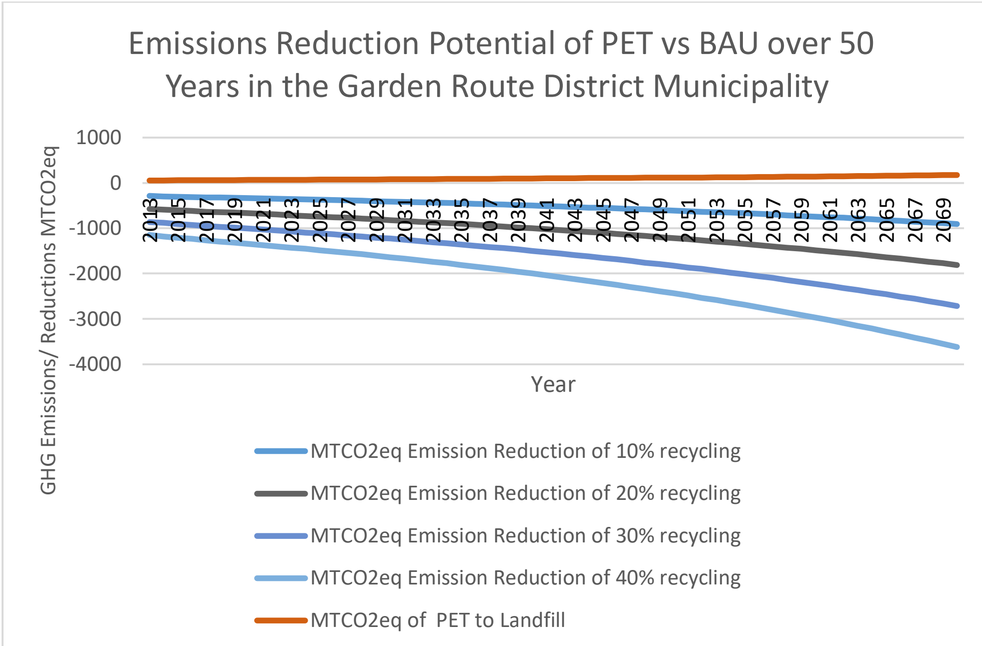

Figure 5. Emissions Reduction Potential of PET vs BAU over 50 Years in the Garden Route District Municipality

Figure 6 below depicts the landfill space saving that can be achieved through the diversion of the LDPE fraction from landfill at various achievable intervals by the year 2070. The potential recycling rates were simulated based on the volume of LDPE plastics that could potentially be viable for recycling. These simulations were considered at 10%, 20%, 30% and 40% of the total LDPE fraction. The higher the percentage of LDPE extracted for recycling, the greater landfill space saving potential.

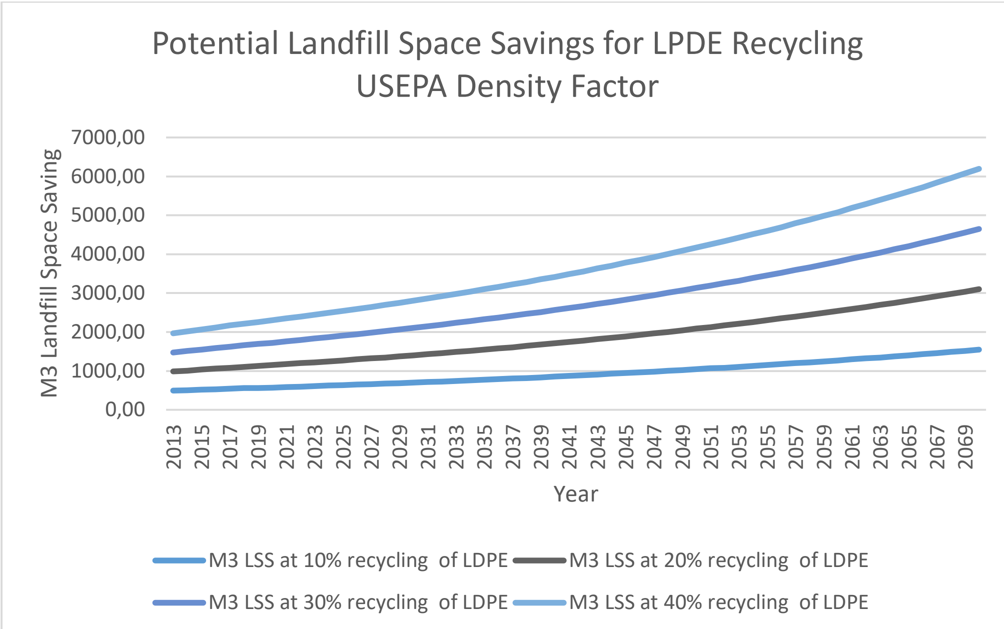

Figure 6. Potential landfill space savings for LDPE recycling over 50 Years in the Garden Route District Municipality

