XLM-SOLID WASTE TOOLKIT

User Manual

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Ministry of Social Security, National Solidarity, and Environment and Sustainable Development
(Environment and Sustainable Development Division)
Republic of Mauritius

XL-Mitigation Solid Waste Toolkit

User Manual

About this manual

This manual, *XL-Mitigation Solid Waste User Reference*, forms part of a family of toolkits to compute and plot a number of other variables including GHG emissions for Solid Waste sector. The user reference has been written from an application developer's perspective. A fundamental conceptual and operational knowledge of Excel is assumed.

Disclaimer

Data used has been obtained from reliable sources. The Ministry of Social Security, National Solidarity, and Environment and Sustainable Development (Environment and Sustainable Development Division) assumes no responsibility for errors and omissions in the data provided. Users are, however, kindly asked to report any errors or deficiencies in this product to the Ministry. The choices of calculation made in this tool are derived from TNC Report (2016).

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Table of Contents

XLM-SOLID WASTE Toolkit

1. Introduction

This document refers to a user-friendly toolkit developed to assess the mitigation of climate change from Greenhouse Gas (GHG) emissions in the Solid Waste sector of the Republic of Mauritius.

The mitigation for Solid Waste sector was assessed in the TNC report (2016) for a Business-as-Usual (BAU) and 4 other scenarios, after a screening exercise to select the most feasible options. Thus, the first scenario, after the BAU, considered that there will be an enhanced Landfill gas (LFG) capture. The second scenario considers composting, the third, recycling, and the fourth, the waste to energy (WTE).

The XLM-Solid Waste Toolkit performs basic calculations taking the population, per capita waste generation, and solid waste disposal, amongst others. The trend for per capita waste generation and other suitable parameters until 2050 was thus worked out following assumptions taken from the TNC. Users of the XLM-Solid Waste Toolkit can adjust the scenarios by choosing appropriate parameters/assumptions to suit their needs for mitigation analysis.

2. Overview of the Solid Waste sector

The amount of solid wastes generated in Mauritius was over 425,000 tonnes in 2016. Most of the solid wastes are landfilled and a few of them have started to be composted as from 2012. LFG, produced in the landfill, are currently captured for electricity production. Recycling is carried out only at small scales.

Transfer stations and landfill facts (Solid Waste Management Division, 2017):

Transfer Stations	Starting Year of Operation	Design capacity /tons / day	Average quantity transferred/tons per month
La Brasserie	1991	150 to 300	6,552
Roche Bois	1992	300 to 400	6,308
Poudre D'Or	2000	150 to 180	4,426
La Laura	2005	100 to 150	3,276
La Chaumiere	2011	350 to 450	10,000
The Mare Chicose Landfill Site: • in operation since 1997; • Approximate area landfilled: 34 ha; • Approximate amount landfilled annually: 420,000 tonnes; • Amount of waste landfilled: ~ 6 million tonnes;			

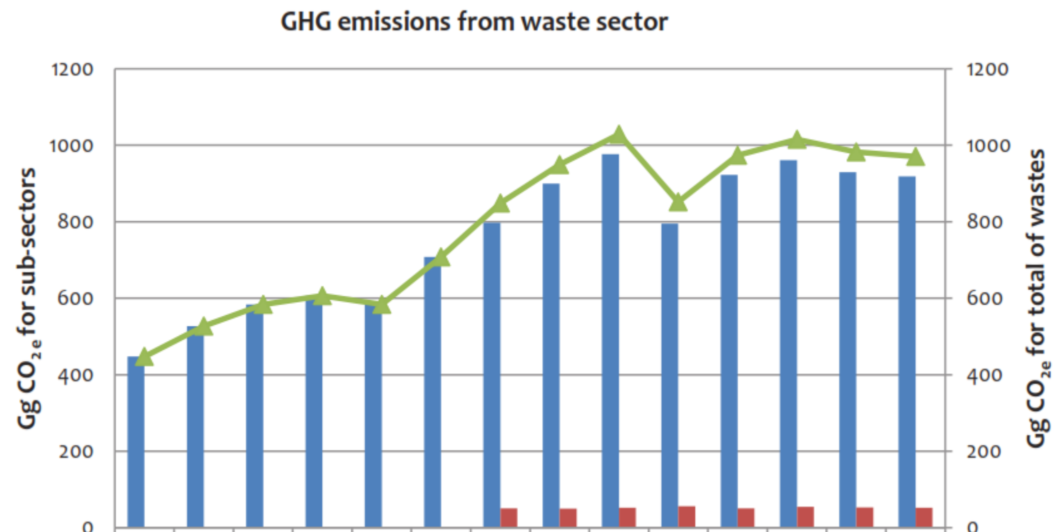
Facts

- Population (2015): ~1.26 million
- Domestic waste landfilled (2016): 428,032 tonnes
- Total waste landfilled (2016): 444,695 tonnes

