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User's Manual
Ecuador Landfill Gas Model

Version 1.0

Prepared for

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Ministry for Urban Development and Housing
Government of Ecuador

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DISCLAIMER

This user's guide has been prepared specifically for Ecuador on behalf of the Methane to Markets Partnership (M2M), the Landfill Methane Outreach Program (LMOP) and the U.S. Environmental Protection Agency (USEPA). The methods contained within are based on engineering judgment and represent the standard of care that would be exercised by a professional experienced in the field of landfill gas projections. Environmental Research Group (ERG) and Carbon Trade (C.T.) do not guarantee the quantity of available landfill gas, and no other warranty is expressed or implied. No other party is intended as a beneficiary of this work product, its content, or information embedded therein. Third parties use this report at their own risk. ERG and C.T. assumes no responsibility for the accuracy of information obtained from, compiled, or provided by other parties.

ABSTRACT

This document is a user's guide for a computer model, Version 1.0 of a landfill gas generation model for estimating landfill gas generation from municipal solid waste landfills in Ecuador (Ecuador LFG Model). The development of the Ecuador specific landfill biogas model is an extension of the LMOP Mexico landfill gas model developed by SCS Engineers under contract to the USEPA in 2003. The model has been re-calibrated based on the experience gained through two Pre-Feasibility studies and gas pumping trials carried out on the Las Iguanas landfill (Guayaquil) and Pichacay Landfill (Cuenca) in March and April of 2007. In addition some information from three Assessment reports carried out on the Chabay (Azogues), El Valle (Cuenca) and Loja (Loja) landfills in Ecuador.

The model addresses the apparently high rate of landfill gas generation from both of these sites. Adjustments of the factors used in traditional first order decay models are used to simulate the effects of high organic and moisture content found in waste in Ecuador.

The Ecuador LFG Model is an Excel® spreadsheet model based on a first order decay equation. The model requires the user to input site-specific data for landfill opening and closing years, refuse disposal rates, average annual precipitation, and collection efficiency.

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GLOSSARY OF TERMS

TERM	DEFINITION
Collection Efficiency	The estimated percentage of generated landfill gas which is or can be collected in a gas collection system.
Collection System Coverage	The estimated percentage of a landfill's refuse mass that is potentially within the influence of a gas collection system's extraction wells. Collection system coverage describes the fraction of recoverable gas that can be captured and can reach 100% in a comprehensive collection system (unlike collection efficiency which is always less than 100%).
Design Capacity of the Landfill	The total amount of refuse that can be disposed of in the landfill.
Landfill Gas	Landfill gas is a product of biodegradation of refuse in landfills and consists of primarily methane and carbon dioxide, with trace amounts of non-methane organic compounds and air pollutants.
Methane Generation Rate Constant (k)	k is a model constant that determines the estimated rate of landfill gas generation. The first-order decomposition model assumes that k values before and after peak landfill gas generation are the same. k is a function of moisture content in the landfill refuse, availability of nutrients for methanogens, pH, and temperature.
Potential Methane Generation Capacity (L_o)	L_o is a model constant that represents the potential capacity of a landfill to generate methane (a primary constituent of landfill gas). L_o depends on the amount of cellulose in the refuse.
Closure Year	The year in which the landfill ceases, or is expected to cease, accepting waste.

1 INTRODUCTION

The Ecuador Landfill Gas Model (Ecuador LFG Model) provides an automated estimation tool for quantifying landfill gas generation and recovery from municipal solid waste (MSW) landfills in Ecuador. This manual provides an introduction to the model and step-by-step instructions for using the model.

The main purpose of the Ecuador LFG Model is to provide the Ministry for the Environment, Ministry for Urban Development and Housing and through them the Municipalities in Ecuador and some landfill operators with a tool to evaluate the feasibility and potential benefits of collecting and using the generated landfill gas for energy recovery or other uses. To accomplish this purpose, this model provides estimates of potential landfill gas recovery rates. This is accomplished using the landfill gas generation rates estimated by the model and estimates of the efficiency of the collection system in capturing generated gas, known as the collection efficiency. The model provides landfill gas recovery estimates by multiplying the landfill gas generation by the estimated recovery efficiency.

Landfill gas is generated by the decomposition of refuse in the landfill, and can be recovered through the operation of gas collection facilities installed at the landfill. The following information is needed to estimate landfill gas generation and recovery from a landfill (see the Glossary of Terms):

- The design capacity of the landfill;
- The amount of refuse in place in the landfill and the annual refuse acceptance rate for the landfill;
- The methane generation rate (k) constant;
- The potential methane generation capacity (L_0);
- The collection efficiency of the gas collection system; and
- The years the landfill has been and will be in operation.

Both the proprietary Carbon Trade Ltd. model and the U.S. EPA Mexico LFG Model are based on the following equation (Eqn.1) which employs a first-order exponential decay function that assumes that LFG generation is at its peak following a time lag representing the period prior to methane generation.

This gas model first order decay mathematics of the following form:

Equation 1 - First Order Decay Model

$$Q = \sum_{0}^{n} \frac{1}{\%_{vol}} k M L_0 e^{-k(t - t_{lag})}$$

Where:

Q	total quantity of landfill gas generated (Normal cubic meters)
n	total number of years modeled
t	time in years since the waste was deposited
t_{lag}	estimated lag time between deposition of waste and generation of methane
$\%_{vol}$	estimated volumetric percentage of methane in landfill gas
L_0	estimated volume of methane generated per tonne of solid waste
k	estimated rate of decay of organic waste
M	mass of waste in place at year t (tones)

The two variables of L_0 and k are dependant on the composition of waste in the site; however these are still based on estimates and empirical experience of gas generation rate on similar sites.