Similarly, to that of PET, the contributions of LDPE's disposal to landfill increases over the next 50 years from the transportation of LDPE. The figure below illustrates the BAU scenario as increasing GHG emissions over the next 50 years from 89.58 MTCO2eq in 2013 to 281.65 MTCO2eq in 2070 through the disposal of LDPE to landfill. However, the extraction of the LDPE fraction for recycling through Scenario 3 at various intervals, depicts the reduction of GHG emissions.

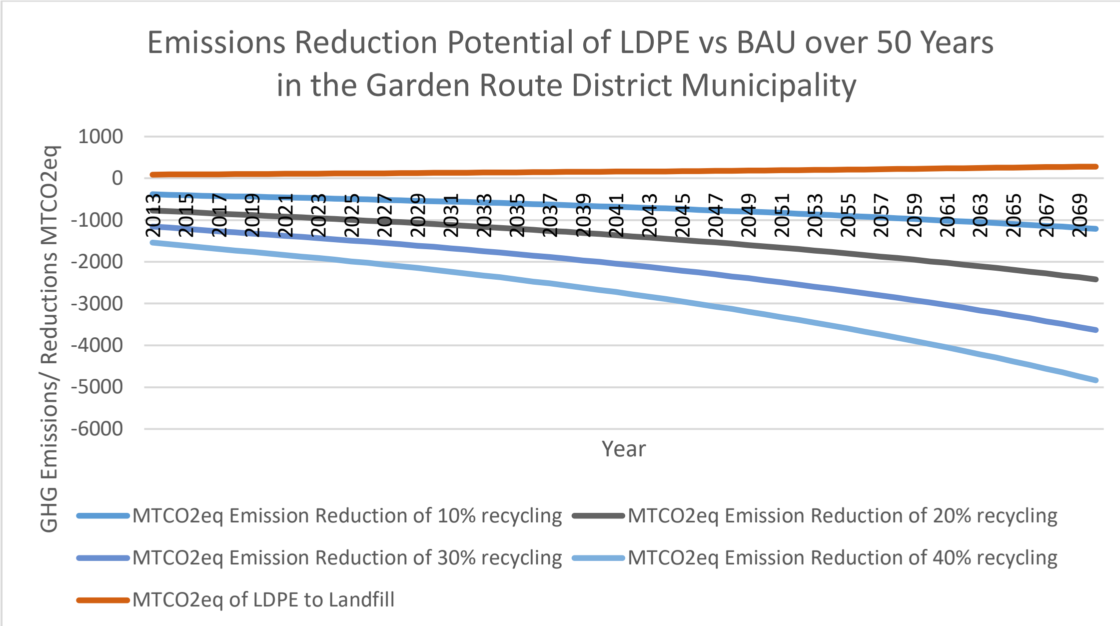

Figure 7. Emissions Reduction Potential of LDPE vs BAU over 50 Years in the Garden Route District Municipality

CONCLUSION

Using the WROSE model, 2 scenarios were identified as relevant to this study. These are Scenario's 1 and 3. This study comprised of 3 key components. The first being the estimation of the landfill space savings that could occur through the diversion of LDPE and PET fractions from the municipal solid waste stream generated in the Garden Route District Municipality. The second component was to determine the waste diversion rate and lastly the determination of GHG emission reductions as a result of the diversion of PET and LDPE. The outcome of the study yielded similar results for both the PET and LDPE fractions. The landfill space savings would be higher as larger amounts of plastics are extracted from the municipal stream. However due to LDPE and PET only accounting for a small fraction of the overall waste generated and only 16% of the total recyclable fraction the landfill diversion rate is low at 1.5%. There is potential for GHG emission reductions however this is due to transportation and energy savings as a result of not having to produce virgin materials.

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