Project design document form
(Version 11.0)

Complete this form in accordance with the instructions attached at the end of this form.

BASIC INFORMATION	
Title of the project activity	Manaus Landfill Gas Project
Scale of the project activity	☒ Large-scale ☐ Small-scale
Version number of the PDD	5
Completion date of the PDD	12/05/2020
Project participants	Conestoga Rovers e Associados Engenharia Ltda. Nordic Environment Finance Corporation
Host Party	Brazil
Applied methodologies and standardized baselines	ACM0001: Flaring or use of landfill gas (version 18.0)
Sectoral scopes	1 - Energy industries (renewable - / non-renewable sources) 13 - Waste handling and disposal
Estimated amount of annual average GHG emission reductions	604,210 tCO_2e

SECTION A. Description of project activity

A.1. Purpose and general description of project activity

>> The Manaus Landfill Gas Project has been developed at the Manaus Landfill (Site), originally called the Aterro Municipal de Manaus. The Site has received non-hazardous solid municipal, industrial, commercial, institutional, and some agricultural wastes for approximately 20 years. Landfills normally emit carbon dioxide (CO_2) and methane (CH_4) into the atmosphere, with these compounds being generated by the anaerobic decomposition of the above-noted wastes placed at the project site. Prior to the implementation of the Project, the Manaus landfill was basically a landfill with has minimal control of surface water and leachate and no control of landfill gas (LFG).

The purpose of the project activity is to collect landfill gas (LFG) at the Manaus Landfill and to combust the extracted LFG over a seven year-period, using a high efficient enclosed flare, thereby generating electricity and reducing greenhouse gas emissions (GHG). During the second crediting period, the project is expected to reduce 604,210 tCO_2e/year and 4,229,470 tCO_2e during the whole period.

The project involved the construction of a LFG collection system consisting of horizontal trenches and vertical LFG extraction wells, centrifugal blower(s), and all other supporting mechanical and electrical subsystems and appurtenances necessary to collect the LFG.

The LFG collected from the site is combusted in an enclosed LFG flare with full process controls and instrumentation installed and operating. The state-of-the-art flare is capable of providing sufficient temperature and retention time of the extracted LFG for complete destruction of hydrocarbons.

Conestoga-Rovers & Associates (CRA) started design activities in late 2005 and construction works started in October 2008. The project was ready for commissioning in July 2009. Accordingly to the completeness check, the official registration date was on July 8th, 2011.

A.2. Location of project activity

>> The project activity takes places in Manaus Landfill, located in the city of Manaus, capital of Amazonas state, at the geographical coordinates 2º57’29.92’’S and 60º00’54.74’’W. The project site is located at Km 19 of Highway AM-010. The Manaus Landfill covers 60 hectares (ha) area and the current waste filling area has 41 ha, with available space for continued filling.

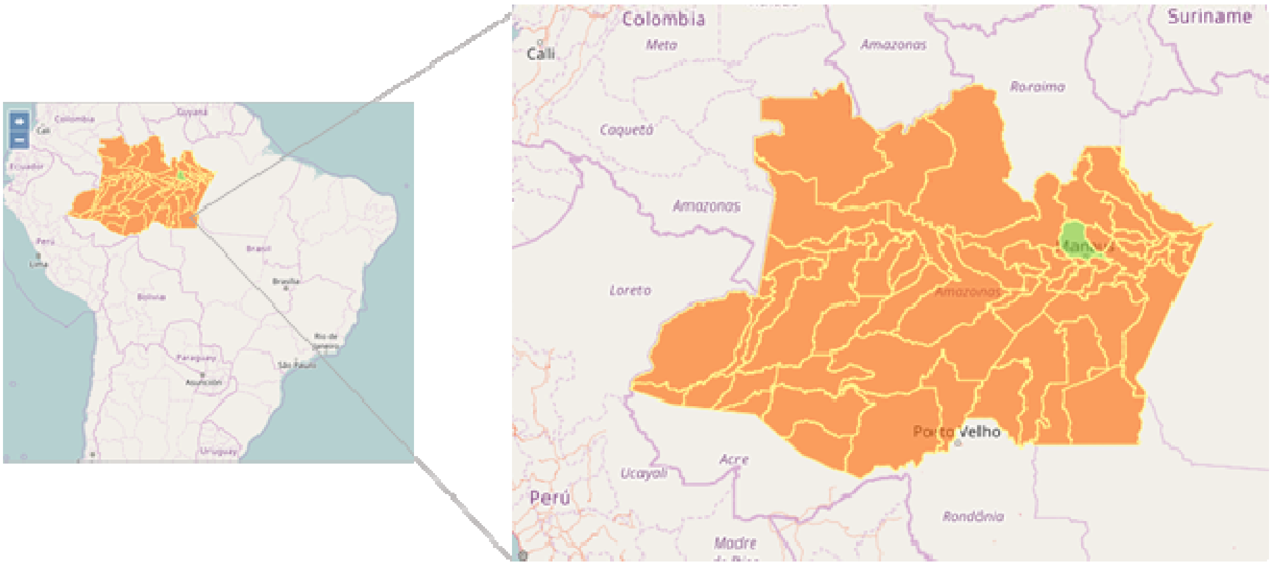

Figure 1 – Geographical position of Manaus city, Brazil.

Source: IBGE, Cid@des[1].

Figure 2 – Aerial view of Manaus Landfill.

A.3. Technologies/measures

>> As there is no legal requirement to capture LFG in landfill sites in Brazil, the baseline scenario is LFG release to the atmosphere. This is also the scenario prior to the project implementation. Therefore, the Project Participants need some incentive to make investment in a LFG recovery and destruction system at the Manaus Landfill.

[1] Available at: < http://cidades.ibge.gov.br/xtras/uf.php?lang=&coduf=13&search=amazonas>.

The baseline scenario is LFG release to the atmosphere and a landfill without any legal requirement to capture this LFG. This is also the scenario prior to the project implementation. Therefore, an extra-incentive is needed for CRA to make additional investment and install an appropriate facility to properly burn the methane produced at the project site.

a) Collecting System

Following concrete examples from other LFG projects in the world, the Project involved the installation of horizontal collecting system and vertical wells to avoid the emission of methane to the atmosphere. An example of configuration used is presented in **Figure 3** below:

Figure 3 – Example of horizontal collection system (trench).

The horizontal collecting system and vertical wells were implemented due to the project activity only. Usually the horizontal colleting systems are made of Polyvinyl Chloride (PVC) or High-Density Polyethylene (HDPE), due to the flexibility and the corrosion resistance.

The horizontal collecting system and vertical wells are connected to the transmission pipeline. This pipeline transports the LFG to the manifolds or gas regulation stations. The manifold is designed to regulate the concentration of the gas (methane, oxygen and others).

Figure 4 – Gas Regulation Station.

b) Transmission Pipeline

The transmission pipeline is the last step of the collecting system. It transports the collected LFG to the flare station. The transmission pipeline might be connected to all manifolds or gas regulation stations around the landfill.

Figure 5 – Example of transmission pipelines.

The collecting pipeline and the transmission pipeline are both usually in HDPE, because this material can support high pressures and is flexible. The transmission pipeline is finally connected to the flare station. A common practice all over the world is to use HDPE, which is more flexible and more resistant to high pressure, if compared to metal or concrete equipment. The disadvantage is represented by the high cost involved.

c) Blowering System

The blowering system is responsible to give negative pressure to the landfill, blowing the gas to the pipeline. The blower dimensioning depends on the final use of the gas (flare, boiler, electricity).

In order to preserve the operation of the blowers, a dewatering system is installed to remove the condensate. This equipment is a single knock-out dewatering component.

Figure 6 – Blower system (at left) and condensate knockout (at right).

d) Flare System

The destruction of the methane content in the LFG collected is made via enclosed flares, in order to ensure high methane destruction (minimum 98%).

Basically, the flare is constructed using refractory material, a gas inlet, dampers to control the air inlet, an ignition spark, flame viewer and points to sample collection, as presented in the pictures below:

Figure 7 – Detail of Enclosed Flare.

e) Biogas Generator (CHP300)

The biogas generator was installed at Manaus Landfill Gas Project on May 26, 2019. The generator CHP300 use biogas as fuel to generate electricity only to supply biogas plant demand.

For the correct operation of the generator, it is necessary to ensure the supply of fuel at the required flow and pressure. Biogas must be clean, free from moisture, contaminants and impurities. The composition of biogas can vary according to the production process. Differences in methane content are reflected in a fuel with greater or lesser calorific value.

Figure 8– Detail of Biogas Generator

Model	CHP300
Manufactures	CHP Brasil
Fuel	Biogas about 55 to 75% CH_4 74 Nm^3/h
Continuous Power	170kW

Among the parameters monitored by the control system are:

- Coolant temperature
- Lubricating oil pressure
- Inlet temperature
- Quality of the air / fuel mixture
- Overload

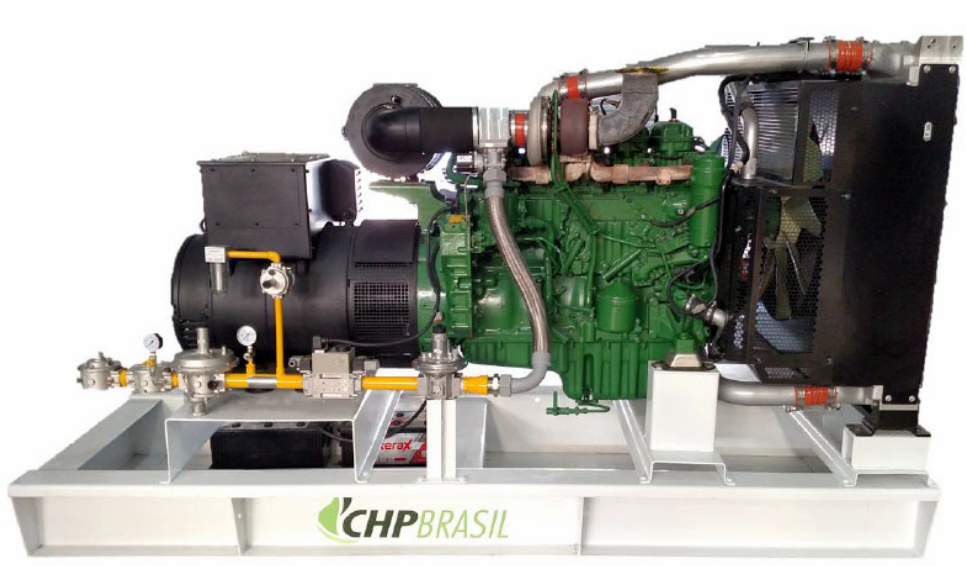

Figure 9– Detail of Biogas Generator

f) Power Generation

The power generation system will be comprise of around 12 engines - 1.6 MW each[2]. The electricity generated by the Project will supply Manaus Electricity Grid, which was interconnected with the National Interconnected System ("SIN" from the Portuguese *Sistema Interligado Nacional*) on July 2013[3].

This kind of technology is still not widely applied in Brazil. Very few landfills have already installed equipment for LFG collection and flaring, even more considering enclosed flares as it is the case of the project activity. Therefore, the company needed engineers and other specialists with experience in this area to advice the company while implementing the project. These professionals also received trainings for the operation and maintenance of the facilities.

Technology was manufactured abroad, and therefore, technology transfer occurred from countries with strict environmental legislative requirements and environmentally sound technologies.

A.4. Parties and project participants

Parties involved	Project participants	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
Brazil (host Party)	Conestoga Rovers e Associados Engenharia Ltda. (Private Entity)	No

[2] Estimated to start on 01/01/2022.

[3] Information available in the ONS Annual Report of 2013: <http://ons.org.br/sites/multimidia/Documentos%20Compartilhados/relatorios%20anuais/2013/HTML/01-00-destaques.html>.

Norway	Nordic Environment Finance Corporation (Private Entity)	No

A.5. Public funding of project activity

>> There is no recourse to any public funding by the Project Participants in the proposed project activity. The project proponents hereby confirm that there is no divergence of Official Development Assistance (ODA) to the project activity.

A.6. History of project activity

>> The Project Participants confirm that the proposed CDM project activity is neither registered as a CDM project activity nor included as a component project activity (CPA) in a registered CDM programme of activities (PoA). Also, confirm that the proposed CDM project activity is not a project activity that has been deregistered.

Project Participants declare that the proposed CDM project activity was not a CPA that has been excluded from a registered CDM PoA. Also, there is no other registered CDM project activity or a CPA under a registered CDM PoA whose crediting period has or has not expired (hereinafter referred to as former project) in the same geographical location as the proposed CDM project activity.

A.7. Debundling

>> Not applicable.

SECTION B. Application of methodologies and standardized baselines

B.1. References to methodologies and standardized baselines

>> The project activity applies ACM0001 methodology “Flaring or use of landfill gas” (Version 18.0)[4].

ACM0001 also refers to the following methodological tools:

- TOOL02-Combined tool to identify the baseline scenario and demonstrate additionality (Version 07.0)[5];

[4] Available at: <https://cdm.unfccc.int/filestorage/0/X/2/0X2IE6B1PJDLKMWN89AZGTFUHR3VYS/EB94_repan04_ACM0001.pdf?t=WWt8b3VyZG8zfDD7RuR_ZF1rU3o9oDc-jIyR>.

[5] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v7.0.pdf>.

- TOOL 03-Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion (Version 03)[6];
- TOOL 04-Emissions from solid waste disposal sites (Version 08.0)[7];
- TOOL 05-Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation (Version 03.0)[8];
- TOOL 06-Project emissions from flaring (Version 02.0.0)[9];
- TOOL08- Tool to determine the mass flow of a greenhouse gas in a gaseous stream (Version 03.0)[10];
- TOOL09- Determine the baseline efficiency of thermal or electric energy generation systems (Version 02.0)[11];
- TOOL10-Tool to determine the remaining lifetime of equipment (Version 01)[12];
- TOOL11-Assessment of the validity of the original/current baseline and update of the baseline at the renewal of the crediting period (Version 03.0.1)[13];
- TOOL12-Project and leakage emissions from transportation of freight (Version 01.1.0)[14];

While applying the methodological tool "*Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*", the "*Tool to calculate the emission factor for an electricity system*" (Version 06.0)[15] was also considered to the project activity.

Since this PDD refers to the second crediting period of Manaus project, the "*Tool for the demonstration and assessment of additionality*" and the "*Combined tool to identify the baseline scenario and demonstrate additionality*" are not applicable.

The tool "*Project and leakage emissions from transportation of freight*" is also not applied to Manaus project, since there are no GHG emissions from transportation of freight in the project boundary.

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[6] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-03-v3.pdf>.

[7] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-04-v8.0.pdf>.

[8] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-05-v3.0.pdf>.

[9] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-06-v2.0.pdf>.

[10] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-08-v3.0.pdf>.

[11] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-09-v2.0.pdf>.

[12] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-10-v1.pdf>.

[13] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-11-v3.0.1.pdf>.

[14] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.1.0.pdf>.