The variable 'k', the rate at which the organic fraction of waste decays within the waste mass, can vary between 0.1 and 0.01. This wide variation (a factor of 10) results from the availability of organic carbon in the waste and is dependant on moisture content within the waste.

The variable L_0, the ultimate amount of methane generated, varies from $60m^3$/tonne to as high as $120m^3$/tonne for typical domestic waste. In more inert wastes this value can be significantly lower. The potential factor of two in this variable is dependant mainly on the amount of organic carbon within the waste and the availability of that organic carbon.

Therefore in both variables availability of organic carbon plays a key role in the amount of biogas generated and this is a function of the condition of the waste. Conversely the amount of organic carbon is a function of the type of waste.

Determining the exact values for both k and L_0 requires a detailed knowledge of the waste inputs of the site, the biological conditions of the landfill site. For waste input from specific communities and environmental conditions the history, developed over a number of years, of gas extraction from similar landfills can be used to empirically adjust the values of k and L_0.

The Ecuador LFG Model requires site-specific data for all the information needed to produce generation estimates. The model provides default values for k and L_0. The default values are based on site specific data gathered from landfills in Ecuador as an outcome from the M2M's technical cooperation with the country.

EPA recognizes that modeling landfill gas generation and recovery accurately is difficult due to limitations in available information for inputs to the model. However, as new landfills are constructed and operated and better information is collected, the present modeling approach may be improved. In addition, as more landfills in Ecuador develop gas collection and control systems, additional data on landfill gas generation and recovery will become available for model calibration and the development of improved model default values.

Questions and comments concerning the landfill gas model should be directed to Victoria Ludwig, EPA's LMOP by E-Mail at Ludwig.Victoria@epamail.epa.gov.

1.1 Landfill Gas Generation

The Ecuador LFG Model estimates landfill gas generation resulting from the biodegradation of refuse in landfills. The anaerobic decomposition of refuse in solid waste landfills causes generation of landfill gas. The composition of MSW landfill gas is assumed by the model to be about 50 percent methane (CH_4) and 50 percent other gases, including carbon dioxide (CO_2) and trace amounts of other compounds.

This computer model uses a first-order decomposition rate equation and estimates volumes of landfill gas generation in cubic meters per minute (m^3/min) and in cubic meters per hour (m^3/hr). It also estimates the energy content of generated landfill gas in gigajoules per year (G J/yr). Total landfill gas generation is estimated by doubling methane generation (the landfill gas is assumed to be 50% methane). Methane generation is estimated using two parameters: (1) L_0 is the methane generation potential of the refuse and k is the methane generation rate constant. Landfill gas generation is assumed to be at its peak upon closure of the landfill or final placement of waste at the site. Although the model allows the user to enter L_0 and k values derived using site-specific data collected at the landfill (site-specific L_0 and k values may be developed for landfills with operating gas collection and control systems by calibrating the Ecuador LFG Model using known landfill gas recovery data), it is recommended that the provided default lookup table values be used for initial modeling applications.

In theory, the value for the potential methane generation capacity of refuse (L_0) depends only on the type of refuse present in the landfill. The higher the cellulose content of the refuse, the higher the value of L_0. In practice, the theoretical L_0 value may not be reached in dry climates where lack of moisture in the landfill inhibits the action of methane-generating bacteria. The units of L_0 are in cubic meters per tonne of refuse, which means that the L_0 value describes the total amount methane gas produced by a tonne of refuse (no time limit is specified). The values of theoretical and obtainable L_0 range from 6.2 to 270 m^3/Mg refuse (EPA, 1991b). Unless a user-specified L_0 value is entered into the Ecuador LFG Model, default values are used for L_0.

The methane generation rate constant, k, determines the rate of generation of methane from refuse in the landfill. The units for k are in year^{-1}, which means that the k value describes the rate at which refuse placed in a landfill decays and produces methane gas. The higher the value of k, the faster total methane decay rate. The value of k is a function of the following factors: (1) refuse moisture content, (2) availability of nutrients for methane-generating bacteria, (3) pH, and (4) temperature. The k values obtained from data collected from U.S. landfills range from 0.003 to 0.21 per year (EPA, 1991a). These values were obtained from theoretical models using field test data and from actual field test measurements. Unless a user-specified k value is used the Ecuador LFG Model suggests that default values in lookup table are used for k.

As a result of the data obtained from the Pichacay and Las Iguanas gas pumping trials in 2007 a range of suggested values of L_o and k are provided in the Ecuador model. The process of determining these values is described in a separate document outlining the development of the Ecuador gas model. Table 1 shows the default lookup table for values of L_0 and k for the Ecuador model.

Table 1 - Lookup Table for Lo and k

Precipitation (mm/yr)	**K Medium Food Waste (=<50%)**	**K High Food Waste (=>65%)**	**Lo (m3/ Metric tonne) Medium Food Waste (=<50%)**	**Lo (m3/ Metric tonne) High Food Waste (=>65%)**
0	0.040	0.043	60	62
250	0.050	0.053	80	83
500	0.065	0.69	84	87
1000 / Saturated	0.080	0.085	84	87
2000 / Saturated	0.080	0.085	84	87

The Lookup table defines the values of k and L_o for different waste compositions and for different rainfall areas.

Users of the model should consult this table to determine which values of Lo and k are most appropriated for their site. Landfills with high organic content have been found to contain high levels of liquid even in areas where rainfall is low. If high levels of water within the site are expected then the user should select the default values for 'Saturated' sites even if the rainfall in the area of the site is low.