3. GHG Emissions for the Solid Waste sector

The Solid Waste sector is particularly important as it is the sector having considerable GHG emissions (918 Gg CO_2 eq. or 19% of total emissions) after the energy sector (77%), in 2013 (TNC 2016).

Figure 3.1 shows the trend of emissions for the overall waste sector. Emissions from solid wastes are much higher than those for liquid wastes. The emission from solid waste dropped in 2009, most probably due to changes in economic activities, production and consumption.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Solid Wastes	447.3	527.3	583.8	606.4	583.8	707.7	797.5	899.4	976.9	795	922.8	960.9	929.5	918.3
Liquid wastes							50.85	49.67	51.84	56.4	50.89	54.76	52.85	52.39
Total Wastes	447.3	527.3	583.8	606.4	583.8	707.7	848.4	949.1	1029	851.4	973.7	1016	982.4	970.7

Figure 3.1: Trend of emissions for Waste Sector (Source: TNC, 2016)

4. Solid Waste Mitigation Actions proposed under 2016 TNC

4.1 Mitigation Scenarios and Assumptions

Relative to the BAU scenario, 4 scenarios were developed in TNC (2016). Scenario 1 (SC1) involves the enhancing of the capture of LFG for either flaring or electricity generation. Scenario 2 (SC2) concerns composting of food, garden and paper degradable that divert organic waste from the landfill, and hence reduce the quantity of methane generated at the landfill (all else being equal). Recycling of paper and textile waste was the third scenario to investigate the impact of recycling of paper and textile waste. The fourth scenario considers a waste-to-energy (WTE) scenario as from 2019 where 600 t/day of MSW is diverted from the landfill for energy production.

The assumptions adopted by TNC for mitigation actions for the Solid Waste sector are summarized in the table below.

Table 4.1: Mitigation actions proposed by TNC (2016) and assumptions used

Scenario		Assumptions
BAU	BAU	BAU Projections in emissions have been calculated by assuming a 2% year-on-year increase in the quantity of Municipal Solid Waste (MSW). The model calculates total waste generated as a product of population and per capita waste. In view of a declining population after 2023 using demographic projections (Statistics Mauritius, 2015, a constant 2% growth in total quantity of waste represents a gradual increase in the per capita MSW generated). Since population projections are given for every 5 years, linear interpolation has been used to derive intermediate levels of population. The waste composition (by type of waste) has been kept the same as the breakdown used in the solid waste national GHG inventory. The projected year-on-year increase in per capita MSW generation is 2.23% in 2030 and 3.15% in 2050, taking into account declining population. BAU scenario also assumes that additional wells and piping system will be added to increase the capture of LFG (and methane) for electricity generation. It has been assumed that the methane capture increases to 85% of its total volume that is 18.3 Gg CH_4 in 2016 as compared to 15.9 Gg CH_4 in 2014.
SC1	Enhancing the capture of LFG for either flaring or electricity generation	Main Assumption: methane capture is increased to 40% in 2030; to 45% in 2040; and to 50% in 2050 – i.e. an absolute increase from 18.3 Gg CH_4 in 2016 to 34.4 Gg CH_4 in 2030, and to 64.1 Gg CH_4 in 2050.
SC2	Composting of food, garden and paper degradables	Main Assumption: The quantity of the waste that is diverted from landfill is 20% (2020), 30% (2030), 40% (2040), and 50% (2030) relative to their baseline values. Hence, the composting is additional to any that is being carried out already in the baseline situation. This incremental composting starts in 2017 at a rate of 2% and increases linearly to the above-mentioned targets. It is assumed that the composting process does not emit any methane, and the compost produced is used in agriculture to support bio-farming.
SC3	Recycling of paper and textile waste	A scenario (yielding the least GHG emission reductions) has been modelled based on the approach used in the SNC to investigate the impact of recycling of paper and textile waste. The targets are to achieve recycling rates of 8% in 2020; 28% in 2030; 38% in 2040; and 48% in 2050.
SC4	A waste-to-energy (WTE)	This scenario has been modelled for 2019 where 600 t of MSW is diverted from the landfill for energy production on a daily basis.