[15] Available at: <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v6.pdf>.

B.2. Applicability of methodologies and standardized baselines

>> The methodology is applicable under the following conditions:

(a) *Install a new LFG capture system in an existing or new (Greenfield) SWDS where no LFG capture system was or would have been installed prior to the implementation of the project activity; or*

The project activity consists on the installation of a new LFG capture system in an existing SWDS, where no LFG capture system have been installed prior to the implementation of the project activity and, therefore, no LFG flow could be controlled to avoid methane free emissions to the atmosphere.

(b) *Make an investment into an existing LFG capture system to increase the recovery rate or change the use of the captured LFG, provided that:*

(i) *The captured LFG was vented or flared and not used prior to the implementation of the project activity; and*

(ii) *In the case of an existing active LFG capture system for which the amount of LFG cannot be collected separately from the project system after the implementation of the project activity and its efficiency is not impacted on by the project system: historical data on the amount of LFG capture and flared is available;*

The LFG venting wells installed prior to the project implementation were passive, shallow and very inefficient. Therefore, the capture LFG was vented only and not used – option (i) above.

(c) *Flare the LFG and/or use the captured LFG in any (combination) of the following ways:*

(i) *Generating electricity;*

(ii) *Generating heat in a boiler, air heater or kiln (brick firing only) or glass melting furnace;1 and/or*

(iii) *Supplying the LFG to consumers through a natural gas distribution network;*

(iv) *Supplying compressed/liquefied LFG to consumers using trucks;*

(v) *Supplying the LFG to consumers through a dedicated pipeline;*

The project activity consists of using the captured gas for generating electricity – option (i) above). The excess of LFG is flared.

(d) *Do not reduce the amount of organic waste that would be recycled in the absence of the project activity.*

The implementation of the project activity does not reduce the amount of organic waste that would be recycled in the absence of the project activity. There is no recycling system at the project site. In reality, the quantity of organic waste is expected to increase due to

demographic expansion and, consequently, waste generation increases. Please refer to the Declaration issued by the Municipal Secretary of Cleaning and Urban Services of Manaus Municipality.

The methodology is only applicable if the application of the procedure to identify the baseline scenario confirms that the most plausible baseline scenario is:

(a) Atmospheric release of the LFG or capture of LFG and destruction through flaring to comply with regulations or contractual requirements, to address safety and odour concerns, or for other reasons; and

(b) In the case that the LFG is used in the project activity for generating electricity and/or generating heat in a boiler, air heater, glass melting furnace or kiln:

(i) For electricity generation: that electricity would be generated in the grid or in captive fossil fuel fired power plants; and/or

(ii) For heat generation: that heat would be generated using fossil fuels in equipment located within the project boundary;

(c) In the case of LFG supplied to the end-user(s) through natural gas distribution network, trucks or the dedicated pipeline, the baseline scenario is assumed to be displacement of natural gas.

(d) In the case of LFG from a Greenfield SWDS, the identified baseline scenario is atmospheric release of the LFG or capture of LFG in a managed SWDS and destruction through flaring to comply with regulations or contractual requirements, to address safety and odour concerns, or for other reasons.

The most plausible baseline scenario for the LFG is identified as atmospheric release of LFG with electricity supplied from grid connected power plants.

This methodology is not applicable:

(a) In combination with other approved methodologies. For instance, ACM0001 cannot be used to claim emission reductions for the displacement of fossil fuels in a kiln or glass melting furnace, where the purpose of the CDM project activity is to implement energy efficiency measures at a kiln or glass melting furnace;

(b) If the management of the SWDS in the project activity is deliberately changed during the crediting in order to increase methane generation compared to the situation prior to the implementation of the project activity.

The ACM0001 is applicable to the proposed CDM Project Activity since the Manaus Project does not make use of other CDM approved methodology. ACM0001 is the only methodology used in this project.

Furthermore, the management of the Manaus landfill in the project activity is not changed in order to increase methane generation compared to the situation prior to the implementation of the project activity.

B.3. Project boundary, sources and greenhouse gases (GHGs)

	Source	GHG	Included?	Justification/Explanation
Baseline	Emissions from decomposition of waste at the SWDS site	CO_2	Yes	The major source of emissions in the baseline.
		CH_4	No	N_2O emission are small compared to CH_4 emissions from SWDS. This is conservative.
		N_2O	No	CO2 emissions from decomposition of organic waste are not accounted since the CO_2 is also released under the project activity.
	Emissions from electricity generation	CO_2	Yes	Major emission source if power generation is included in the project activity.
		CH_4	No	Excluded for simplification. This is conservative.
		N_2O	No	Excluded for simplification. This is conservative.
	Emissions from heat generation	CO_2	No	There is no heat generation in the project activity.
		CH_4	No	There is no heat generation in the project activity.
		N_2O	No	There is no heat generation in the project activity.
	Emissions from the use of natural gas	CO_2	No	There is no use of natural gas in the project activity.
		CH_4	No	There is no use of natural gas in the project activity.
		N_2O	No	There is no use of natural gas in the project activity.
Project activity	Emissions from fossil fuel consumption for purposes other than electricity generation or transportation due to the project activity	CO_2	Yes	May be an important emission source.
		CH_4	No	Excluded for simplification. This emission source is assumed to be very small.
		N_2O	No	Excluded for simplification. This emission source is assumed to be very small.
	Emissions from electricity consumption due to the project activity	CO_2	Yes	May be an important emission source.
		CH_4	No	Excluded for simplification. This emission source is assumed to be very small.
		N_2O	No	Excluded for simplification. This emission source is assumed to be very small.
	Emissions from flaring	CO_2	No	Emissions are considered negligible.
		CH_4	Yes	May be an important emission source.
		N_2O	No	Emissions are considered negligible.
	Emissions from distribution of LFG using trucks and dedicated pipelines	CO_2	No	There is no distribution of LFG using trucks in the project activity.
		CH_4	No	There is no distribution of LFG using trucks in the project activity.

Source		GHG	Included?	Justification/Explanation
		N_2O	No	There is no distribution of LFG using trucks in the project activity.

According to the ACM0001 methodology the project boundary includes the site where the LFG is captured (Manaus Landfill) and:

- Sites where the LFG is flared or used (e.g. flare, power plant, boiler, air heater, glass melting furnace, kiln or natural gas distribution network or biogas processing facility);

  In the case of the proposed CDM Project Activity, the site where the LFG is flared/used consists of the collection system, biogas upgrading facility, gas station facilities (including flaring).

- Captive power plant(s) (including emergency diesel generators) or power generation sources connected to the grid, which are supplying electricity to the project baseline that is displaced by electricity generated by captured LFG in the project activity;

  All the power generation sources connected to the Brazilian National Grid are included in the project boundary once electricity from the grid will be consumed by the LFG plant. On May 26th, 2008, the Brazilian Designated Authority published Resolution #817 defining the Brazilian Interconnected Grid as a single system covering all five geographical regions of the country (North, Northeast, South, Southeast and Midwest). Hence, this is the configuration of the national grid that is to be considered.

  The figure below is a simplified representation of the project boundary:

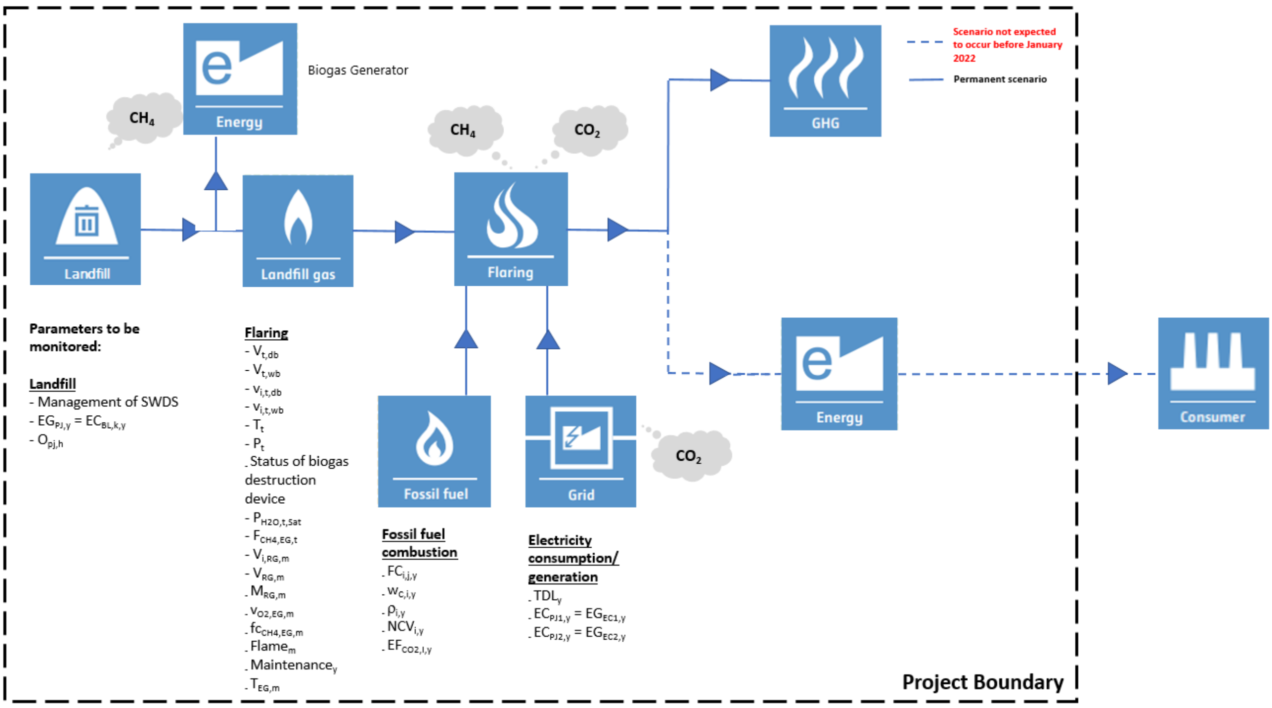

Figure 10 – Simplified diagram of the Project Boundary[16].

As the installed biogas generator has very low capacity, the PP decided not to monitor it, since the cost of monitoring would be greater than the savings on the electricity bill.[17]

B.4. Establishment and description of baseline scenario

>> Since the project installed capacity is higher than 10MW, it shall apply "*Combined tool to identify the baseline scenario and demonstrate additionality*", while defining baseline scenarios for LFG, electricity and heat. In the case of the project activity, the following baseline scenarios apply:

LFG2: Atmospheric release of the LFG or capture of LFG in an managed SWDS and destruction through flaring to comply with regulations or contractual requirements, to address safety and odour concerns, or for other reasons.

E3: Electricity generation in existing and/or new grid-connected power plants.

No heat generation is involved in the project activity.

According to the CDM Project Standard for Project Activities (version 1.0):

To demonstrate the validity of the original baseline or its update, project participants are not required to re-assess the baseline scenario. Instead, project participants shall assess the GHG emission reductions that would have resulted from that scenario.

The project participants shall assess and incorporate the impact of national and/or sectoral policies and circumstances, existing at the time of requesting the renewal of the crediting period, on the current baseline GHG emissions, without reassessing the baseline scenario".

According to the methodological tool "*Assessment of the validity of the original/current baseline and update of the baseline at the renewal of the crediting period*", the following steps were taken:

Step 1: Assess the validity of the current baseline for the next crediting period

Step 1.1: Assess compliance of the current baseline with relevant mandatory national and/or sectorial policies

In Brazil, there are no policies regarding mandatory LFG capture or destruction requirements neither local environmental regulations nor policies which promote the productive use of LFG.

In the beginning of 2010, the *Política Nacional de Resíduos Sólidos* (National Solid Waste Policy), under discussion since 2000, was approved. One of the scopes of this policy is to enforce the

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[16] Some of the icons used to illustrate the project boundary were adapted from the CDM Methodology Booklet available at: http://cdm.unfccc.int/methodologies/documentation/meth_booklet.pdf.

[17] costs of purchasing monitoring, calibration and maintenance equipment.

adequate environmental final destination of the solid waste. However, the Policy does not foresee either the obligation of landfill gas destruction or the promotion of the landfill gas use such as those for the production of renewable energy and processing of organic waste[18].

Concerning energetic use of the landfill gas, the *PROINFA – Programa de Incentivo a Fontes Alternativas* was created in 2002, in order to incentive the use of renewable sources to generate electricity. The goal of the program was to generate 3,300 MW of renewable energy, divided in three groups: wind-energy (1,100 MW), small-hydro power plants (1,100 MW) and biomass (1,100 MW, including bagasse, wood, solid waste, rice husk, etc.). Despite of achieving the goals, no landfill-gas-to-energy project was implemented. The calls for PROINFA were closed in 2003, before the beginning of the Manaus Landfill Project Activity's operation and investment decision.

The following table presents an analysis of the compliance of the alternatives listed previously with the local/national regulation.

Alternative	Compliance with Local / National Policies	Observations
LFG1: Project Activity undertaken without being registered as a CDM Project Activity	Yes	-
LFG2: Continuation of the landfill operation and LFG atmospheric release (Business as Usual – BAU scenario) or partial LFG capture and destruction trough flaring to comply with regulations or contractual requirements, or to address safety and odour concerns, or for other reasons.	Yes	As stated before, there is no current law or contractual requirements to capture/destroy/use the LFG nor enforcing the supply of natural gas

In this second crediting period of the project, the CO_2 emission factor of the grid has changed considering the electricity system delineation of grid-connected projects following the Brazilian DNA definition. According to Resolution # 8 issued by the Brazilian DNA on May 26th, 2008, the project electricity system for projects connected to the SIN shall cover all five macro-geographical regions of the country (North, Northeast, South, Southeast and Midwest).

[18] PROJETO DE LEI – Institui a Política Nacional de Resíduos Sólidos e dá outras providências. Available at: <http://www.camara.gov.br/sileg/integras/501911.pdf>, accessed on 04/02/2018.

The delineation considered in the first crediting period of the project is Manaus Electricity Grid (isolated and independent system). In this second crediting period, the delineation for CO_2 emission factor calculation purposes is SIN following the Brazilian DNA delineation.

Therefore, the current baseline complies with national and sectoral policies which have come into effect after the submission of the project for registration and are applicable at the time of requesting renewal of the crediting period. The current baseline complies all requirements from:

- The National Electric System Operator ("ONS" from the Portuguese *Operador Nacional do Sistema Elétrico*);
- The Electricity Regulatory Agency ("ANEEL" from the Portuguese *Agência Nacional de Energia Elétrica*);
- The Mines and Energy Ministry ("MME" from the Portuguese *Ministério de Minas e Energia*);
- The Chamber of Electrical Energy Commercialization ("CCEE" from the Portuguese *Câmara de Comercialização de Energia Elétrica*);
- The Amazonas Environmental Agency ("IPAAM" from the Portuguese *Instituto de Proteção Ambiental do Estado do Amazonas*);
- The CDM Executive Board.

Since circumstances related to the calculation of the emission factor of the grid have changed, information related to baseline emission factor calculation was reviewed in this second crediting period (see sections B.6.1 and B.6.3).