1.2 Collection Efficiency

The basic landfill gas model calculates how much landfill gas (or methane) the landfill is generating. This does not mean that all the landfill gas generated can be collected. It is usual to apply a value for 'Collection Efficiency' which estimates the percentage of the methane generated that can be collected.

Collection efficiency will vary depending on the construction of the landfill and the level of water (leachate) within the landfill. The design of gas collection wells will also affect the collection efficiency. Results from the trials at Pichacay and Las Iguanas landfills indicated that despite high leachate levels within the waste, high collection efficiency could be achieved (when compared to models available at the time).

The Ecuador model contains a lookup table with suggested default vales of collection efficiency. The values should be used where there is no other information.

The model suggests that vertical or horizontal wells installed while waste is being placed may have the highest collection efficiency. However the use of converted passive vents may result in lower gas collection. While significant data on the conversion of passive vents was obtained only from the Pichacay landfill this provided a preliminary indication that lower suctions (and hence flow rates) would be obtained from these conversions.

The model also suggests that the technology used for the capping layer of the landfill will have an effect on collection efficiency. Where a capping layer does not provide a good seal between the waste and the atmosphere it is usually necessary to collect gas using a lower than normal vacuum. This will reduce the amount of gas collected and therefore reduce the collection efficiency.

The sites examined in Ecuador had either dry (non-saturated) or wet (saturated) clay capping layers and collection efficiency for these two, as well as any site which use geomembrane (plastic) capping liners is given. Table 2 provides a suggested value of collection efficiency for Ecuador;

Table 2 - Suggested values of collection efficiency for Landfills in Ecuador

Capping Layer / **Collection Technique**	**Saturated Clay / Geomembrane**	**Non-Saturated Clay**
Drilled Gas Wells Horizontal Collectors	80%	70%
Converted (existing) Passive Vents	60%	40%

Because some site may satisfy the conditions of both the ‘Saturated’ and ‘Non-Saturated’ columns depending on the season (Wet or Dry) a collection efficiency should be calculated based on the proportion of time the capping layer is expected to satisfy each condition.

1.2.1 Available Area

On many landfills there are areas from which gas cannot be easily extracted. These may include the following areas:

- Active waste disposal cells
- Completed but uncapped areas
- Areas which are planned to accept further waste (over-tip or ‘piggy-back’ operations)
- Areas of intensive vehicle movement
- Areas with high gradients (for instance preventing access for drilling equipment)
- Areas of particularly shallow or older waste

These areas will contain a **mass** of waste that is not available for collection. The model therefore includes a % factor for the available mass from which landfill gas can be extracted.

No guidance can be given in the model on identification of each of these areas for a specific site and it will be necessary for the user to estimate or calculate what % of total mass is available in year of the gas model. This can be achieved by considering when each phase of the landfill will have gas extraction systems installed.

The Ecuador gas model therefore includes a column where available **mass** % can be inserted for each year of operation of the landfill. This value is then multiplied by the collection efficiency to provide an ***available*** gas yield for each year.

1.3 The Model

The Ecuador LFG Model can be operated in a Windows 98®, Windows 2000®, Windows XP® or Windows Vista® environment. The program is a Microsoft Excel® spreadsheet, which allows the user considerable control over model calculations and output appearances. Excel® software must be opened prior to running the model. Once Excel® is running, open the model file ("LMOP Ecuador Model.xls") by choosing "file" "open," and then "open" when the correct file is highlighted. The model has three worksheets that are accessible by clicking on the tabs at the bottom of the Excel® window screen. The three worksheets are as follows:

- A model inputs worksheet;
- A model outputs worksheet in a table format;
- A model outputs worksheet in a graph format; and

When using the model, most of the editing by the user takes place in the model inputs worksheet. Some editing may be required in the outputs worksheet for formatting purposes. The calculations worksheet should not be changed and is password protected to prevent changes.

2 ESTIMATING LANDFILL GAS GENERATION AND RECOVERY

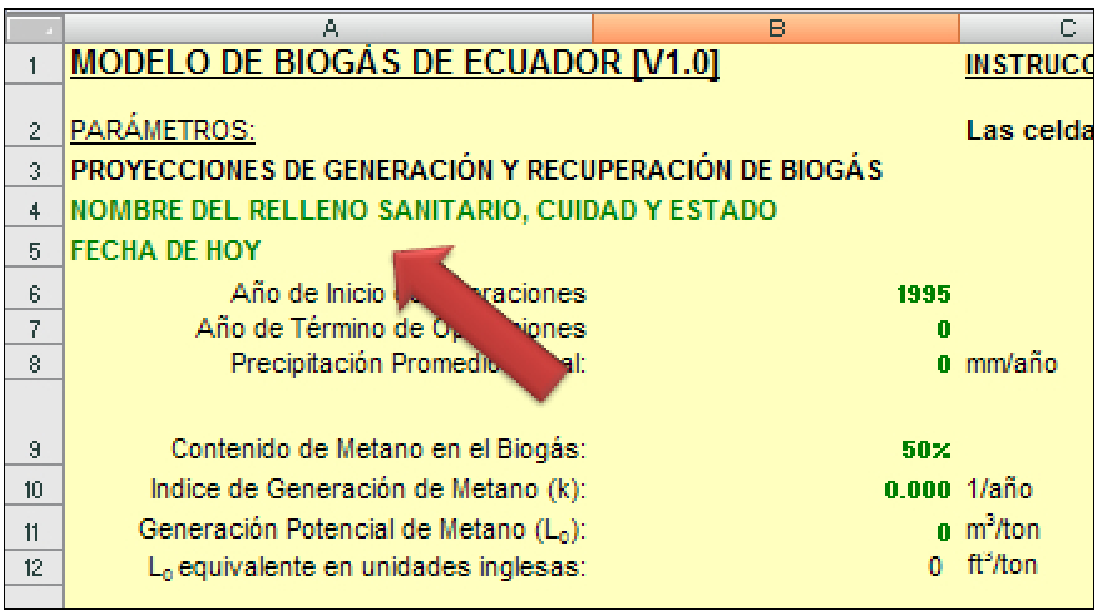
2.1 Model Inputs

All model inputs are to be put into an “Inputs” worksheet. Cells with green bold text require user inputs. The following inputs are required to run the model properly and produce acceptable outputs (tables and graphs):

<u>Step 1:</u> Enter the Site Identification

The name and location of the landfill (goes in Cell A4 – see Figure 1 below). What you enter here will automatically appear in the heading of the output table.