***Note** #. Some of these percentages have already been incorporated into the projections in the TNC and are as such in the worksheets and can be updated by the user.*

The assumptions in this table are taken into the calculations and the User of the toolkit only needs to update these in the relevant worksheet(s), if required. This means that worksheets for assumptions already contain the percentages for the different waste disposal options that can be updated by the User.

The parameters used for the different scenarios appear in section 5.2.

4.2 TNC Targets under different scenarios

For this sector, the increase in GHG sequestration relative to BAU scenario for the various scenarios is summarized in both Table 4.15 and Figure 4.1.

Table 4: TNC (2016) GHG (GgCO2e) for the Solid Waste sector

Scenario		**TNC TARGETS** *Expected GHG emissions*	**TNC Remarks**
BAU	Business-As-Usual	1290 Gg CO2e in 2020; 1691 Gg CO2e in 2030; 2168 Gg CO2e in 2040; 2745 Gg CO2e in 2050;	The waste composition (by type of waste) has been kept the same as the breakdown used in the solid waste national inventory
SC1	Enhancing LFG Capture	1175 Gg CO2e in 2020; 1289 Gg CO2e in 2030; 1444 Gg CO2e in 2040; 1602 Gg CO2e in 2050	Methane capture is increased to 40% in 2030; to 45% in 2040; and to 50% in 2050
SC2	Composting	1256 Gg CO2e in 2020; 1298 Gg CO2e in 2030; 1297 Gg CO2e in 2040; 1342 Gg CO2e in 2050.	It is assumed that the composting process does not emit any methane, and the compost produced is used in agriculture to support bio-farming
SC3	Recycling	1289 GgCO2e in 2020; 1680 GgCO2e in 2030; 2139 GgCO2e in 2040; 2694 GgCO2e in 2050.	Based on the approach used in the SNC to investigate the impact of recycling of paper and textile waste
SC4	WTE	1135 Gg CO2e in 2020; 907 Gg CO2e in 2030; 1270 Gg CO2e in 2040; 1824 Gg CO2e in 2050.	The emission profile of the WTE scenario is non-linear

Of all scenarios, the recycling scenario is the least promising scenario.

Composting of food, garden and paper degradables has the highest reductions; assuming that the composting process does not emit any methane, and the compost produced is used in agriculture to support bio-farming. By 2050, TNC reductions for SC1 to SC4 are, respectively, 1144, 1403, 51 and 921 Gg CO2e relative to BAU.

The overall projected emissions from BAU, SC1, SC2, SC3 and SC4 are shown in Figure 4.1.