Step 1.2: Assess the impact of circumstances

As mentioned above, circumstances related to CO_2 emission factor of the grid have changed and, therefore, it was reviewed in this PDD. The operating, build and combined margin CO_2 emission factor of the grid for the first crediting periods is presented below:

Table 1 - Estimated Operating, Build and Combined CO_2 emission factor of Manaus project during the first crediting period.

Crediting period	$EF_{OM,y}$ (tCO_2/MWh)	$EF_{BM,y}$ (tCO_2/MWh)	$EF_{CM,y}$ (tCO_2/MWh)
First 08 Jul 2011- 07 Jul 2018*	0.7329	0.6992	0.7160

Source: Registered PDD.

*The emission factor was determined *ex-ante* and fixed during the first crediting period.

The CO_2 EF of the grid reflects the GHG emissions of existing and the prospective power plants connected to the electricity system. In the case of Brazil, it possesses a large share of

hydroelectricity and, for this reason, it presents a low CO_2 emission factor of the grid when comparing to other countries. However, during the years when an atypical short rainy season is observed, the generation of electricity by the thermal power plants fueled with fossil fuels rises.

While analyzing methods and source of data, the main difference from the 1st and 2nd crediting periods in respect to the CO_2 EF calculation is the delineation of the grid. In the first crediting period, the delineation of the grid was based on the isolated system, for which emission factor was calculated by the Project Participants based on data from the Brazilian Electric System Operator ("ONS" from the Portuguese *Operador Nacional do System*). At the time of the renewal of the 2nd crediting period, the Brazilian DNA made public available data $EF_{OM,y}$ and $EF_{BM,y}$ parameters – used to calculate the $EF_{CM,y}$. Therefore, delineation and data from the Brazilian DNA were used for Manaus project.

Furthermore, the weights established in the CO_2 EF tool also impacted the $EF_{CM,y}$ results at the time of the 2nd crediting period, since 0.25 for OM and 0.75 for BM shall be considered for the 2nd crediting period. Detailed description of methods applied for the calculation of emission reductions are presented in sections B.6.1 and B.6.3.

Step 1.3: Assess whether the continuation of the use of current baseline equipment(s) is technically possible

In the absence of the project, the electricity would be generated by grid connected power plants. SIN is currently composed by 4.714 plants[19] and each one has specific characteristics and equipment. Therefore, the whole system would continue to supply energy independently of the lifetime of individual equipment.

Regarding the project lifetime, the generator-group has 25-30 year expected lifetime without any new investment required. Since the project startup occurred in 2009 year, the project is expected to be operational up to 2039 year. Then, the remaining technical lifetime exceeds the end of the last crediting period of the project (2031 year).

Regarding LFG, the project is a greenfield project type and no equipment was installed prior to the project implementation and no heat generation is involved in the project activity.

Step 1.4: Assessment of the validity of the data and parameters

Considering the applied methodology at the project activity registration ACM0001 version 11 has changed to consolidated methodology ACM0001 version 18 and all related applicable tools some ex-ante parameters published by IPCC have been updated accordingly.

[19] Source ANEEL's website accessed on 14/09/2017. Available at: <http://www.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm>.

According to the methodological tool "*Tool to assess the validity of the original/current baseline and to update the baseline at the renewal of a crediting period*", where any data and parameter used and not monitored during the crediting period are not valid anymore they should be updated following the Step 2 as follows:

Step 2: Update the current baseline and the data and parameters

Step 2.1: Update the current baseline

The baseline emissions for the second crediting period have been updated, without reassessing the baseline scenario, based on the latest approved version of the methodology ACM0001.

This update was applied in the context of the sectorial policies and circumstances that are applicable at the time of requesting for renewal of the crediting period, which has not changed as to affect the project. More details for the updated baseline emissions for the second crediting period can be seen in section B.6.

Step 2.2: Update the data and parameters

All parameters regarding the baseline emissions calculation have been updated for the 2^{nd} crediting period. Further information can be seen in section B.6.

B.5. Demonstration of additionality

>> The demonstration of additionality is not applicable for the renewal of the crediting period of a registered CDM project activity. The whole assessment and demonstration of additionality for the given registered CDM project activity is included in the latest version of the PDD valid for the 1st 7-year renewable crediting period.

The following table shows the timeline of the Project showing that the CDM benefits were taken into account when deciding to implement it.

Table 1 - Implementation timeline of the Project

Key Events	Date
PDD submitted to SGS for validation	2 December 2005
PDD in Global Stakeholder Consultation (GSC) for the first time	07 December 2005 to 06 January 2006
PDD public comments availability closes	6 January 2006
SGS issues validation report	29 May 2006
Host country approval submitted	2 June 2006
CRA signed a contract (including CDM consideration) with Tumpex (landfill operator), Manaus City Hall and Enterpa to develop the proposed project (starting date of the project activity).	25 July 2008
Construction works started	October 2008
CRA notifies SGS of revised PDD submittal for new validation	5 November 2008
CRA develops revised PDD and submits to SGS for validation	4 December 2008
PDD in GSC for the second time	21 January 2009 to 19 February 2009
PDD public comments availability closes	19 February 2009
PDD in GSC for the third time	26 May 2010 to 24 June 2010

As can be seen from the Table above, several actions were taken at an early stage, indicating that consideration of applying for CDM was taken seriously well before the final investment decision was made.

The additionality of the project activity will be demonstrated and assessed using version 5.2 of the "Tool for the demonstration and assessment of additionality" agreed by the CDM Executive Board.

Step 1: Identification of alternatives to the project activity consistent with current laws and regulations

Sub-step 1a. Define alternatives to the project activity

The identified alternatives for the disposal of the waste in the absence of the project activity include:

LFG1 – The project activity (capture of landfill gas and power generation) undertaken without being registered as a CDM project activity;

LFG2 – Atmospheric release of the landfill gas;

For power generation, the realistic and credible alternatives include:

- P1 – Power generated from landfill gas undertaken without being registered as CDM project activity;
- P6 – Existing and/or new grid-connected power plants;

The only remaining real alternatives to the project activity are LFG1, LFG2, P1 and P6.

Outcome of Step 1a: Four realistic and credible alternative scenarios to the project activity were identified.

Sub-step 1b. Consistency with mandatory laws and regulations:

In Brazil, there is no regulation or policy that obliges the landfill operator to burn the LFG generated in the landfill. In documents below, there is no regulation or obligation about burning LFG in landfill. Following below the source of this statement:

Documents	Elaborated by	Reference
Solid Waste Integrated Management	Ministry of Environment and Ministry of Cities	http://www.ibam.org.br/publique/media/01-girs.pdf
SNIS	Ministry of Cities	SNIS: Secretaria Nacional de Informações sobre Saneamento Sistema Nacional de Informações sobre Saneamento: diagnóstico do manejo de resíduos sólidos urbanos, page II.281 http://www.pmss.gov.br/snis/PaginaCarrega.php?EWRErterterTERTer=80

The project participants will monitor all relevant policies and circumstances at the beginning of each crediting period and adjust the baseline accordingly.

Step2. Investment analysis

Sub-step2a. Determine appropriate analysis method

As the proposed project activity will generate financial benefits other than CDM related income, the Option III is chosen.

Sub-step2b. – Option III. Apply benchmark analysis

For the purpose of assessing the financial/economic attractiveness, the most appropriate financial indicator for the decision context is the Internal Rate of Return (IRR).

The benchmark parameter used for this comparison was the government bond rates increased by a suitable risk premium, calculated as follows:

Table 2 - Benchmark calculation method

Benchmark real terms	
A	Brazilian Government Bond Rate NTN-B, maturity 2024 (maturity similar to the project lifetime, real terms)
B	Market Risk Premium (S&P 500 - T-Bonds)
C	Unlevered Beta (in lack of open companies with the same risk profile)
D = A + B x C	**Benchmark - Real Terms**

The government bond rate chosen in the Brazilian Bond NTN-B 15082024, with a similar tenor of the project activity. The yield is based on the inflation rate (IPCA - Indice Nacional de Preços ao Consumidor Amplo) increased by a fixed rate at the moment of the acquisition[20]. The fixed rate used for the benchmark calculation was based on 3 years prior to the project investment decision (i.e. 2005, 2006 and 2007[21]), resulting in 7.9%. The inflation rate was not considered in this analysis, as the investment analysis is done in real terms.

In order to calculate this spread, the project participants used the risk premium calculated by the average historical difference between the US T-bonds and the S&P 500. This would result in a Market risk premium of 6.42%.[22]

To estimate the risk in investing in a power generation project, the project participants should consider also the beta of companies with the same risk profile (such as public held companies with the same portfolio). However, there is no other company with a comparable portfolio to CRA listed in a stock exchange. Therefore, the project proponents considered the beta of all utilities (0.63).[23] This approach is deemed conservative as most of those companies operates with widely known technologies, less risky than LFG to energy projects. With these input data, the benchmark calculated follows:

Table 3 - Benchmark value

Benchmark real terms		
A	Brazilian Government Bond Rate NTN-B, maturity 2024 (maturity similar to the project lifetime, real terms)	7.90%
B	Market Risk Premium (S&P 500 - T-Bonds)	6.42%
C	Unlevered Beta (in lack of open companies with the same risk profile)	0.63

20 Source: http://www.tesouro.fazenda.gov.br/tesouro_direto/consulta_titulos/consultatitulos.asp, accessed on 13 May 2010.

21 Source: http://www.tesouro.fazenda.gov.br/tesouro_direto/historico.asp, accessed on 13 May 2010

22 http://www.stern.nyu.edu/~adamodar/pc/datasets/histretSP.xls

23 http://www.stern.nyu.edu/~adamodar/pc/archives/betas07.xls

D = A + B x C	Benchmark - Real Terms[7]	11.94%

[24]

[24] Note: It was not considered the currency risk. Consequently, this benchmark calculation is deemed conservative

Sub-step 2c. Calculation and comparison of financial indicators

The following assumptions were taken for the purpose of the calculation of the financial indicator:

Table 4 - Main assumptions

	Parameter	Value	Unit	Reference
Assumptions	Asset's Life time	25	Years	Tool to determine the remaining lifetime of equipment (EB 50 - Annex 15, page 4)
	Installed capacity for each engine	1.6	MW	gas engine technical data.pdf
	Total installed capacity	19.2	MW	-
	Load factor	99.06%	%	Parasitic Losses and Load Factor april 08.pdf
	Exchange Rate	1.57	R$/US$	"Banco Central do Brasil" on 25/07/2008 (http://www4.bcb.gov.br/?TXCONVERSAO)
	Electricity price	156.78	R$/MWh	notatcnicamanaus276_31_08.pdf, page 8, table III-A, Breitener (Jaraqui).
	Price per MW installed	2,637,433.98	US$/MWinstalled	LFG Utilization System.pdf
	Power plant operation cost	26.36	US$/MWh	Agreement and Proposal for operation and maintenance services.pdf
	Tax (PIS)	1.65%	%	Contribution to the Social Integration Program and Civil Service Asset Formation Program – PIS/PASEP (http://www.receita.fazenda.gov.br/principal/Ingles/SistemaTributarioBR/Taxes.htm)
	Tax (Confins)	7.60%	%	COFINS - Contribution to Social Security Financing (http://www.receita.fazenda.gov.br/principal/Ingles/SistemaTributarioBR/Taxes.htm)
	Tax (IRPJ)	15%	%	Art. 541. (http://www.receita.fazenda.gov.br/Legislacao/rir/L2Parte3.htm)
	Tax (IRPJ additional)	10%	%	Art. 542. (http://www.receita.fazenda.gov.br/Legislacao/rir/L2Parte3.htm)
	Tax (CSLL)	9%	%	(Social contribution on net profit) Art. 3o - II (http://www.planalto.gov.br/ccivil_03/LEIS/L7689.htm)
	Contingency	5%	%	“Landfill Full Cost Accounting Guide” (5% Contingency Factor.pdf) http://www.mfe.govt.nz/publications/waste/landfill-full-cost-accounting-guide-mar04/html/page7.html

Note: The documents above were made available to DOE in validation visit.

For the project alternative: LFG1 – The project activity (capture of landfill gas and power generation) undertaken without being registered as a CDM project activity, the estimated project cash flow is present below:

	YEAR	0	1	2	3	4	5	6
		2008	2009	2010	2011	2012	2013	2014
Electricity dispatched (MWh)			0	0	0	40,823	54,707	68,591
Electricity price (USD/MWh)			99.86	99.86	99.86	99.86	99.86	99.86
Gross Revenues			-	-	-	4,076,554	5,463,034	6,849,513
PIS/Cofins	9.25%		-	-	-	(377,081.29)	(505,330.63)	(633,579.98)
Net revenues			-	-	-	3,699,473.20	4,957,703.26	6,215,933.31
O&M		0	(1,500,610.00)	(1,500,610.00)	(1,500,610.00)	(2,653,474.78)	(3,037,763.04)	(3,422,051.30)
Variable costs			(82,883.69)	(82,883.69)	(82,883.69)			
Total Costs			(1,583,493.69)	(1,583,493.69)	(1,583,493.69)	(2,653,474.78)	(3,037,763.04)	(3,422,051.30)
Gross Margin			(1,583,493.69)	(1,583,493.69)	(1,583,493.69)	1,045,998.42	1,919,940.21	2,793,882.01
SG&A								
EBITDA			(1,583,493.69)	(1,583,493.69)	(1,583,493.69)	1,045,998.42	1,919,940.21	2,793,882.01
Depreciation			(627,056.43)	(705,255.18)	(783,453.93)	(2,726,728.10)	(3,248,015.76)	(3,769,303.42)
EBIT			(2,210,550.12)	(2,288,748.87)	(2,366,947.62)	(1,680,729.68)	(1,328,075.55)	(975,421.41)
Income Taxes (IRPJ+CSLL)	34.00%		-	-	-	-	-	-
NET EARNINGS			(2,210,550.12)	(2,288,748.87)	(2,366,947.62)	(1,680,729.68)	(1,328,075.55)	(975,421.41)
CAPEX		(6,270,564)	(781,988)	(781,988)	(19,432,742)	(5,212,877)	(5,212,877)	(5,212,877)
Depreciation			627,056.43	705,255.18	783,453.93	2,726,728.10	3,248,015.76	3,769,303.42
Account Receivable (35 days)			-	-	-	(390,902.49)	(523,852.56)	(656,802.64)
Account payable (30 days)			130,150.17	130,150.17	130,150.17	218,093.82	249,679.15	281,264.49
Working Capital			130,150.17	130,150.17	130,150.17	(172,808.67)	(274,173.41)	(375,538.15)
+/- Working Capital increase			130,150.17	-	-	(302,958.83)	(101,364.74)	(101,364.74)
FCF		**(6,270,564.27)**	**(2,235,331.03)**	**(2,365,481.19)**	**(21,016,235.45)**	**(4,469,837.00)**	**(3,394,301.11)**	**(2,520,359.32)**