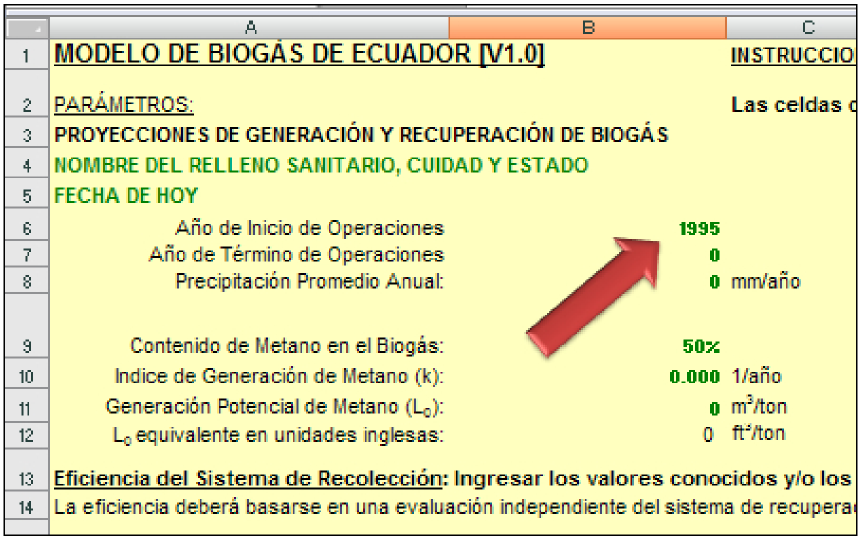
Figure 1 - Site Identification Data



<u>Step 2:</u> Enter the Operational Years

The year the landfill opened and began receiving waste is entered into Cell B6 – see Figure 2. What you enter here will feed into the table of numbers below and in the output table

Figure 2 - Operational Years Data Input



<u>Step 3:</u> Enter the Environmental Data

The average annual precipitation in mm at the landfill (goes into Cell B8 – see Figure 3 below). This information can be obtained by looking up precipitation data for the closest city or town at www.inhami.gov.ec. This value is for reference only. The user will need to look up appropriate default values for k and Lo from the appropriate table within the model or use values specific to the landfill.

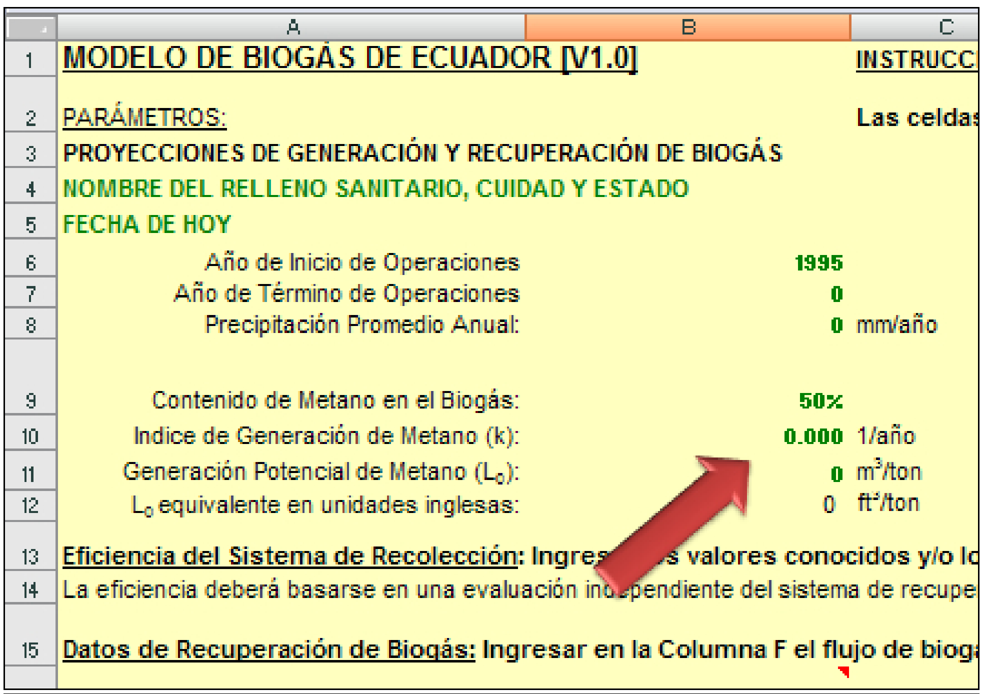
Figure 3 – Environmental Data Input

<u>Step 4: Select the value k, Lo and methane concentration.</u>

The model is calibrated to operate with a methane concentration of 50%. Although this value can be altered in the model it is advised that the default value is used. If information exists that indicates a different value of methane concentration then this can be entered in cell B9.