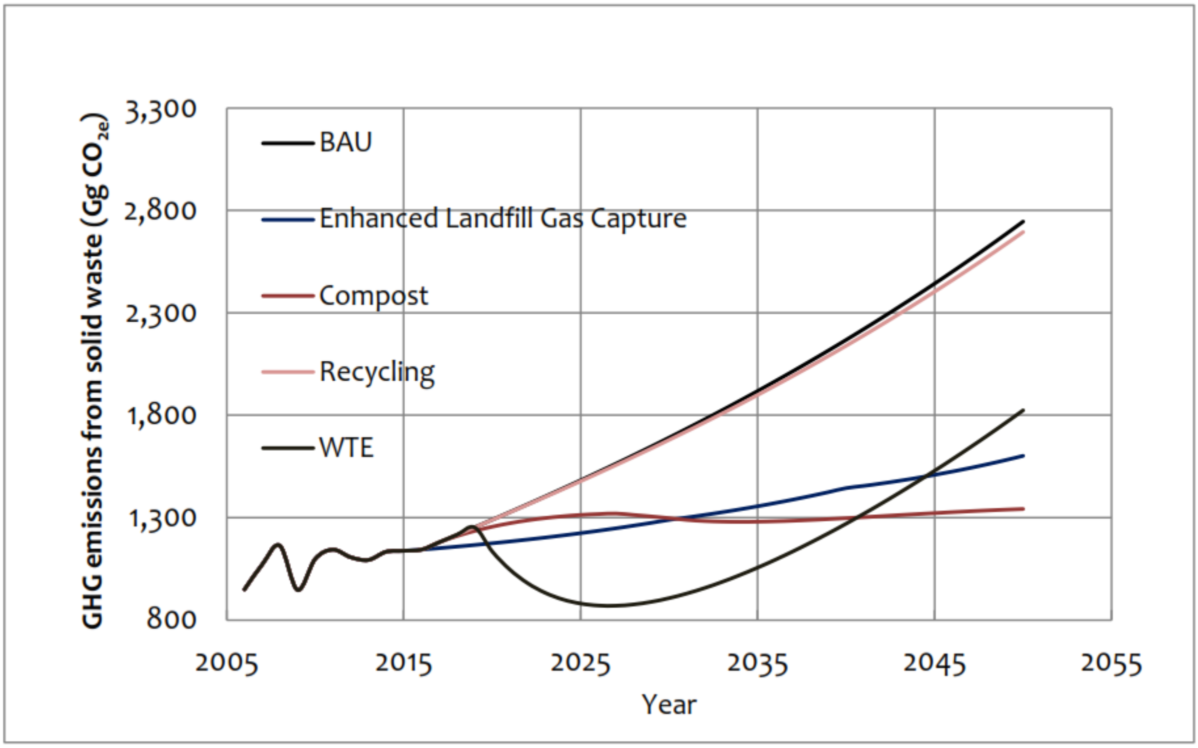


Figure 4.1: GHG Emissions scenarios in Solid Waste sector (2010-2050) (source: TNC, 2016)

5. XLM–Solid Waste Toolkit

The structure, methodology, components/modules and other details of the XLM Toolkits has been described in the main User Manual.

5.1 Solid Waste Data

The '*Data*' worksheet essentially contains the population, waste per capita, waste to waste disposals, etc., for each year. The actual data pertains to year 2000 to 2014 and beyond that, the projections have been made for the TNC (2016) study. These data are used in combination with the parameters in the '*Parameters*' worksheet (Global warming potentials, methane correction fractions, CH_4 emission factors, etc.) and the assumptions in the 'Assumptions', to make the calculations for the GHG emissions. The projected data are also used in the calculations for future emissions. The data sources for this sector are typically from the Solid Waste Management Division (SWMD) of the MSSNSESD which keeps a record of the wastes by types, etc.

5.2 Solid Waste Parameters

Table 5.1 presents the major parameters used for the SW sector used in the XLM-Solid Waste Toolkit; all parameters used appear in the '*Parameters*' worksheet. It is to be noted that most parameters are from the IPCC Guidelines (2006) for GHG inventories, but local factors can be used whenever available.

Table 5.1: List of Parameters for the Solid Waste sector

Model Parameters

Solid Wastes	Degradable Organic Carbon (DOC)		Methan generation rate constant - k (1/yr)		exp(-k)		Half Life of waste - ln(2)/k	
	TNC	USER	TNC	USER	TNC	USER	TNC	USER
Food	0.190	0.190	0.400	0.400	0.670	0.670	1.733	1.733
Garden	0.588	0.588	0.170	0.170	0.844	0.844	4.077	4.077
Paper	0.130	0.130	0.070	0.070	0.932	0.932	9.902	9.902
Wood	0.005	0.005	0.035	0.035	0.966	0.966	19.804	19.804
Textiles	0.040	0.040	0.070	0.070	0.932	0.932	9.902	9.902
Nappies	0.002	0.002	0.050	0.050	0.951	0.951	13.863	13.863
Sludge	0.030	0.030	0.030	0.030	0.970	0.970	23.105	23.105
Industrial	0.015	0.015	0.170	0.170	0.844	0.844	4.077	4.077

Note: a few equations are provided below abd more details can be found in the IPCC (2006) Guidelines.

Weighted Methane Correction Factor (MCF)

Year/period	Value (dimensionless)	
	TNC	USER
2000		0.91
2001		0.96
>2001		1.00
DOCf		0.75
CH4 in LFG		0.50
C to CH4		1.33
GWP CH4		25.00

Note: Oxidation factor is zero.