IRR	4.29%
Benchmark	11.94%
NPV	(20,530,849.37)

7	8	9	10	11	12	13	14	15	16
2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
82,475	96,360	110,244	124,128	138,012	151,897	165,781	165,781	165,781	165,781
99.86	99.86	99.86	99.86	99.86	99.86	99.86	99.86	99.86	99.86
8,235,993	9,622,472	11,008,951	12,395,431	13,781,910	15,168,390	16,554,869	16,554,869	16,554,869	16,554,869
(761,829.32)	(890,078.67)	(1,018,328.01)	(1,146,577.36)	(1,274,826.70)	(1,403,076.04)	(1,531,325.39)	(1,531,325.39)	(1,531,325.39)	(1,531,325.39)
7,474,163.36	8,732,393.41	9,990,623.47	11,248,853.52	12,507,083.57	13,765,313.62	15,023,543.67	15,023,543.67	15,023,543.67	15,023,543.67
(3,806,339.56)	(4,190,627.82)	(4,574,916.08)	(4,959,204.34)	(5,343,492.60)	(5,727,780.86)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)
(3,806,339.56)	(4,190,627.82)	(4,574,916.08)	(4,959,204.34)	(5,343,492.60)	(5,727,780.86)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)
3,667,823.80	4,541,765.59	5,415,707.38	6,289,649.17	7,163,590.97	8,037,532.76	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55
3,667,823.80	4,541,765.59	5,415,707.38	6,289,649.17	7,163,590.97	8,037,532.76	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55
(4,290,591.08)	(4,811,878.74)	(5,333,166.39)	(5,854,454.05)	(5,748,685.28)	(6,191,774.19)	(6,634,863.10)	(4,769,787.68)	(4,326,698.77)	(3,883,609.86)
(622,767.28)	(270,113.15)	82,540.99	435,195.12	1,414,905.68	1,845,758.56	2,276,611.45	4,141,686.87	4,584,775.78	5,027,864.69
-	-	(28,063.94)	(147,966.34)	(481,067.93)	(627,557.91)	(774,047.89)	(1,408,173.54)	(1,558,823.77)	(1,709,473.99)
(622,767.28)	(270,113.15)	54,477.05	287,228.78	933,837.75	1,218,200.65	1,502,563.56	2,733,513.34	3,025,952.02	3,318,390.70
(5,212,877)	(5,212,877)	(5,212,877)	(5,212,877)	(5,212,877)	(5,212,877)	(781,988)	(781,988)	(781,988)	(781,988)
4,290,591.08	4,811,878.74	5,333,166.39	5,854,454.05	5,748,685.28	6,191,774.19	6,634,863.10	4,769,787.68	4,326,698.77	3,883,609.86
(789,752.72)	(922,702.80)	(1,055,652.88)	(1,188,602.96)	(1,321,553.04)	(1,454,503.12)	(1,587,453.20)	(1,587,453.20)	(1,587,453.20)	(1,587,453.20)
312,849.83	344,435.16	376,020.50	407,605.84	439,191.17	470,776.51	502,361.85	502,361.85	502,361.85	502,361.85
(476,902.90)	(578,267.64)	(679,632.38)	(780,997.12)	(882,361.87)	(983,726.61)	(1,085,091.35)	(1,085,091.35)	(1,085,091.35)	(1,085,091.35)
(101,364.74)	(101,364.74)	(101,364.74)	(101,364.74)	(101,364.74)	(101,364.74)	(101,364.74)	-	-	-
(1,646,417.53)	**(772,475.74)**	**73,402.12**	**827,441.51**	**1,368,281.71**	**2,095,733.52**	**7,254,074.41**	**6,721,313.51**	**6,570,663.28**	**6,420,013.05**

17	18	19	20	21	22	23	24	25
2025	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
165,781	165,781	165,781	165,781	165,781	165,781	165,781	165,781	165,781
99.86	99.86	99.86	99.86	99.86	99.86	99.86	99.86	99.86
16,554,869	16,554,869	16,554,869	16,554,869	16,554,869	16,554,869	16,554,869	16,554,869	16,554,869
(1,531,325.39)	(1,531,325.39)	(1,531,325.39)	(1,531,325.39)	(1,531,325.39)	(1,531,325.39)	(1,531,325.39)	(1,531,325.39)	(1,531,325.39)
15,023,543.67	15,023,543.67	15,023,543.67	15,023,543.67	15,023,543.67	15,023,543.67	15,023,543.67	15,023,543.67	15,023,543.67
(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)
(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)	(6,112,069.13)
8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55
8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55	8,911,474.55
(3,440,520.95)	(2,997,432.04)	(2,554,343.13)	(2,111,254.23)	(1,668,165.32)	(1,225,076.41)	(781,987.50)	(781,987.50)	(781,987.50)
5,470,953.60	5,914,042.51	6,357,131.42	6,800,220.32	7,243,309.23	7,686,398.14	8,129,487.05	8,129,487.05	8,129,487.05
(1,860,124.22)	(2,010,774.45)	(2,161,424.68)	(2,312,074.91)	(2,462,725.14)	(2,613,375.37)	(2,764,025.60)	(2,764,025.60)	(2,764,025.60)
3,610,829.37	3,903,268.05	4,195,706.73	4,488,145.41	4,780,584.09	5,073,022.77	5,365,461.45	5,365,461.45	5,365,461.45
(781,988)	(781,988)	(781,988)	(781,988)	(781,988)	(781,988)	(781,988)	(781,988)	(781,988)
3,440,520.95	2,997,432.04	2,554,343.13	2,111,254.23	1,668,165.32	1,225,076.41	781,987.50	781,987.50	781,987.50
(1,587,453.20)	(1,587,453.20)	(1,587,453.20)	(1,587,453.20)	(1,587,453.20)	(1,587,453.20)	(1,587,453.20)	(1,587,453.20)	(1,587,453.20)
502,361.85	502,361.85	502,361.85	502,361.85	502,361.85	502,361.85	502,361.85	502,361.85	502,361.85
(1,085,091.35)	(1,085,091.35)	(1,085,091.35)	(1,085,091.35)	(1,085,091.35)	(1,085,091.35)	(1,085,091.35)	(1,085,091.35)	(1,085,091.35)
-	-	-	-	-	-	-	-	1,085,091.35
6,269,362.83	**6,118,712.60**	**5,968,062.37**	**5,817,412.14**	**5,666,761.91**	**5,516,111.68**	**5,365,461.45**	**5,365,461.45**	**6,450,552.80**

The capital expenses estimated includes the power generation plant and the landfill gas extraction system. As presented above, the Project IRR is 4.29%. Consequently, this scenario is not deemed attractive by the project participants.

The second alternative (LFG2) is the continuation of the current practice, which is in compliance with all applicable regulations and policies, and was deemed the most plausible alternative to the project activity.

Sub-step 2d. Sensitivity analysis

The sensitivity analysis was performed varying the electricity tariff (income), the capital expenses and operational expenses. All parameters ranging from -10% to +10%, as the result presented below:

Table 5 - Sensitivity analysis

	Variation	IRR
CapEx	-10%	5.27%
	10%	3.38%
O&M	-10%	5.17%
	10%	3.36%
Revenues	-10%	2.28%
	10%	6.00%
Base Case	0%	4.29%

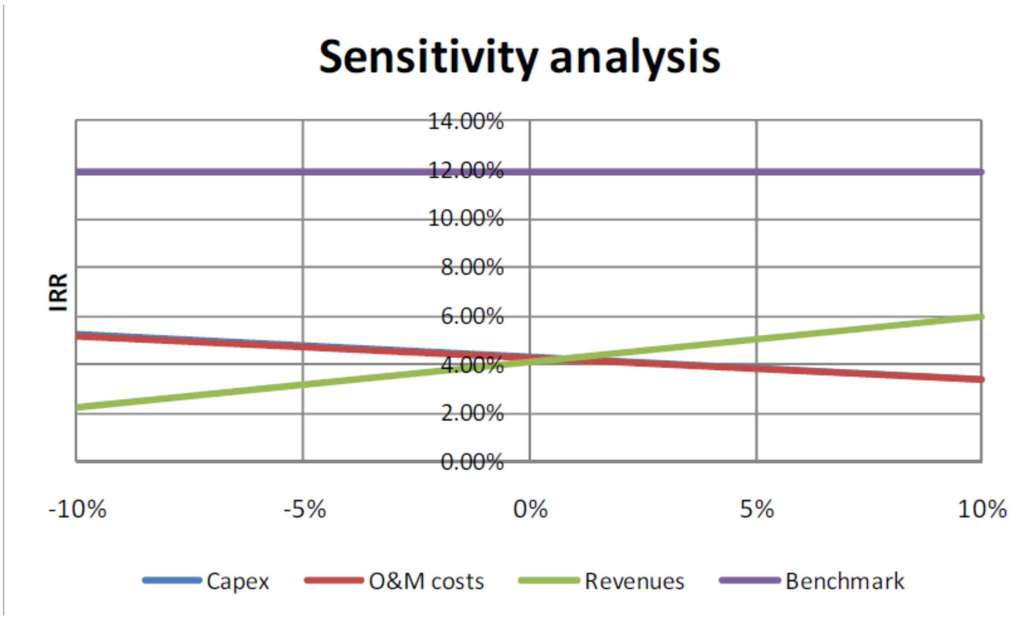

Figure 10 - Sensitivity analysis

As presented above, even if the best scenario is applied, the project IRR is lower than the chosen benchmark.

To ensure the additionality of this project, the project proponents varied the three identified parameters (CapEx, O&M and Revenues) until each of them reached the benchmark. The results are presented below and the spreadsheet was provided to the audit team:

Capital Expenditures (CapEx) – To reach the benchmark, the Capital Expenditures should be reduced in 56%. This result is extremely unlikely to happen in the future, as this reduction is too large for any kind of project which has a reliable investment estimate (such as Manaus Landfill Gas Project) and as usually the CapEx increases during the project implementation.

O&M – Also, to reach the benchmark, the O&M shall be reduced in 99%. This means that PPs should receive and not pay to operate the project. Consequently, this scenario is unreal.

Revenues – this value should be increased in 55% to reach the benchmark. This means that the electricity tariff should reach BRL 243.37, deemed unrealistic as this value is far superior to the average values from the latest electricity sale auction in this subsystem.[25] Also, the second way to increase the revenue is by increasing the electricity generation. The system, as well as the number of gensets to be installed is deemed accurate by the project developers. Some adjustments might occur, but is really not expected to have a variation of 55% in the number of gensets or in the LFG generation. Thus, the PP deemed this situation to be unlikely to happen in the future.

As could be noted, this project lacks of financial attractiveness by giving an IRR without the CER revenue below the selected benchmark.

Thus, it seems reasonable to conclude that the project activity is unlikely to be the most financially attractive scenario.

[25] Source: Eletrobras Amazonas Energia (http://www.amazonasenergia.gov.br), accessed on 14 May 2010

Step 4. Common practice analysis

Sub-step 4a. Analyze other activities similar to the proposed project activity:

Based on the documents below:

- SNIS (2007) - Secretaria Nacional de Informações sobre Saneamento Sistema Nacional de Informações sobre Saneamento: diagnóstico do manejo de resíduos sólidos urbanos[26];
- Brazilian Greenhouse Gases Emissions Inventory Report for Waste Sector[27] and;
- Brazilian Country Profile for waste sector by Methane to Markets[28].
- Understanding methane emissions from passive systems in landfills in Brazil[29].

There are no similar activities[30] like the proposed project activity in Brazil, because all of the landfills that are developing capture and destruction of the LFG, are being developed as CDM project activities. The table below shows the landfill projects implemented or underway in Brazil.

Project Title	Status	Source
NovaGerar Landfill Gas to Energy Project	Registered on 18/11/2004	http://cdm.unfccc.int/Projects/DB/DNV-CUK1095236970.6/view
Salvador da Bahia Landfill Gas Management Project	Registered on 15/08/2005	http://cdm.unfccc.int/Projects/DB/DNV-CUK1117823353.4/view
Onyx Landfill Gas Recovery Project – Trémembé, Brazil	Registered on 24/11/2005	http://cdm.unfccc.int/Projects/DB/DNV-CUK1126082019.35/view
Brazil MARCA Landfill Gas to Energy Project	Registered on 23/01/2006	http://cdm.unfccc.int/Projects/DB/DNV-CUK1132565688.17/view

[26] Source: Ministry of the Cities (http://www.pmss.gov.br/snis/PaginaCarrega.php?EWRErterterTERTer=80)

[27] Source: Ministry of Science and Technology (http://www.mct.gov.br/index.php/content/view/21465.html), page 45.

[28] Source: Methane to Markets (http://www.methanetomarkets.org/documents/landfills_cap_brazil.pdf), page 2.

[29] Source: MAGALHÃES, G.HC.; ALVES, J.W.S.; SANTO FILHO. F.; COSTA, R.M.; KELSON. M. Understanding methane emissions from passive systems in landfills in Brazil. São Paulo, Brasil, 2010. Page 2. http://homologa.ambiente.sp.gov.br/biogas/docs/artigos_dissertacoes/magalhaes_alves_santofilho_costa_kelson.pdf

[30] The "Tool for the demonstration and assessment of additionality" – version 5.2, states: "Projects are considered similar if they are in the same country/region and/or rely on a broadly similar technology, are of a similar scale, and take place in a comparable environment with respect to regulatory framework, investment climate, access to technology, access to financing, etc. Other CDM project activities (registered project activities and project activities which have been published on the UNFCCC website for global stakeholder consultation as part of the validation process) are not to be included in this analysis"