Using the environmental information, or knowledge of the water content of the waste, select values for k and Lo from the lookup table and enter these into cells B10 and B11

Figure 4 – k, Lo data Input and lookup table



	A	B	C
1	MODELO DE BIOGÁS DE ECUADOR [V1.0]		INSTRUCC
2	PARÁMETROS:		Las celdas
3	PROYECCIONES DE GENERACIÓN Y RECUPERACIÓN DE BIOGÁS		
4	NOMBRE DEL RELLENO SANITARIO, CUIDAD Y ESTADO		
5	FECHA DE HOY		
6	Año de Inicio de Operaciones	1995	
7	Año de Término de Operaciones	0	
8	Precipitación Promedio Anual:	0	mm/año
9	Contenido de Metano en el Biogás:	50%	
10	Indice de Generación de Metano (k):	0.000	1/año
11	Generación Potencial de Metano (L_0):	0	m^3/ton
12	L_0 equivalente en unidades inglesas:	0	ft^3/ton
13	Eficiencia del Sistema de Recolección: Ingres... s valores conocidos y/o lo		
14	La eficiencia deberá basarse en una evaluación independiente del sistema de recupe		
15	Datos de Recuperación de Biogás: Ingresar en la Columna F el flujo de biog		

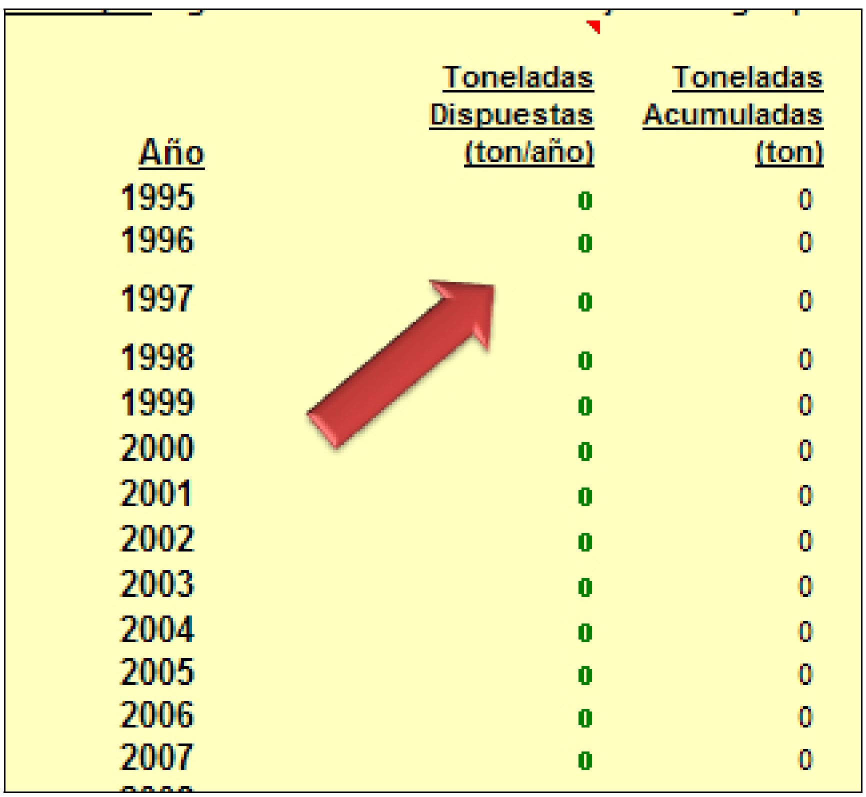
TABLA 1 - TABLA DE CALCULO DE VALORES k Y L_0				
Precipitación (mm/año)	k Contenido Medio de Residuos de Comida o Alimenticios =<50%	k Alto Contenido de Residuos de Comida o Alimenticios=>60%	L_0 (m^3/ Tonelada métrica) Contenido Medio de Residuos de Comida o Alimenticios =<50%	L_0 (m^3/ Tonelada métrica) Alto Contenido de Residuos de Comida o Alimenticios =>60%
0-249	0.04	0.043	60	62
250-499	0.05	0.053	80	83
500-999	0.065	0.069	84	87
1000 - 1999 o Saturado	0.08	0.085	84	87
2000+ o Saturado	0.08	0.085	84	87

<u>Step 5:</u> Enter the amount of Waste

Metric tonnes of waste disposed in the site for each year is entered into Cells B17 – B116

- If the disposal history is unknown, calculate the landfill’s average annual disposal rate by dividing the number of years the site was/will be open into the total site capacity (in metric tonnes).
- Enter the resulting value into Cell B17 and subsequent cells.
- The value entered into Cell B17 and subsequent cells will be automatically copied into cell C17 and summed to provide a cumulative total of waste disposed . It is a good idea to ensure that this cumulative total agrees with the estimated total amount of waste in the landfill.
- The model allows a maximum of 100 years of waste disposal to be modeled.
- Enter a “0” into the cell corresponding to the years following site closure.

Figure 5 – Waste amount data



Año	Toneladas Dispuestas (ton/año)	Toneladas Acumuladas (ton)
1995	0	0
1996	0	0
1997	0	0
1998	0	0
1999	0	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
2004	0	0
2005	0	0
2006	0	0
2007	0	0

Step 6: Enter the estimated % of available waste mass.

If not all the landfill is available for landfill gas extraction then an estimate of the percentage of the total mass that is available for the gas collection system can be entered into Cell D17 and subsequent Cells. If no estimates are available then 100% should be entered in all the Cells.