5.3 Solid Waste Assumptions

The assumptions (in the '*Assumptions'* worksheet) used in the XLM-Solid Waste Toolkit are essentially the changes over the years which fluctuates depending on national circumstances such as households and industrial activities, etc, (Table 5.2). These assumptions used are derived from TNC (2016).

Table 5.2: List of Assumptions for the Solid Waste sector

1	Composition of Wastes
2	Waste composted
3	Waste recycled
4	Waste for WTE

5.4 Graphic Analysis and Reporting

Graphic analysis in the '*Query'* worksheet provides the following choices for the type of plots.

Sector	Type of Plot	Plot numbers
Solid Waste	ALL	1-133;
	General and Waste Composition	1-13;
	Waste Generation	14-22; 38-46; 62-70; 86-94; 110-118;
	GHG Emissions	23-37; 47-61; 71-85; 95-109; 119-133;
	Total GHG Emissions (TNC)	37, 61, 85, 109, 133;

The complete set of figures that the XLM-Solid Waste Toolkit provides is listed in Table 5.3. In this table, the rightmost column denotes the general topic or item for which the plots can be generated for graphical analysis.

Table 5.3: XLM-Solid Waste Toolkit Plots

		Plot Number				
		BAU	SC1	SC2	SC3	SC4
General and Waste Composition	Population (Million)	1				
	Waste per capita, WPC (kg/cap/yr)	2				
	Total Waste (Gg/yr)	3				
	Waste to SWDS under WTE scenario (Gg/yr)	4				
	Solid Waste % Composition for Food (%)	5				
	Solid Waste % Composition for Garden (%)	6				
	Solid Waste % Composition for Paper (%)	7				
	Solid Waste % Composition for Wood (%)	8				
	Solid Waste % Composition for Textiles (%)	9				
	Solid Waste % Composition for Nappies (%)	10				
	Solid Waste % Composition for Inert (%)	11				
	Solid Waste % Composition for Sludge (%)	12				
	Solid Waste % Composition for Industrial (%)	13				
Waste Generation	Solid Waste generation - Food (Gg/yr)	14	38	62	86	110
	Solid Waste generation - Garden (Gg/yr)	15	39	63	87	111
	Solid Waste generation - Paper (Gg/yr)	16	40	64	88	112
	Solid Waste generation - Wood (Gg/yr)	17	41	65	89	113
	Solid Waste generation - Textiles (Gg/yr)	18	42	66	90	114
	Solid Waste generation - Nappies (Gg/yr)	19	43	67	91	115
	Solid Waste generation - Inert (Gg/yr)	20	44	68	92	116
	Solid Waste generation -Sludge (Gg/yr)	21	45	69	93	117
	Solid Waste generation - Industrial (Gg/yr)	22	46	70	94	118
GHG Emissions	Emissions (GgCH4) - Food	23	47	71	95	119
	Emissions (GgCH4) - Garden	24	48	72	96	120
	Emissions (GgCH4) - Paper	25	49	73	97	121
	Emissions (GgCH4) - Wood	26	50	74	98	122
	Emissions (GgCH4) - Textiles	27	51	75	99	123
	Emissions (GgCH4)- Nappies	28	52	76	100	124
	Emissions (GgCH4) -Sludge	29	53	77	101	125
	Emissions (GgCH4) - Industrial	30	54	78	102	126
	Total CH4 generated (Gg CH4)	31	55	79	103	127
	Total CH4 generated - (Gg CO2e)	32	56	80	104	128
	Recovered Gg CH4	33	57	81	105	129
	Emissions Gg CH4 - With Industrial	34	58	82	106	130
	Emissions Gg CH4 - Without Industrial	35	59	83	107	131
	Emissions Gg CO2e - With Industrial	36	60	84	108	132
	Emissions Gg CO2e - Without Industrial	37	61	85	109	133

6. References

- Statistics Mauritius (2016): Statistics Mauritius, Digest of Environment Statistics 2015, Vol. 14, Ministry of Finance and Economic Development, November 2016
- Solid Waste Management Division (2017), Ministry of Social Security, National Solidarity, and Environment and Sustainable Development
- Ministry Strategic Plan
- **TNC (2016).** Third National Communication: Report to the United Nations Framework Convention on Climate Change. Republic of Mauritius, Port Louis
- **IPCC (2006).** Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