Bandeirantes Landfill Gas to Energy Project (BLFGE)	Registered on 20/02/2006	http://cdm.unfccc.int/Projects/DB/DNV-CUK1134130255.56/view
ESTRE's Paulínia Landfill Gas Project (EPLGP)	Registered on 03/03/2006	http://cdm.unfccc.int/Projects/DB/DNV-CUK1134989999.25/view
Caieiras landfill gas emission reduction	Registered on 09/03/2006	http://cdm.unfccc.int/Projects/DB/DNV-CUK1134509951.62/view
Landfill Gas to Energy Project at Lara Landfill, Mauá, Brazil	Registered on 15/05/2006	http://cdm.unfccc.int/Projects/DB/DNV-CUK1138957573.9/view
São João Landfill Gas to Energy Project (SJ)	Registered on 02/07/2006	http://cdm.unfccc.int/Projects/DB/DNV-CUK1145141778.29/view
Project Anaconda	Registered on 15/12/2006	http://cdm.unfccc.int/Projects/DB/DNV-CUK1155134946.56/view
Central de Resíduos do Recreio Landfill Gas Project	Registered on 31/12/2006	http://cdm.unfccc.int/Projects/DB/DNV-CUK1158844635.31/view
Canabrava Landfill Gas Project	Registered on 08/04/2007	http://cdm.unfccc.int/Projects/DB/SGS-UKL1169669649.47/view
Aurá Landfill Gas Project	Registered on 30/04/2007	http://cdm.unfccc.int/Projects/DB/SGS-UKL1169639070.69/view
Quitaúna Landfill Gas Project (QLGP)	Registered on 27/05/2007	http://cdm.unfccc.int/Projects/DB/DNV-CUK1169931302.54/view
ESTRE Itapevi Landfill Gas Project (EILGP)	Registered on 17/09/2007	http://cdm.unfccc.int/Projects/DB/DNV-CUK1169886803.63/view
URBAM/ARAUNA - Landfill Gas Project (UALGP)	Registered on 14/10/2007	http://cdm.unfccc.int/Projects/DB/DNV-CUK1185017358.24/view
Embralixo/Araúna - Bragança Landfill Gas Project (EABLGP)	Registered on 15/10/2007	http://cdm.unfccc.int/Projects/DB/DNV-CUK1182151832.44/view
Alto-Tiete landfill gas capture project	Registered on 29/05/2008	http://cdm.unfccc.int/Projects/DB/RWTUV1204280292.23/view
Probiogas - JP-João Pessoa Landfill Gas Project	Registered on 30/01/2008	http://cdm.unfccc.int/Projects/DB/SGS-UKL1181685608.94/view
ESTRE Pedreira Landfill Gás Project (EPLGP)	Registered on 12/02/2008	http://cdm.unfccc.int/Projects/DB/DNV-CUK1179394615.79/view
SANTECH – Saneamento & Tecnologia Ambiental Ltda. – SANTEC Resíduos landfill gas emission reduction Project Activity	Registered on 19/02/2009	http://cdm.unfccc.int/Projects/DB/TUEV-SUED1214902532.06/view
Terrestre Ambiental Landfill Gás Project	Registered on 06/05/2008	http://cdm.unfccc.int/Projects/DB/DNV-CUK1179391286.32/view
CTRVV Landfill emission reduction project	Registered on 28/05/2008	http://cdm.unfccc.int/Projects/DB/SGS-UKL1198775230.25/view
Feira de Santana Landfill Gas Project	Registered on 12/08/2008	http://cdm.unfccc.int/Projects/DB/DNV-CUK1203743009.45/view
Proactiva Tijuquinhas Landfill Gas Capture and Flaring project	Registered on 13/08/2008	http://cdm.unfccc.int/Projects/DB/DNV-CUK1200058130.23/view

Natal Landfill Gas Recovery Project	Validation	http://cdm.unfccc.int/Projects/Validation/DB/K82DG9XUKVQ8IGUYJZMLMYLPQRAL1S/view.html
Projeto de Gas de Aterro TECIPAR – PROGAT	Validation	http://cdm.unfccc.int/Projects/Validation/DB/O7LXRYICDY6UWTAIEGYKIZXMEM2SMO/view.html
Marilia/Arauna Landfill Gas Project	Validation	http://cdm.unfccc.int/Projects/Validation/DB/FQBM6GP50MLPJPM39192IFGG9T783R/view.html
Laguna Landfill Methane Flaring	Validation	http://cdm.unfccc.int/Projects/Validation/DB/ZYNYNR7MAYN1HUBX6W98E7BWLMWOI4/view.html
Gramacho Landfill Gas Project	Validation	http://cdm.unfccc.int/Projects/Validation/DB/IOJKHC9RUXNKFXMF0GW8V7YS4BV4UU/view.html
Exploitation of the biogas from Controlled Landfill in Solid Waste Management Central-CTRS/BR.040	Validation	http://cdm.unfccc.int/Projects/Validation/DB/MOYBL8JBAF6YGLLMXD0Q4EWLGPF9M7/view.html
Embralixo/Araúna - Bragança Landfill Gas Project (EABLGP)	Validation	http://cdm.unfccc.int/Projects/Validation/DB/BLH87CY04LN8PYLXEF6VS7X0PX8O60/view.html
Corpus/Araúna – Landfill Biogas Project.	Validation	http://cdm.unfccc.int/Projects/Validation/DB/XRCDRQ6VTVP6B8NFCCTH92OZI9D6B7/view.html
CGR Guatapará landfill Project	Validation	http://cdm.unfccc.int/Projects/Validation/DB/0RXYM30S4G1B0J9KBZ81WGM9CWL93L/view.html
CTR Candeias Sanitary Landfill	Validation	http://cdm.unfccc.int/Projects/Validation/DB/N6QEYV2VTTLSA6IHMB5246UONLXAA3/view.html

Summarizing, there are no landfill projects in Brazil burning LFG without CDM revenues.

Sub-step 4b. Discuss any similar options that are occurring:

Not applicable. There are no similar options to the proposed project activity not being developed as a CDM project activity.

Conclusion:

Since all the criteria of the “Tool for the demonstration and assessment of additionality” 5.2 are satisfied, the proposed project activity is additional.

However, due to the installation of a biogas generator on 26 May 2019, it was decided to remake the financial analysis[31]. As a result, the IRR value changed from 4.29 to 4.37%, maintaining the additional project. [32]

[31] The new analysis is being done conservatively. It is not considering the generator investment, only the savings provides.

[32] A new sensitivity analysis was not performed due to the value being less than 10%

	YEAR	0	1	2	3	4	5	6
		2008	2009	2010	2011	2012	2013	2014
Electricity dispatched (MWh)			0	0	0	40.823	54.707	68.591
Electricity price (USD/MWh)			99,86	99,86	99,86	99,86	99,86	99,86
Gross Revenues			-	-	-	4.076.554	5.463.034	6.849.513
PIS/Cofins	9,25%		-	-	-	(377.081,29)	(505.330,63)	(633.579,98)
Net revenues			-	-	-	3.699.473,20	4.957.703,26	6.215.933,31
Savings from electricity bills due to 170kWh from biogas generator								
O&M		0	(1.500.610,00)	(1.500.610,00)	(1.500.610,00)	(2.653.474,78)	(3.037.763,04)	(3.422.051,30)
Variable costs			(82.883,69)	(82.883,69)	(82.883,69)			
Total Costs			(1.583.493,69)	(1.583.493,69)	(1.583.493,69)	(2.653.474,78)	(3.037.763,04)	(3.422.051,30)
Gross Margin			(1.583.493,69)	(1.583.493,69)	(1.583.493,69)	1.045.998,42	1.919.940,21	2.793.882,01
SG&A								
EBITDA			(1.583.493,69)	(1.583.493,69)	(1.583.493,69)	1.045.998,42	1.919.940,21	2.793.882,01
Depreciation			(627.056,43)	(705.255,18)	(783.453,93)	(2.726.728,10)	(3.248.015,76)	(3.769.303,42)
EBIT			(2.210.550,12)	(2.288.748,87)	(2.366.947,62)	(1.680.729,68)	(1.328.075,55)	(975.421,41)
Income Taxes (IRPJ+CSLL)	34,00%		-	-	-	-	-	-
NET EARNINGS			(2.210.550,12)	(2.288.748,87)	(2.366.947,62)	(1.680.729,68)	(1.328.075,55)	(975.421,41)
CAPEX		(6.270.564)	(781.988)	(781.988)	(19.432.742)	(5.212.877)	(5.212.877)	(5.212.877)
Depreciation			627.056,43	705.255,18	783.453,93	2.726.728,10	3.248.015,76	3.769.303,42
Account Receivable (35 days)			-	-	-	(390.902,49)	(523.852,56)	(656.802,64)
Account payable (30 days)			130.150,17	130.150,17	130.150,17	218.093,82	249.679,15	281.264,49
Working Capital			130.150,17	130.150,17	130.150,17	(172.808,67)	(274.173,41)	(375.538,15)
+/- Working Capital increase			130.150,17	-	-	(302.958,83)	(101.364,74)	(101.364,74)
FCF		**(6.270.564,27)**	**(2.235.331,03)**	**(2.365.481,19)**	**(21.016.235,45)**	**(4.469.837,00)**	**(3.394.301,11)**	**(2.520.359,32)**

IRR	4,37%
Benchmark	11,94%
NPV	(20.386.219,64)

2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
82.475	96.360	110.244	124.128	138.012	151.897	165.781	165.781	165.781	165.781
99,86	99,86	99,86	99,86	99,86	99,86	99,86	99,86	99,86	99,86
8.235.993	9.622.472	11.008.951	12.395.431	13.781.910	15.168.390	16.554.869	16.554.869	16.554.869	16.554.869
(761.829,32)	(890.078,67)	(1.018.328,01)	(1.146.577,36)	(1.274.826,70)	(1.403.076,04)	(1.531.325,39)	(1.531.325,39)	(1.531.325,39)	(1.531.325,39)
7.474.163,36	8.732.393,41	9.990.623,47	11.248.853,52	12.507.083,57	13.765.313,62	15.023.543,67	15.023.543,67	15.023.543,67	15.023.543,67
				64.801,07	105.722,33	105.722,33	105.722,33	105.722,33	105.722,33
(3.806.339,56)	(4.190.627,82)	(4.574.916,08)	(4.959.204,34)	(5.343.492,60)	(5.727.780,86)	(6.112.069,13)	(6.112.069,13)	(6.112.069,13)	(6.112.069,13)
(3.806.339,56)	(4.190.627,82)	(4.574.916,08)	(4.959.204,34)	(5.278.691,53)	(5.622.058,53)	(6.006.346,80)	(6.006.346,80)	(6.006.346,80)	(6.006.346,80)
3.667.823,80	4.541.765,59	5.415.707,38	6.289.649,17	7.228.392,04	8.143.255,09	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88
3.667.823,80	4.541.765,59	5.415.707,38	6.289.649,17	7.228.392,04	8.143.255,09	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88
(4.290.591,08)	(4.811.878,74)	(5.333.166,39)	(5.854.454,05)	(5.748.685,28)	(6.191.774,19)	(6.634.863,10)	(4.769.787,68)	(4.326.698,77)	(3.883.609,86)
(622.767,28)	(270.113,15)	82.540,99	435.195,12	1.479.706,75	1.951.480,89	2.382.333,78	4.247.409,20	4.690.498,11	5.133.587,02
-	-	(28.063,94)	(147.966,34)	(503.100,30)	(663.503,50)	(809.993,48)	(1.444.119,13)	(1.594.769,36)	(1.745.419,59)
(622.767,28)	(270.113,15)	54.477,05	287.228,78	976.606,46	1.287.977,39	1.572.340,29	2.803.290,07	3.095.728,75	3.388.167,43
(5.212.877)	(5.212.877)	(5.212.877)	(5.212.877)	(5.212.877)	(5.212.877)	(781.988)	(781.988)	(781.988)	(781.988)
4.290.591,08	4.811.878,74	5.333.166,39	5.854.454,05	5.748.685,28	6.191.774,19	6.634.863,10	4.769.787,68	4.326.698,77	3.883.609,86
(789.752,72)	(922.702,80)	(1.055.652,88)	(1.188.602,96)	(1.321.553,04)	(1.454.503,12)	(1.587.453,20)	(1.587.453,20)	(1.587.453,20)	(1.587.453,20)
312.849,83	344.435,16	376.020,50	407.605,84	433.865,06	462.087,00	493.672,34	493.672,34	493.672,34	493.672,34
(476.902,90)	(578.267,64)	(679.632,38)	(780.997,12)	(887.687,98)	(992.416,12)	(1.093.780,86)	(1.093.780,86)	(1.093.780,86)	(1.093.780,86)
(101.364,74)	(101.364,74)	(101.364,74)	(101.364,74)	(106.690,86)	(104.728,13)	(101.364,74)	-	-	-
(1.646.417,53)	**(772.475,74)**	**73.402,12**	**827.441,51**	**1.405.724,30**	**2.162.146,87**	**7.323.851,15**	**6.791.090,25**	**6.640.440,02**	**6.489.789,79**

2025	2026	2027	2028	2029	2030	2031	2032	2033
165.781	165.781	165.781	165.781	165.781	165.781	165.781	165.781	165.781
99,86	99,86	99,86	99,86	99,86	99,86	99,86	99,86	99,86
16.554.869	16.554.869	16.554.869	16.554.869	16.554.869	16.554.869	16.554.869	16.554.869	16.554.869
(1.531.325,39)	(1.531.325,39)	(1.531.325,39)	(1.531.325,39)	(1.531.325,39)	(1.531.325,39)	(1.531.325,39)	(1.531.325,39)	(1.531.325,39)
15.023.543,67	15.023.543,67	15.023.543,67	15.023.543,67	15.023.543,67	15.023.543,67	15.023.543,67	15.023.543,67	15.023.543,67
105.722,33	105.722,33	105.722,33	105.722,33	105.722,33	105.722,33	105.722,33	105.722,33	105.722,33
(6.112.069,13)	(6.112.069,13)	(6.112.069,13)	(6.112.069,13)	(6.112.069,13)	(6.112.069,13)	(6.112.069,13)	(6.112.069,13)	(6.112.069,13)
(6.006.346,80)	(6.006.346,80)	(6.006.346,80)	(6.006.346,80)	(6.006.346,80)	(6.006.346,80)	(6.006.346,80)	(6.006.346,80)	(6.006.346,80)
9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88
9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88	9.017.196,88
(3.440.520,95)	(2.997.432,04)	(2.554.343,13)	(2.111.254,23)	(1.668.165,32)	(1.225.076,41)	(781.987,50)	(781.987,50)	(781.987,50)
5.576.675,93	6.019.764,84	6.462.853,75	6.905.942,65	7.349.031,56	7.792.120,47	8.235.209,38	8.235.209,38	8.235.209,38
(1.896.069,82)	(2.046.720,04)	(2.197.370,27)	(2.348.020,50)	(2.498.670,73)	(2.649.320,96)	(2.799.971,19)	(2.799.971,19)	(2.799.971,19)
3.680.606,11	3.973.044,79	4.265.483,47	4.557.922,15	4.850.360,83	5.142.799,51	5.435.238,19	5.435.238,19	5.435.238,19
(781.988)	(781.988)	(781.988)	(781.988)	(781.988)	(781.988)	(781.988)	(781.988)	(781.988)
3.440.520,95	2.997.432,04	2.554.343,13	2.111.254,23	1.668.165,32	1.225.076,41	781.987,50	781.987,50	781.987,50
(1.587.453,20)	(1.587.453,20)	(1.587.453,20)	(1.587.453,20)	(1.587.453,20)	(1.587.453,20)	(1.587.453,20)	(1.587.453,20)	(1.587.453,20)
493.672,34	493.672,34	493.672,34	493.672,34	493.672,34	493.672,34	493.672,34	493.672,34	493.672,34
(1.093.780,86)	(1.093.780,86)	(1.093.780,86)	(1.093.780,86)	(1.093.780,86)	(1.093.780,86)	(1.093.780,86)	(1.093.780,86)	(1.093.780,86)
-	-	-	-	-	-	-	-	1.093.780,86
6.339.139,56	**6.188.489,33**	**6.037.839,11**	**5.887.188,88**	**5.736.538,65**	**5.585.888,42**	**5.435.238,19**	**5.435.238,19**	**6.529.019,05**

B.6. Estimation of emission reductions

B.6.1. Explanation of methodological choices

>> ***Baseline Emissions***

Baseline emissions for the proposed project activity are determined according to the following equation:

$$BE_y = BE_{CH4,y} + BE_{EC,y} + BE_{HG,y} + BE_{NG,y}$$ **Equation 1**

Where:

BE_y	=	Baseline emissions in year y (tCO_2e/yr)
$BE_{CH4,y}$	=	Baseline emissions of methane from the SWDS in year y (tCO_2e/yr)
$BE_{EC,y}$	=	Baseline emissions associated with electricity generation in year y (tCO_2e/yr)
$BE_{HG,y}$	=	Baseline emissions associated with heat generation in year y (tCO_2e/yr)
$BE_{NG,y}$	=	Baseline emissions associated with natural gas use in year y (tCO_2e/yr)

Baseline emissions associated with heat generation in year *y* ($BE_{HG,y}$) and natural gas use in year *y* ($BE_{NG,y}$) are not applicable to the proposed project activity.