Figure 6 – Waste mass available data

Toneladas Dispuestas (ton/año)	Toneladas Acumuladas (ton)	Toneladas Masa Disponibles	Eficienc Sister Recole
0	0	0%	
0	0	0%	
0	0	0%	
0		0%	
0	0	0%	
0	0	0%	
0	0	0%	
0	0	0%	
0	0	0%	

<u>**Step 7:**</u> Enter the estimated Collection Efficiency

Estimated collection efficiency for each year after a gas collection system was/will be installed is enetered into Cells D17 and subsequent cells

- Suggested Collection Efficiency figures are given in a Lookup Table in the model
- Collection system efficiency for years prior to the present should reflect the status of the collection system in prior years.
- Collection system efficiency for future years should reflect the estimated collection system build-out in future years.
- Remember to complete the figure for Collection Efficiency for all years that the gas system will operate. This is usually many years after the landfill has stopped receiving waste.

Figure 7 – Collection efficiency estimate data and lookup table

Toneladas cumuladas (ton)	Toneladas Masa Disponibles	Eficiencia del Sistema de Recolección	Re
0	0%	0%	
0	0%	0%	
0	0%	0%	
0		0%	
0	0%	0%	
0	0%	0%	
0	0%	0%	
0	0%	0%	
0	0%	0%	

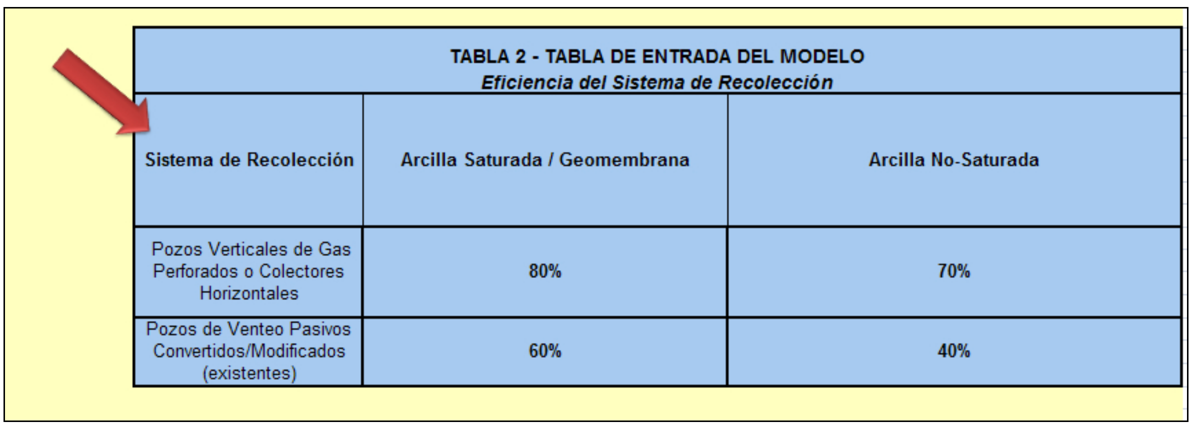


TABLA 2 - TABLA DE ENTRADA DEL MODELO
Eficiencia del Sistema de Recolección

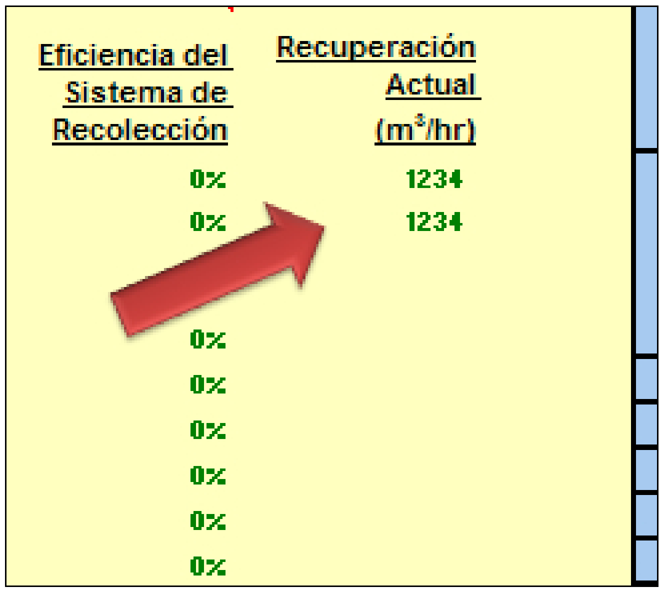
Sistema de Recolección	Arcilla Saturada / Geomembrana	Arcilla No-Saturada
Pozos Verticales de Gas Perforados o Colectores Horizontales	80%	70%
Pozos de Venteo Pasivos Convertidos/Modificados (existentes)	60%	40%

<u>Step 8: Gas Recovery Data</u>

Actual landfill gas recovery rates in cubic meters per hour (for sites with active gas collection systems) can be input into Cells E17 – E116. This should be the average annual total landfill gas flow at the flare station and/or energy recovery plant (NOT the sum of flows at individual wells). Adjust all flow rates to 50% methane equivalent by multiplying the measured flow by the measured methane content of the landfill gas and then dividing the result by 50%. The numbers placed in these cells will be displayed in the graph output sheet, so do not input zeros for years with no flow data (leave blank).

Actual recovery rates are not required for the model calculations. However they provide a useful reference to compare actual recovery rates to the model predictions.

Figure 8 – Gas recovery data



2.2 Model Outputs - Table

Model results are displayed in a table located in the “Outputs-Table” worksheet that is ready for printing with minimal editing (the following page for a sample table layout). The title of the table has been set by user inputs in the Inputs worksheet. The table provides the following information which was either copied from the Inputs worksheet or calculated by the model:

- Projection years starting with the landfill opening year and ending in a year of the user’s choosing.
- Annual disposal rates.
- Cumulative amount of waste in place for each projection year.
- Landfill gas generation rates for each projection year in cubic meters per minute, cubic meters per hour, and billion joules (G J) per year.
- Collection system efficiency for each projection year.