7. Appendices

A: List of Acronyms and Abbreviations

Toolkit		**Others**	
BAU	Business-As-Usual	IPCC	International Panel of Climate Change
GUI	Graphics User Interface	SNC	Second National Communications
LFG	Landfilled Gas	TNC	Third National Communications
UD1	User-defined Scenario – Case 1	GHG	Greenhouse Gas
UD2	User-defined Scenario – Case 2	SWMD	Solid Waste Management Division
SC*i*	Scenario *i*	GWP	Global Warming Potential
XLMT	Excel Mitigation Toolkit		
WTE	Waste-to-Energy		

B: Useful Links

IPCC

TNC

SWMD

Digest environment and others

Digest demography

C: Governing Equations for the Solid Waste sector

Terms	Description	Units	Data Sources	Remarks
(1) Estimating Solid Waste generated $SW = P \times WPC$				
SW	Solid waste generated	Gg		Calculated
P	Population (annual)	Numbers (missions)	Statistics Mauritius	Need to be updated regularly
WPC	Waste generated per capita	Gg/person/yr		Estimated by SWMD
(2) General equation to calculate CH4 emitted from solid waste disposals $CH_4 \text{ emissions} = \left[\sum_x CH_4 \text{ Generated}_{x,T} - R_T\right] \times (1 - OX_T)$				
CH_4 Emissions	CH_4 emitted in year T	Gg		
T	Inventory year			
x	Waste category or type/material			
R_T	CH4 recovered in year T	Gg		
OX_T	Oxidation factor in year T	fraction		
(3) Decomposable DOC From Waste Disposal Data $DDOCm = W \times DOC \times DOCf \times MCF$				
DDOCm	Mass of decomposable DOC deposited	Gg		
W	Mass of waste deposited	Gg		
DOC	Degradable organic carbon in the year of deposition	Gg C/Gg waste fraction		
DOCf	Fraction of DOC that can be decomposed	fraction		
MCF	CH_4 correction factor for aerobic decomposition in the year of deposition	fraction		

(4) Estimates DOC Using Default Carbon Content Values $$DOC = \sum_i (DOC_i \times W_i)$$				
DOC	Fraction of degradable organic carbon in bulk waste	Gg C/Gg waste		
DOCi	Fraction of degradable organic carbon in waste type i, e.g., the default value for paper is 0.4 (wet weight basis)			
W_i	Fraction of waste type i by waste category			
(5) Transformation From DDOCm To L_o $$L_o = DDOCm \times F \times 16/12$$				
L_o	CH_4 generation potential	Gg CH_4		
DDOCm	Mass of decomposable DOC	Gg		
F	Fraction of CH_4 in generated landfill gas - LFG	volume fraction		
To understand the First Order Decay (FOD) basics, the following equations are applied: DDOCm Accumulated In The SWDS At The End Of Year T (6) $DDOCma_T = DDOCmd_T + (DDOCma_{T-1} \times e^{-k})$ DDOCm Decomposed at the end of Year T (7) $DDOCm\ decomp_T = DDOCma_{T-1} \times (1 - e^{-k})$				
T	Inventory year			
$DDOCma_T$	DDOCm accumulated in the SWDS at the end of year T	Gg		
$DDOCma_{T-1}$	DDOCm accumulated in the SWDS at the end of year (T-1)	Gg		
$DDOCmd_T$	DDOCm deposited into the SWDS in year T	Gg		
DDOCm $decomp_T$	DDOCm decomposed in the SWDS in year T	Gg		
k	Reaction constant, $k = \ln(2)/t_{1/2}$	y^{-1}		
$t_{1/2}$	Half-life time	y		
(8) CH_4 generated from decomposable $DDOC_m$ $$CH4\ generated_T = DDOCm\ decomp_T \times F \times (16/12)$$				
CH_4 $generated_T$	Amount of CH_4 generated from decomposable material	Gg		
DDOCm $decomp_T$	DDOCm decomposed in year T	Gg		
F	Fraction of CH_4, by volume, in generated landfill gas	fraction		
16/12	Molecular weight ratio CH_4/C	ratio		