Baseline emissions of methane from the SWDS ($BE_{CH4,y}$)

Baseline emissions of methane from the SWDS are determined based on the amount of methane that is captured under the project activity and the amount that would be captured and destroyed in the baseline (such as due to regulations). In addition, the effect of methane oxidation that is present in the baseline and absent in the project is taken into account[33].

[33] $OX_{top-layer}$ is the fraction of the methane in the LFG that would oxidize in the top layer of the SWDS in the absence of the project activity. Under the project activity, this effect is reduced as a part of the LFG is captured and does not pass through the top layer of the SWDS. This oxidation effect is also accounted for in the methodological tool "*Emissions from solid waste disposal sites*". In addition to this effect, the installation of a LFG capture system under the project activity may result in the suction of additional air into the SWDS. In some cases, such as with a high suction pressure, the air may decrease the amount of methane that is generated under the project activity. However, in most circumstances where the LFG is captured and used this effect was considered to be very small, as the operators of the SWDS have in most cases an incentive to main a high methane concentration in the LFG. For this reason, this effect is neglected as a conservative assumption.

$$BE_{CH4} = \left(\left(1 - OX_{top\_layer}\right) \times F_{CH4,PJ,y} - F_{CH,BL,y}\right) \times GWP_{CH4}$$ **Equation 2**

Where:

BE_{CH4y}	=	Baseline emissions of LFG from the SWDS in year y (tCO_2e/yr)
OX_{top_layer}	=	Fraction of methane in the LFG that would be oxidized in the top layer of the SWDS in the baseline (dimensionless)
$F_{CH4,PJ,y}$	=	Amount of methane in the LFG which is flared and/or used in the project activity in year y (tCH_4/yr)
$F_{CH4,BJ,y}$	=	Amount of methane in the LFG that would be flared in the baseline in year y (tCH_4/yr)
GWP_{CH4}	=	Global warming potential of CH_4 (tCO_2e/tCH_4)

Ex post determination of $F_{CH4,PJ,y}$

During the crediting period, $F_{CH4,PJ,y}$ is to be determined as the sum of the quantities of methane flared and forwarded to electricity generation, considering the following equation:

$$F_{CH4,PJ,y} = F_{CH4,flared,y} + F_{CH4,EL,y} + F_{CH4,HG,y} + F_{CH4,NG,y}$$ **Equation 3**

Where:

$F_{CH4,PJ,y}$	=	Amount of methane in the LFG which is flared and/or used in the project activity in year y (tCH_4/yr)
$F_{CH4,flared,y}$	=	Amount of methane in the LFG which is destroyed by flaring in year y (tCH_4/yr)
$F_{CH4,EL,y}$	=	Amount of methane in the LFG which is used for electricity generation in year y (tCH_4/yr)
$F_{CH4,HG,y}$	=	Amount of methane in the LFG which is used for heat generation in year y (tCH_4/yr)
$F_{CH4,NG,y}$	=	Amount of methane in the LFG which is sent to the natural gas distribution network in year y (tCH_4/yr)

As the project only flares LFG and generates electricity, then $F_{CH4,HG,y}$ and $F_{CH4,NG,y}$ equals to 0 (zero).

$F_{CH4,EL,y}$ is determined using the "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" and monitoring the working hours of the power plant(s), boiler(s), air heater(s), glass melting furnace(s) and kiln(s), so that no emission reduction are claimed for methane

destruction during non-working hours. This is taken into account by monitoring the hours that the equipment utilizing the LFG is operating in year y ($Op_{j,h,y}$).

The following requirements apply:

a) As per the gaseous stream tool, if the LFG is used for multiple purposes (e.g. flaring or energy generation), and all methane destruction devices are verified to be operational (e.g. by means of flame detectors records, energy generated), a single flow meter may be used to record the flow into multiple destruction devices. The destruction efficiency of the least efficient among the destruction devices shall be used as the destruction efficiency for all destruction devices monitored by this flow meter. If there are any periods for which one or more destruction devices are not operational, paragraph 5 (a) and (b) of the Appendix of the "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" tool shall be followed;

b) CH_4 is the greenhouse gas for which the mass flow should be determined;

c) The simplification offered for calculating the molecular mass of the gaseous stream is valid (equations (3) or (17) in the tool);

d) The mass flow should be calculated on an hourly basis for each hour *h* in year *y*;

e) The mass flow calculated for hour *h* is 0 if the equipment is not working in hour *h* ($Op_{j,h}$ = not working), the hourly values are then summed to a yearly unit basis.

The amount of methane destroyed by flaring ($F_{CH4,flared,y}$) will be determined as follows:

$$F_{CH4,flared,y} = F_{CH4,sent\_flare,y} - \frac{PE_{flare,y}}{GWP_{CH4}} \quad \textbf{Equation 4}$$

Where:

$F_{CH4,flared,y}$	=	Amount of methane in the LFG which is destroyed by flaring in year y (tCH_4/yr)
$F_{CH4,sent\_flare,y}$	=	Amount of methane in the LFG which is sent to the flare in year y (tCH_4/yr)
$PE_{flare,y}$	=	Project emissions from flaring of the residual gas stream in year y (tCO_2e/yr)
GWP_{CH4}	=	Global warming potential of CH_4 (tCO_2e/tCH_4)

$F_{CH4,sent\_flare,y}$ will be determined directly using the "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*", applying the requirements described below.

According to "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" the following options will be considered for the present project activity:

- Option A (Volume flow in dry basis and volumetric fraction in dry basis) when the temperature of the gaseous stream is less than 60ºC (333.15 K) at the flow measurement point; and
- Option B (Volume flow in wet basis and volumetric fraction in dry basis) when the temperature of the gaseous stream is higher than 60ºC (333.15 K) at the flow measurement point.

Option A

Flow measurement on a dry basis is not doable for a wet gaseous stream. Therefore, it is necessary to demonstrate that the gaseous stream is dry to use this option. There are two ways to do this:

(a) Measure the moisture content of the gaseous stream ($C_{H2O,t,db,n}$) and demonstrate that this is less or equal to 0.05 kg H2O/m3 dry gas; or

(b) Demonstrate that the temperature of the gaseous stream (T_t) is less than 60ºC (333.15 K) at the flow measurement point.

In this case, the mass flow of greenhouse gas *i* ($F_{i,t}$) is determined as follows:

$$F_{i,t} = V_{t,db} * v_{i,t,db} * \rho_{i,t}$$ **Equation 5**

With:

$$\rho_{i,t} = \frac{P_t * MM_i}{R_u * T_t}$$ **Equation 6**

Where:

$F_{i,t}$	=	Mass flow of greenhouse gas *i* in the gaseous stream in time interval *t* (kg gas/h)
$V_{t,db}$	=	Volumetric flow of the gaseous stream in time interval *t* on a dry basis (m³ dry gas/h)
$V_{i,t,db}$	=	Volumetric fraction of greenhouse gas *i* in the gaseous stream in a time interval *t* on a dry basis (m³ gas *i*/m³ dry gas)
$\rho i_{,t}$	=	Density of greenhouse gas i in the gaseous stream in time interval *t* (kg gas *i*/m³ gas *i*)
P_t	=	Absolute pressure of the gaseous stream in time interval *t* (Pa)
MM_i	=	Molecular mass of greenhouse gas *i* (kg/kmol)

R_u	=	Universal ideal gases constant (8,314 Pa.m³/kmol.K)
T_t	=	Temperature of the gaseous stream in time interval *t* (K)

If it cannot be demonstrated that the gaseous stream is dry, then the flow measurement should be assumed to be on a wet basis and the option B should be applied instead.

Option B

The mass flow of greenhouse gas *i* ($F_{i,t}$) is determined using equations used to Option A. The volumetric flow of the gaseous stream in time interval *t* on a dry basis ($V_{t,db}$) is determined by converting the measured volumetric flow from wet basis to dry basis as follows:

$$V_{t,tb} = V_{t,wb}/(1 + v_{H2O,t,db}) \quad \textbf{Equation 7}$$

Where:

$V_{t,db}$	=	Volumetric flow of the gaseous stream in time interval *t* on a dry basis (m³ dry gas/h)
$V_{t,wb}$	=	Volumetric flow of the gaseous stream in time interval *t* on a wet basis (m³ wet gas/h)
$V_{H2O,t,db}$	=	Volumetric fraction of H_2O in the gaseous stream in time interval *t* on a dry basis (m³ H_2O/m³ dry gas)

The volumetric fraction of H_2O in time interval *t* on a dry basis ($V_{H2O,t,db}$) is estimated according to following equation.

$$v_{H2O,t,db} = \frac{m_{H2O,t,db} * MM_{t,db}}{MM_{H2O}} \quad \textbf{Equation 8}$$

Where:

$V_{H2O,t,db}$	=	Volumetric fraction of H_2O in the gaseous stream in time interval *t* on a dry basis (m³ H_2O/m³ dry gas)
$m_{H2O,t,db}$	=	Absolute humidity in the gaseous stream in time interval *t* on a dry basis (kg H_2O/kg dry gas)
$MM_{t,db}$	=	Molecular mass of the gaseous stream in time interval *t* on a dry basis (kg dry gas/kmol dry gas)
MM_{H2O}	=	Molecular mass of H_2O (kg H_2O/kmol H_2O)

The absolute humidity of the gaseous stream ($m_{H2O,t,db}$) will be determined using Option 2 (simplified calculation without measurement of the moisture content):

Option 2: Simplified calculation without measurement of the moisture content

This option provides a simple and conservative approach to determine the absolute humidity by assuming the gaseous stream is dry or saturated depending on which is the conservative situation[34].

Concerning the project activity, the conservative situation will be to assume that the gaseous stream is saturated, then $m_{H2O,t,db}$ is assumed to equal the saturation absolute humidity ($m_{H2O,t,db,sat}$) and calculated using the following equation:

$$m_{H2O,t,db,Sat} = \frac{p_{H2O,t,Sat} * MM_{H2O}}{(P_t - p_{H2O,t,Sat}) * MM_{t,db}}$$

Equation 9

Where:

$m_{H2O,t,db,sat}$	=	Saturation absolute humidity in time interval *t* on a dry basis (kg H_2O/kg dry gas)
$\rho_{H2O,t,Sat}$	=	Saturation pressure of H_2O at temperature Tt in time interval t (Pa)
T_t	=	Temperature of the gaseous stream in time interval *t* (K)
P_t	=	Absolute pressure of the gaseous stream in time interval *t* (Pa)
MM_{H2O}	=	Molecular mass of H_2O (kg H_2O/kmol H_2O)
$MM_{t,db}$	=	Molecular mass of the gaseous stream in a time interval *t* on a dry basis (kg dry gas/kmol dry gas)

Parameter $MM_{t,db}$ is estimated using the following equation.

$$MM_{t,db} = \sum_k (v_{k,t,db} * MM_k)$$

Equation 10

Where:

$MM_{t,db}$	=	Molecular mass of the gaseous stream in time interval *t* on a dry basis (kg dry gas/kmol dry gas)
$V_{k,t,db}$	=	Volumetric fraction of gas *k* in the gaseous stream in time interval *t* on a dry basis (m³ gas k/m³ dry gas)
MM_k	=	Molecular mass of gas *k* (kg/kmol)

[34] An assumption that the gaseous stream is saturated is conservative for the situation that the mass flow of greenhouse gas *i* is underestimated (applicable for calculating baseline emissions). Conversely, an assumption that the gas stream is dry is conservative for the situation that the greenhouse gas *i* is overestimated (applicable for calculating project emissions).

k	=	All gases, except H_2O, contained in the gaseous stream (e.g. N_2 and CH_4). See available simplification below

The determination of the molecular mass of the gaseous stream ($MM_{t,db}$) requires measuring the volumetric fraction of all gases (k) in the gaseous stream. However, as a simplification, in the case of the project activity, the volumetric fraction of the methane that is a greenhouse gas and considered in the emission reduction calculation in the underlying methodology must be monitored and the difference to 100% may be considered as pure nitrogen. The simplification is not acceptable if it is differently specified in the underlying methodology.

Project Emissions from flaring:

$PE_{flare,y}$ shall be determined using the methodological tool "*Project emissions from flaring*". If LFG is flared through more than one flare, then $PE_{flare,y}$ is the sum of the emissions for each flare determined separately.

Enclosed flare has been installed in the project activity to increase the destruction efficiency. Those flares reach 98% (minimum)[35] of methane destruction efficiency.

To determine the project emissions from flaring gases the methodological tool "*Project emissions from flaring*" was used. The project emissions calculation procedure is given in the following steps:

STEP 1: Determination of the methane mass flow of the residual gas;

STEP 2: Determination of the flare efficiency;

STEP 3: Calculation of project emissions from flaring.

Step 1: Determination of the methane mass flow in the residual gas

The "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" shall be used to determine the following parameter:

Parameter	**Unit**	**Description**
$F_{CH4,m}$	kg	Mass flow of methane in the residual gaseous stream in the minute *m*

The following requirements apply:

- The gaseous stream tool shall be applied to the residual gas;
- The flow of the gaseous stream shall be measured continuously;

[35] In accordance with the Manufacturer's specification.

- CH_4 is the greenhouse gas i for which the mass flow should be determined;
- The simplification offered for calculating the molecular mass of the gaseous stream is valid (equations 3 and 17 in the tool); and
- The time interval t for which mass flow should be calculated is every minute m.

$F_{CH4,m}$ which is measured as the mass flow during minute *m*, shall then be used to determine the mass of methane in kilograms fed to the flare in minute m ($F_{CH4,RG,m}$). $F_{CH4,m}$ shall be determined on a dry basis.

The option chosen for the "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" by the project participant is option A. However, during the project operational monitoring, if not demonstrated that the temperature of the gaseous stream (T_t) is less than 60ºC (dry basis), then the flow measurement should be assumed to be on a wet basis and the option B should be applied instead.

Step 2: Determination of flare efficiency

Enclosed flare

In the case of enclosed flares, project participants may choose between the following two options to determine the flare efficiency for minute m ($n_{flare,m}$).

Option A: Apply a default value for flare efficiency;

Option B: Measure the flare efficiency.