- Landfill gas recovery rates for each projection year in cubic meters per minute, cubic meters per hour, and billion joules (G J) per year.
- The methane content assumed for the model projection (50% in most cases).
- The k value used for the model run.
- The L_0 value used for the model run.

The table is set up to display up to 100 years of landfill gas generation and recovery estimates. As provided, the table shows 60 years of information. The last 40 years are in hidden rows. The user will likely want to change the number of years of information displayed, depending on how old the site is and how many years into the future the user wants to display information. Typically, projections up to the year 2035 are adequate for most uses of the model. To hide additional rows, highlight cells in the rows to be hidden and select “Format” “Row” “Hide”. To unhide rows, highlight cells in rows above and below rows to be displayed, and select “Format” “Row” “Unhide”.

To print the table, select “File” “Print” “OK”. The table should print out correctly formatted.

2.3 Sample of Model Outputs Table

Tabla 3 – Muestra de Tabla de Resultados

PROYECCIONES DE GENERACIÓN Y RECUPERACIÓN DE BIOGÁS
Relleno Teórico

	Indice de Disposición	Toneladas Acumuladas	Generación de Biogás			Eficiencia del Sistema de Recolección	Recuperación de Biogás del Sistema Existente/Planeado		
Año	(Ton/año)	(Ton)	(m^3/min)	(m^3/hr)	(mmBTU/año)	(%)	(m^3/min)	(m^3/hr)	(mmBTU/año)
1995	200,000	200,000	0.0	0	0	0%	0.0	0	0
1996	200,000	400,000	5.1	307	48,013	0%	0.0	0	0
1997	200,000	600,000	9.8	590	92,334	0%	0.0	0	0
1998	200,000	800,000	14.2	851	133,248	0%	0.0	0	0
1999	200,000	1,000,000	18.2	1,093	171,016	45%	8.2	492	76,957
2000	200,000	1,200,000	21.9	1,315	205,881	45%	9.9	592	92,646
2001	200,000	1,400,000	25.3	1,521	238,065	45%	11.4	684	107,129
2002	200,000	1,600,000	28.5	1,711	267,774	45%	12.8	770	120,498
2003	200,000	1,800,000	31.4	1,886	295,199	45%	14.1	849	132,840
2004	200,000	2,000,000	34.1	2,048	320,516	45%	15.4	921	144,232
2005	200,000	2,200,000	36.6	2,197	343,887	45%	16.5	989	154,749
2006	200,000	2,400,000	38.9	2,335	365,460	45%	17.5	1,051	164,457
2007	200,000	2,600,000	41.0	2,462	385,375	45%	18.5	1,108	173,419
2008	200,000	2,800,000	43.0	2,579	403,759	45%	19.3	1,161	181,691
2009	200,000	3,000,000	44.8	2,688	420,729	45%	20.2	1,209	189,328
2010	200,000	3,200,000	46.5	2,788	436,395	45%	20.9	1,255	196,378
2011	0	3,200,000	48.0	2,880	450,856	60%	28.8	1,728	270,514
2012	0	3,200,000	44.3	2,659	416,192	60%	26.6	1,595	249,715
2013	0	3,200,000	40.9	2,454	384,194	60%	24.5	1,473	230,516
2014	0	3,200,000	37.8	2,266	354,656	60%	22.7	1,359	212,793
2015	0	3,200,000	34.9	2,091	327,389	60%	20.9	1,255	196,433
2016	0	3,200,000	32.2	1,931	302,218	60%	19.3	1,158	181,331
2017	0	3,200,000	29.7	1,782	278,982	60%	17.8	1,069	167,389
2018	0	3,200,000	27.4	1,645	257,533	60%	16.5	987	154,520
2019	0	3,200,000	25.3	1,519	237,733	60%	15.2	911	142,640
2020	0	3,200,000	23.4	1,402	219,455	60%	14.0	841	131,673
2021	0	3,200,000	21.6	1,294	202,583	0%	0.0	0	0
2022	0	3,200,000	19.9	1,195	187,007	0%	0.0	0	0
2023	0	3,200,000	18.4	1,103	172,630	0%	0.0	0	0
2024	0	3,200,000	17.0	1,018	159,357	0%	0.0	0	0
2025	0	3,200,000	15.7	940	147,105	0%	0.0	0	0
2026	0	3,200,000	14.5	868	135,795	0%	0.0	0	0
2027	0	3,200,000	13.3	801	125,355	0%	0.0	0	0
2028	0	3,200,000	12.3	739	115,717	0%	0.0	0	0
2029	0	3,200,000	11.4	682	106,820	0%	0.0	0	0
2030	0	3,200,000	10.5	630	98,608	0%	0.0	0	0
2031	0	3,200,000	9.7	582	91,026	0%	0.0	0	0
2032	0	3,200,000	8.9	537	84,028	0%	0.0	0	0
2033	0	3,200,000	8.3	496	77,567	0%	0.0	0	0
2034	0	3,200,000	7.6	457	71,604	0%	0.0	0	0
2035	0	3,200,000	7.0	422	66,099	0%	0.0	0	0
2036	0	3,200,000	6.5	390	61,017	0%	0.0	0	0
2037	0	3,200,000	6.0	360	56,326	0%	0.0	0	0
2038	0	3,200,000	5.5	332	51,995	0%	0.0	0	0
2039	0	3,200,000	5.1	307	47,997	0%	0.0	0	0
2040	0	3,200,000	4.7	283	44,307	0%	0.0	0	0
2041	0	3,200,000	4.4	261	40,901	0%	0.0	0	0
2042	0	3,200,000	4.0	241	37,756	0%	0.0	0	0
2043	0	3,200,000	3.7	223	34,853	0%	0.0	0	0
2044	0	3,200,000	3.4	206	32,174	0%	0.0	0	0
2045	0	3,200,000	3.2	190	29,700	0%	0.0	0	0
2046	0	3,200,000	2.9	175	27,417	0%	0.0	0	0
2047	0	3,200,000	2.7	162	25,309	0%	0.0	0	0
2048	0	3,200,000	2.5	149	23,363	0%	0.0	0	0
2049	0	3,200,000	2.3	138	21,567	0%	0.0	0	0
2050	0	3,200,000	2.1	127	19,909	0%	0.0	0	0
2051	0	3,200,000	2.0	117	18,378	0%	0.0	0	0
2052	0	3,200,000	1.8	108	16,965	0%	0.0	0	0
2053	0	3,200,000	1.7	100	15,661	0%	0.0	0	0
2054	0	3,200,000	1.5	92	14,457	0%	0.0	0	0