The Project Participant has chosen Option B. However, in case of flare failure, Option A (default) will be used.

In the present project activity the flare efficiency for minute *m* ($\eta_{flare,m}$) will be determined by Option B.2 of the methodological tool "*Project emissions from flaring*", where the flare efficiency is measured in each minute. Both options are described below:

For enclosed flares that are defined as low height flares, which is the case of the project activity, the flare efficiency in the minute m ($n_{flare,m}$) shall be adjusted, as a conservative approach, by subtracting 0.1 from the efficiency as determined in Option A. For example, the default value applied should be 80%, rather than 90%, and if for example the measured value was 99%, then the value to be used shall correspond to 89%.

Option A: Default value

The flare efficiency for the minute m ($n_{flare,m}$) is 90% when the following two conditions are met to demonstrate that the flare is operating:

(1) The temperature of the flare ($T_{EG.m}$) and the flow rate of the residual gas to the flare ($F_{RG,m}$) is within the manufacturer's specification for the flare ($SPEC_{flare}$) in minute m; and

(2) The flame is detected in minute m ($Flame_m$).

Otherwise $n_{flare,m}$ is 0%.

Option B: Measured flare efficiency

The flare efficiency in the minute *m* is a measured value ($n_{flare,m}$ = $n_{flare,calc,m}$) when the following three conditions are met to demonstrate that the flare is operating:

(1) The temperature of the flare ($T_{EG.m}$) and the flow rate of the residual gas to the flare ($F_{RG,m}$) is within the manufacturer's specification for the flare ($SPEC_{flare}$) in minute *m*;

(2) The flame is detected in minute *m* ($Flame_m$); and

Otherwise $n_{flare,m}$ is 0%.

In applying Option B, the project participants may choose to determine $n_{flare,calc,m}$ using either Option B.1 or Option B.2. Under Option B.1 the measurement is conducted by an accredited entity on a biannual basis and under Option B.2 the flare efficiency is measured in each minute. For the case of the project activity, the option B.2 has been chosen.

Option B.2: Measurement of the flare efficiency in each minute

The calculated flare efficiency $\eta_{flare,calc,m}$ is determined based on monitoring the methane content in the exhaust gas, the residual gas, and the air used in the combustion process during the minute *m* in a year *y* ($\eta_{flare,calc,y}$), as follows:

$$\eta_{flare,calc,m} = 1 - \frac{F_{CH4,EG,m}}{F_{CH4,RG,m}}$$ **Equation 11**

Where:

$\eta_{flare,calc,m}$	=	Flare efficiency in the minute *m*
$F_{CH4,EG,\,m}$	=	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the minute *m* (kg)
$F_{CH4,RG,\,m}$	=	Mass flow of methane in the residual gas on a dry basis at reference conditions in the minute *m* (kg)

$F_{CH4,RG,m}$ is calculated according to Step 1.

$F_{CH4,EG,m}$ is determined according to Steps 2.1 – 2.4:

<u>*Step 2.1: Determine the methane mass flow in the exhaust gas on a dry basis*</u>

The mass flow of methane in the exhaust gas is determined based on the volumetric flow of the exhaust gas and the measured concentration of methane in the exhaust gas, as follows:

$$F_{CH4,EG,m} = V_{EG,m} \times fc_{CH4,EG,m} \times 10^{-6}$$ **Equation 12**

Where:

$F_{CH4,EG,m}$	=	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the minute *m* (kg)
$V_{EG,m}$	=	Volumetric flow of the exhaust gas of the flare on a dry basis at reference conditions in minute *m* (m^3)
$fc_{CH4,EG,m}$	=	Concentration of methane in the exhaust gas of the flare on a dry basis at reference conditions in minute *m* (mg/m^3)

<u>*Step 2.2: Determine the volumetric flow of the exhaust gas ($V_{EG,m}$)*</u>

Determine the average volume flow of the exhaust gas in minute *m* based on a stoichiometric calculation of the combustion process. This depends on the chemical composition of the residual gas, the amount of air supplied to combust it and the composition of the exhaust gas. It is calculated as follows:

$$V_{EG,m} = Q_{EG,m} \times M_{RG,m}$$ **Equation 13**

Where:

$V_{EG,m}$	=	Volumetric flow of the exhaust gas on a dry basis at reference conditions in minute *m* (m^3)
$Q_{EG,m}$	=	Volume of the exhaust gas on a dry basis at reference conditions per kilogram of residual gas on a dry basis at reference conditions in minute *m* (m^3 exhaust gas/kg residual gas)
$M_{RG,m}$	=	Mass flow of the residual gas on a dry basis at reference conditions in the minute *m* (kg)

<u>*Step 2.3: Determine the mass flow of the residual gas ($M_{RG,m}$)*</u>

Project participants may select to monitor the mass flow of the residual gas in minute m directly (see monitored parameter $M_{RG,m}$) or, according to the procedure given in this step, calculate $M_{RG,m}$

based on the volumetric flow and the density of the residual gas. The density of the residual gas is determined based on the volumetric fraction of all components in the gas.

$$M_{RG,m} = \rho_{RG,ref,m} \times V_{RG,m}$$ **Equation 14**

Where:

$M_{RG,m}$	=	Mass flow of the residual gas on a dry basis at reference conditions in minute *m* (kg)
$\rho_{RG,ref,m}$	=	Density of the residual gas at reference conditions in minute *m* (kg/m^3)
$V_{RG,m}$	=	Volumetric flow of the residual gas on a dry basis at reference conditions in the minute *m* (m^3)

and

$$\rho_{RG,ref,m} = \frac{P_{ref}}{\frac{R_u}{MM_{RG,m}} \times T_{ref}}$$ **Equation 15**

Where:

$\rho_{RG,ref,m}$	=	Density of the residual gas at reference conditions in minute *m* (kg/m^3)
P_{ref}	=	Atmospheric pressure at reference conditions (Pa)
R_u	=	Universal ideal gas constant (Pa.m^3/kmol.K)
$MM_{RG,m}$	=	Molecular mass of the residual gas in minute *m* (kg/kmol)
T_{ref}	=	Temperature at reference conditions (K)

Use the equation below to calculate $MM_{RG,m}$. When applying this equation, project participants may choose to either a) use the measured volumetric fraction of each component *i* of the residual gas, or b) as a simplification, measure the volumetric fraction of methane and consider the difference to 100% as being nitrogen (N_2). The same equation applies, irrespective of which option is selected.

$$MM_{RG,m} = \sum_{i} (v_{i,RG,m} \times MM_i)$$ **Equation 16**

Where:

$MM_{RG,m}$	=	Molecular mass of the residual gas in minute *m* (kg/kmol)
MM_i	=	Molecular mass of residual gas component *i* (kg/kmol)

$V_{i,RG,m}$	=	Volumetric fraction of component i in the residual gas on a dry basis at reference conditions in the hour *h*
i	=	Components of the residual gas. If Option (a) is selected to measure the volumetric fraction, then i = CH_4, CO, CO_2, O_2, H_2, H_2S, NH_3, N_2 or if Option (b) is selected then i = CH_4 and N_2

Step 2.4: Determine the volume of the exhaust gas on a dry basis at reference conditions per kilogram of residual gas ($Q_{EG,m}$)

$Q_{ECO2,EG,m}$ shall be determined as follows:

$$Q_{EG,m} = Q_{CO_2,EG,m} + Q_{O_2,EG,m} + Q_{N_2,EG,m}$$ **Equation 17**

Where:

$Q_{EG,m}$	=	Volume of the exhaust gas on a dry basis per kg of residual gas on a dry basis at reference conditions in the minute *m* (m^3/kg residual gas)
$Q_{CO2,EG,m}$	=	Quantity of CO_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute *m* (m^3/kg residual gas)
$Q_{N2,EG,m}$	=	Quantity of N_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute *m* (m_3/kg residual gas)
$Q_{O2,EG,m}$	=	Quantity of O_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute *m* (m^3/kg residual gas)

with

$$Q_{O_2,EG,m} = n_{O2,EG,m} \times VM_{ref}$$ **Equation 18**

Where:

$Q_{O2,EG,m}$	=	Quantity of O_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute *m* (m^3/kg residual gas)
$n_{O2,EG,m}$	=	Quantity of O_2 (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in minute m (kmol/kg residual gas)
VM_{ref}	=	Volume of one mole of any ideal gas at reference temperature and pressure (m^3/kmol)

$$Q_{N2,EG,m} = VM_{ref} \times \left\{ \frac{MF_{N,RG,m}}{2 \times AM_N} + \left(\frac{1 - v_{O2,air}}{v_{O_2,air}} \right) \times \left[F_{O2,RG,m} + n_{O2,EG,m} \right] \right\}$$ **Equation 19**

Where:

$Q_{N2,EG,m}$	=	Quantity of N_2 (volume) in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m3/kg residual gas)
VM_{ref}	=	Volume of one mole of any ideal gas at reference temperature and pressure (m^3/kmol)
$MF_{N,RG,m}$	=	Mass fraction of nitrogen in the residual gas in the minute *m*
AM_N	=	Atomic mass of nitrogen (kg/kmol)
$V_{O2,air}$	=	Volumetric fraction of O_2 in air
$F_{O2,RG,m}$	=	Stochiometric quantity of moles of O_2 required for a complete oxidation of one kg residual gas in minute *m* (kmol/kg residual gas)
$n_{O2,EG,m}$	=	Quantity of O_2 (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in minute *m* (kmol/kg residual gas)

$$Q_{CO_2,EG,m} = \frac{MF_{C,RG,m}}{AM_C} \times VM_{ref}$$ **Equation 20**

Where:

$Q_{CO2,EG,m}$	=	Quantity of CO_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute *m* (m^3/kg residual gas)
$MF_{C,RG,m}$	=	Mass fraction of carbon in the residual gas in the minute *m*
AM_C	=	Atomic mass of carbon (kg/kmol)
VM_{ref}	=	Volume of one mole of any ideal gas at reference temperature and pressure (m^3/kmol)

$$n_{O2,EG,m} = \frac{v_{O_2,EG,m}}{\left(1 - \left(v_{O_2,EG,m} / v_{O_2,air}\right)\right)} \cdot \left[\frac{MF_{C,RG,m}}{AM_C} + \frac{MF_{N,RG,m}}{2 \times AM_N} + \left(\frac{1 - v_{O_2,air}}{v_{O_2,air}} \right) \times F_{O2,RG,m} \right]$$ **Equation 21**

Where:

$n_{CO2,EG,m}$	=	Quantity of O_2 (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in minute *m* (kmol/kg residual gas)
$V_{O2,EG,m}$	=	Volumetric fraction of O_2 in the exhaust gas on a dry basis at reference conditions in the minute *m*
$V_{O2,air}$	=	Volumetric fraction of O_2 in the air
$MF_{C,RG,m}$	=	Mass fraction of carbon in the residual gas in the minute *m*
AM_C	=	Atomic mass of carbon (kg/kmol)
$MF_{N,RG,m}$	=	Mass fraction of nitrogen in the residual gas in the minute *m*
AM_N	=	Atomic mass of nitrogen (kg/kmol)
$F_{02,RG,m}$	=	Stochiometric quantity of moles of O_2 required for a complete oxidation of one kg residual gas in minute *m* (kmol/kg residual gas)

$$F_{O2,RG,m} = \frac{MF_{C,RG,m}}{AM_C} + \frac{MF_{H,RG,m}}{4AM_H} - \frac{MF_{O,RG,m}}{2AM_O} \quad \textbf{Equation 22}$$

Where:

$F_{02,RG,m}$	=	Stochiometric quantity of moles of O_2 required for a complete oxidation of one kg residual gas in minute *m* (kmol/kg residual gas)
$MF_{C,RG,m}$	=	Mass fraction of carbon in the residual gas in the minute *m*
AM_C	=	Atomic mass of carbon (kg/kmol)
$MF_{O,RG,m}$	=	Mass fraction of oxygen in the residual gas in the minute *m*
AM_O	=	Atomic mass of oxygen (kg/kmol)
$MF_{H,RG,m}$	=	Mass fraction of hydrogen in the residual gas in the minute *m*
AM_H	=	Atomic mass of hydrogen (kg/kmol)

Determine the mass fractions of carbon, hydrogen, oxygen and nitrogen in the residual gas, using the volumetric fraction of component i in the residual gas and applying the equation below. In applying this equation, the project participants may choose to either a) use the measured volumetric fraction of each component i of the residual gas, or (b) as a simplification, measure the volumetric fraction of methane and consider the difference to 100% as being nitrogen (N_2). The same equation applies, irrespective of which option is selected.

$$MF_{j,RG,m} = \frac{\sum_i V_{i,RG,m} \times AM_j \times NA_{j,i}}{MM_{RG,m}}$$ **Equation 23**

Where:

$MF_{j,RG,m}$	=	Mass fraction of element *j* in the residual gas in the minute *m*
$V_{i,RG,m}$	=	Volumetric fraction of component *i* in the residual gas on a dry basis in the minute *m*
AM_j	=	Atomic mass of element *j* (kg/kmol)
$NA_{i,i}$	=	Number of atoms of element *j* in component *i*
$MM_{RG,m}$	=	Molecular mass of the residual gas in minute *m* (kg/kmol)
j	=	Elements C, O, H and N
i	=	Component of residual gas. If Option (a) is selected to measure the volumetric fraction, then i = CH_4, CO, CO_2, O_2, H_2, H_2S, NH_3, N_2 or if Option (b) is selected then i= CH_4 and N_2

Step 3: Calculation of project emissions from flaring

Project emissions from flaring are calculated as the sum of emissions for each minute *m* in year *y,* based on the methane mass flow in the residual gas ($F_{CH4,RG,m}$) and the flare efficiency ($\eta_{flare,m}$), as follows:

$$PE_{flare,y} = GWP_{CH4} \times \sum_{m=1}^{525600} F_{CH4,RG,m} \times (1 - \eta_{flare,m}) \times 10^{-3}$$ **Equation 24**

Where:

$PE_{flare,y}$	=	Project emissions from flaring of the residual gas in year *y* (tCO_2e)
GWP_{CH4}	=	Global warming potential of methane valid for the commitment period (tCO_2e/tCH_4)
$F_{CH4,RG,m}$	=	Mass flow of methane in the residual gas in the minute *m* (kg)
$\eta_{flare,m}$	=	Flare efficiency in minute *m*

Table 2 – Parameters used in the tool "*Project emissions from flaring*"

Parameter	Description	Value	Unit

MM_{CH4}	Molecular mass of methane	16.04	kg/kmol
MM_{CO}	Molecular mass of carbon monoxide	28.01	kg/kmol
MM_{CO2}	Molecular mass of carbon dioxide	44.01	kg/kmol
MM_{O2}	Molecular mass of oxygen	32.00	kg/kmol
MM_{H2}	Molecular mass of hydrogen	2.02	kg/kmol
MM_{N2}	Molecular mass of nitrogen	28.02	kg/kmol
AM_{C}	Atomic mass of carbon	12.00	kg/kmol (g/mol)
AM_{H}	Atomic mass of hydrogen	1.01	kg/kmol (g/mol)
AM_{O}	Atomic mass of oxygen	16.00	kg/kmol (g/mol)
AM_{N}	Atomic mass of nitrogen	14.00	kg/kmol (g/mol)
P_{ref}	Atmospheric pressure at reference conditions	101,325	Pa
R_{u}	Universal ideal gas constant	0.008314472	$Pa.m^3/kmol.K$
T_{ref}	Temperature at references conditions	273.15	K
GWP_{CH4}	Global warming potential of methane valid for the second commitment period	25[36]	tCO_2/tCH_4
$\rho_{CH4,n}$	Density of methane at references conditions	0.716	Kg/m^3

Step A.1.1: Ex-ante estimation of $F_{CH4,PJ,y}$

An *ex ante* estimate of $F_{CH4,PJ,y}$ is required to estimate baseline emission of methane from the SWDS in order to estimate the emission reductions of the proposed project activity in the CDM-PDD.