NOTES:
Contenido de Metano en el Biogás: 50%
Indice de Generación de Metano (k): 0.080 1/año
Generación Potencial de Metano (L_0): 84 m^3/ton

2.4 Model Outputs - Graph

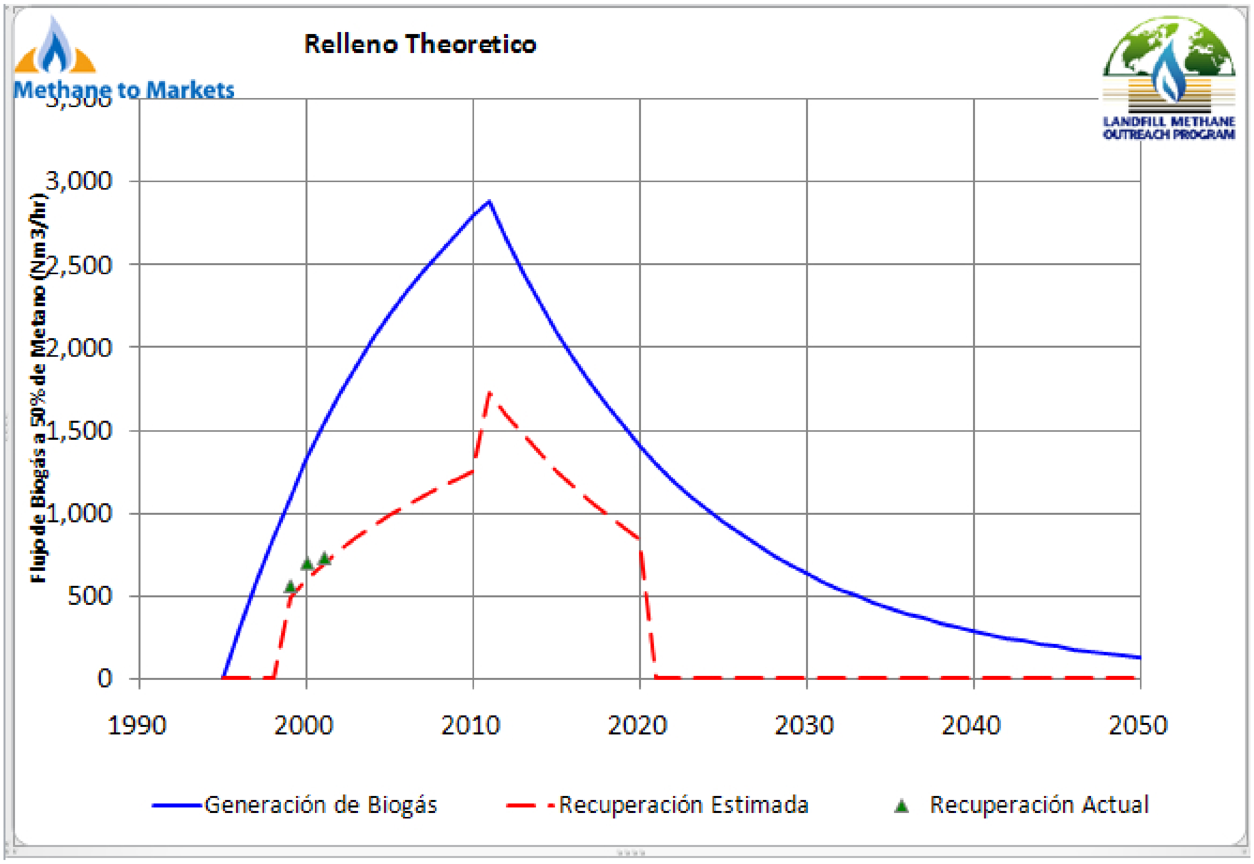
Model results are also displayed in graphical form in the “Outputs-Graph” worksheet (see the figure on the following page for a sample graph layout). Data displayed in the graph includes the following:

- Landfill gas generation rates for each projection year in cubic meters per minute.
- Landfill gas recovery rates for each projection year in cubic meters per minute.
- Actual (historical) landfill gas recovery rates in cubic meters per minute.

As noted in the instructions listed below the graph, the title of the graph will need to be edited by clicking on the graph title and typing the desired title. The timeline in the X axis is set to finish in 2050. Also, because the graph is linked to the table, it will show data for all projection years shown in the table (given the limits set for the x-axis). It will not show any hidden rows. If the table shows years beyond the range set for the x-axis, the line of the graph will appear to go off of the edge of the graph.

To print the graph, click anywhere on the graph and select “File” “Print” OK”. If the user does not click on the graph prior to printing, the instructions will also appear in the printout.

Figure 9 – Sample Model Output Graph



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