It is determined as follows:

$$F_{CH4,PJ,y} = \eta_{PJ} \times BE_{CH4,SWDS,y} / GWP_{CH4}$$

Equation 25

Where:

$F_{CH4,PJ,y}$	=	Amount of methane in the LFG which is flared and/or used in the project activity in year *y* (tCH_4/yr)
$BE_{CH4,SWDS,y}$	=	Amount of methane in the LFG that is generated from the SWDS in the baseline scenario in year *y* (tCO_2e/yr)
η_{PJ}	=	Efficiency of the LFG capture system that will be installed in the project activity

[36] Value for the 2nd commitment period updated according to COP/MOP decisions.

GWP_{CH4}	=	Global warming potential of CH_4 (tCO_2e/tCH_4)

$BE_{CH4,SWDS,y}$ is determined using the methodological tool "*Emissions from solid waste disposal sites*". The calculation of $BE_{CH4,SWDS,y}$ according the tool is:

$$BE_{CH4,SWDS,y} = \varphi_y \cdot (1-f_y) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_{f,y} \cdot MCF_y \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j \cdot (y-x)} \cdot \left(1-e^{-k_j}\right)$$

Equation 26

Where:

$BE_{CH4,SWDS,y}$	=	Baseline, project or leakage methane emissions occurring in year *y* generated from waste disposal at a SWDS during a time period ending in year *y* (tCO_2e/yr)
X	=	Years in the time period in which waste is disposed at the SWDS, extending from the first year in the time period (x = 1) to year y (x = y).
Y	=	Year of the crediting period for which methane emissions are calculated (*y* is a consecutive period of 12 months)
$DOC_{f,y}$	=	Fraction of degradable organic carbon (DOC) that decomposes under the specific conditions occurring in the SWDS for year *y* (weight fraction)
$Wj_{,x}$	=	Amount of solid waste type j disposed or prevented from disposal in the SWDS in the year *x* (t)
φ_y	=	Model correction factor to account for model uncertainties for year *y*
f_y	=	Fraction of methane captured at the SWDS and flared, combusted or used in another manner that prevents the emissions of methane to the atmosphere in year *y*
GWP_{CH4}	=	Global Warming Potential of methane
OX	=	Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)
F	=	Fraction of methane in the SWDS gas (volume fraction)
MCF_y	=	Methane correction factor for year *y*
DOC_j	=	Fraction of degradable organic carbon in the waste type *j* (weight fraction)
k_j	=	Decay rate for the waste type *j* (1 / yr)
j	=	Type of residual waste or types of waste in the MSW

According to ACM0001 methodology, the parameter f_y in the methodological tool "*Emissions from solid waste disposal sites*" shall be assigned a value of 0 (zero) because the amount of LFG that

would have been captured and destroyed is already accounted for in Equation 2 of this methodology. Also, according to ACM0001 methodology, the parameter *X* begins with the year that the SWDS started receiving wastes (1986). For this reason, the parameter f_y and *X* will not be monitored.

Step A.2: Determination of $F_{CH4,BL,Y}$

As required by ACM0001, this step provides a stepwise procedure for the determination of the amount of methane that would have been captured and destroyed in the baseline scenario (absence of the project) due to regulatory or contractual requirements, or to address safety and odors concerns (collectively referred to as requirement under this step). The four cases summarized in the table below are distinguished in ACM0001. The appropriate case is identified and justified below:

Table 3 – Cases for determining methane captured and destroyed in the baseline.

Situation at the start of the project activity	Requirement to destroy methane	Existing LFG capture and destruction system
Case 1	No	No
Case 2	Yes	No
Case 3	No	Yes
Case 4	Yes	Yes

Requirement to destroy methane

Non-existence of regional or national regulatory or contractual requirements related to LFG management in the region of the project site and in Brazil: There is no legal obligation to capture and destroy the LFG at the Manaus landfill.

Non-existence of requirements to destroy methane due to safety or odor concerns: In the case of the project activity, there are no requirements to destroy methane due to safety or odor concerns either.

In the particular case of the Manaus landfill, as per the project design and licensing requirements, no LFG is to be destroyed by combustion in LFG venting drains in order to address odors or safety concerns. Direct venting of LFG through LFG venting drains (with no combustion) is enough to prevent dangerous accumulation of LFG in the inner section of the landfill.

Therefore, Case 2 and Case 4 are not applicable for the determination of $F_{CH4,BL,y}$.

Existing LFG capture and destruction system

Non-Existence of LFG capture and destruction system at the Manaus landfill: By taking into account the definitions of "LFG capture system" and "existing LFG capture system" as per ACM0001[37], it is thus assumed that there is a LFG capture system at the Manaus landfill. While combustion of LFG is not a practice, no destruction of methane occurs. Thus, it is assumed that there is no LFG capture and destruction system at the Manaus landfill. Therefore, Case 3 is not applicable either. Thus, the only remaining and applicable case for the project activity is Case 1 (Requirement to destroy methane = No; Existing LFG capture and destruction system = No).

No LFG capture and destruction system would be implemented in the absence of the project (baseline scenario) at the Manaus landfill.

Thus, as per ACM0001 in this situation:

$F_{CH4,BL,y} = 0$

Baseline emissions associated with electricity generation ($BE_{EC,y}$)

Baseline emissions associated with electricity generation in year y ($BE_{EC,y}$) shall be calculated by applying applicable guidance of the tool "*Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*". When applying this methodological tool:

- The electricity sources *k* in the tool correspond to the sources of electricity generated identified in the selection of the most plausible baseline scenario; and
- $EC_{BL,k,y}$ in the tool is equivalent to the net amount of electricity generated using LFG in year *y*.

This Tool declares:

> *"In the generic approach, project, baseline and leakage emissions from consumption of electricity are calculated based on the quantity of electricity consumed, an emission factor for electricity generation and a factor to account for transmission losses (…)"*

Specifically for baseline emissions, we have:

$$BE_{EC,y} = \sum_{j} EC_{BL,k,y} * EF_{EL,k,y} * (1 + TDL_{k,y})$$

Equation 27

[37] As per ACM0001, "LFG capture system" is defined as follows: *A system to capture LFG. The system may be passive, active or a combination of both active and passive components. Passive systems capture LFG by means of natural pressure, concentration, and density gradients. Active systems use mechanical equipment to capture LFG by providing pressure gradients. Captured LFG can be vented, flared or used.*

Also, "Existing LFG capture system" is defined as follows: *a system that has been in operation in the last calendar year prior to the start of the operation of the project activity*.

Where:

$BE_{EC,y}$	=	Baseline emissions associated with electricity generation (in tCO_2/yr)
$EC_{BL,k,y}$	=	Net amount of electricity generated using LFG in year *y* (in MWh)
$EF_{EL,k,y}$	=	Emission factor for electricity generation for source *k* in year y (in tCO_2/MWh)
$TDL_{k,y}$	=	Average technical transmission and distribution losses for providing electricity to source *j* in year *y*
k	=	Sources of electricity generated identified in the selection of the most plausible baseline scenario

Project participant choose Option A.1 of the tool "*Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*" for determining $EF_{EL,k,y}$. thus according to the option chosen we:

> *"Calculate the combined margin emission factor of the applicable electricity system, using the procedures in the latest approved version of the Tool to calculate the emission factor for an electricity system ($EF_{EL,j/k/l,y} = EF_{grid,CM,y}$)".*

More details about the emission factor calculation are presented in the Appendix 4.

Step C: Baseline emissions associated with heat generation (*$BE_{HG,y}$*)

As the project design does not encompass utilization of collected LFG for heat generation, (in boiler, air heater, glass melting furnace(s) and/or kiln), baseline emissions associated with heat generation in year *y* ($BE_{HG,y}$) are not considered. Thus, this step is not applicable.

Step D: Baseline emissions associated with natural gas use (*$BE_{NG,y}$*)

As the project design does not encompass use of collected LFG displacing the use of natural gas or injection of collected LFG into a natural gas distribution network, baseline emissions associated with natural gas use in year y ($BE_{NG,y}$) are not considered. Thus, this step is not applicable.

Finally:

$$BE_y = \left(1 - OX_{top\_layer}\right) * \left(\eta_{PJ} * BE_{CH4,SWDS,y} / GWP_{CH4} - 0\right) * GWP_{CH4} + \sum_j EC_{BL,j,y} * EF_{EL,j,y} * \left(1 + TDL_{j,y}\right)$$

Equation 28

<u>Project emissions</u>

Project emissions are calculated as follows:

$$PE_y = PE_{EC,y} + PE_{FC,y} + PE_{DT,y} + PE_{SP,y}$$ **Equation 29**

Where:

PE_y	=	Project emissions in year *y* (in tCO_2/yr)
$PE_{EC,y}$	=	Emissions from consumption of electricity due to the project activity in year *y* (in tCO_2/yr)
$PE_{FC,y}$	=	Emissions from consumption of fossil fuels due to the project activity, for purpose other than electricity generation, in year *y* (in tCO_2/yr)
$PE_{DT,y}$	=	Emissions from the distribution of compressed/liquefied LFG using trucks, in year y (tCO_2/yr)
$PE_{SP,y}$	=	Emissions from the supply of LFG to consumers through a dedicated pipeline, in year *y* (tCO_2/yr)

The parameters $PE_{DT,y}$ and $PE_{SP,y}$ are not used in the calculation of project emissions since there is no distribution of compressed/liquefied LFG using trucks and supply of LFG to consumers through a dedicated pipeline in the project activity.

According to methodological tool "*Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*", the project emission from consumption of electricity will be from three sources:

- *Scenario A:* $PE_{EC1,y}$ – Electricity consumption from the grid;
- *Scenario B:* $PE_{EC2,y}$ – Electricity consumption from an off-grid captive power plant;
- *Scenario C*: $PE_{EC2,y}$ – Electricity consumption from the grid and (a) fossil fuel fired captive power plant(s).

In the case of the project activity, electricity consumption from the grid and diesel generators are used in the project. Since the captive power plant (diesel generator) is not connected to the electricity grid, scenarios A and B apply.

Thus,

$$PE_{EC,y} = PE_{EC1,y} + PE_{EC2,y}$$ **Equation 30**

<u>$PE_{EC1,y}$ - Project emission from electricity consumption from the grid</u>

As electricity is consumed from the grid, the option A1 of the scenario A was chosen, as follows:

Option A1: Calculate the combined margin emission factor of the applicable electricity system, using the procedures in the latest approved version of the "Tool to calculate the emission factor for an electricity system" ($EF_{EL,j/k/l,y} = EF_{grid,CM,y}$).

Thus, the project emission is calculated as following:

$$PE_{EC1,y} = EC_{PJ1,y} \times EF_{grid,CM,y} \times \left(1 + TDL_y\right)$$ **Equation 31**

Where:

$EC_{PJ1,y}$	=	Quantity of electricity consumed from the grid by the project activity during the year *y* (MWh)
$EF_{grid,CM,y}$	=	The emission factor for the grid in year *y* (tCO_2/MWh)
TDL_y	=	Average technical transmission and distribution losses in the grid in year *y* for the voltage level at which electricity is obtained from the grid at the project site

$PE_{EC2,y}$ - Project emission from electricity consumption from an off-grid captive power plant (diesel generator(s))

As electricity is consumed from diesel generators (off-grid captive power plant), a conservative approach was adopted and the option B2 of the scenario B was chosen since "*electricity consumption source is a project or leakage electricity consumption source*". Therefore, the value used will be 1.3 tCO_2/MWh for project emission from diesel generator(s).

$$PE_{EC2,y} = EC_{PJ2,y} \times EF_{diesel\_generator,y} \times \left(1 + TDL_y\right)$$ **Equation 32**

Where:

$EC_{PJ2,y}$	=	Quantity of electricity consumed from diesel generator by the project activity during the year *y* (MWh)
$EF_{diesel\_generator,y}$	=	The emission factor for the diesel generator in year *y* (tCO_2/MWh)
TDL_y	=	Average technical transmission and distribution losses in the grid in year *y* for the voltage level at which electricity is obtained from the grid at the project site

$PE_{FC,y}$ - Emissions from consumption of fossil fuels due to the project activity, for purpose other than electricity generation

Considering that Manaus project activity have a consumption of fossil fuels due to the project activity, for purpose other than electricity generation, such as LPG to flare ignition, the project emissions has to be accounted and monitored.

According to the *"Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion"*, CO_2 emissions from fossil fuel combustion in process *j* are calculated based on the quantity of fuels combusted and the CO_2 emission coefficient of those fuels, as follows:

$$PE_{FC,j,y} = \sum_i FC_{i,j,y} \times COEF_{i,y}$$ **Equation 33**

Where:

$PE_{FC,j,y}$	=	Are the CO_2 emissions from fossil fuel combustion in process *j* during the year *y* (tCO_2/yr)
$FC_{i,j,y}$	=	Is the quantity of fuel type *i* combusted in process *j* during the year y (mass or volume unit/yr)
$COEF_{i,y}$	=	Is the CO_2 emission coefficient of fuel type *i* in year *y* (tCO_2/mass or volume unit)
i	=	Are the fuel types combusted in process *j* during the year *y*

The CO_2 emission coefficient $COEF_{i,y}$ can be calculated using one of the following two Options, depending on the availability of data on the fossil fuel type *i*, as follows:

Option A: The CO_2 emission coefficient $COEF_{i,y}$ is calculated based on the chemical composition of the fossil fuel type *i*, using the following approach:

If $FC_{i,j,y}$ is measured in a mass unit: $COEF_{i,y} = w_{c,i,y} \times 44/12$ **Equation 34**

If $FC_{i,j,y}$ is measured in a volume unit: $COEF_{i,y} = w_{c,i,y} \times \rho_{i,y} \times 44/12$ **Equation 35**

Where:

$COEF_{i,y}$	=	Is the CO_2 emission coefficient of fuel type *i* (tCO_2/mass or volume unit)
$w_{Ci,y}$	=	Is the weighted average mass fraction of carbon in fuel type *i* in year *y* (tC/mass unit of the fuel)
$\rho_{i,y}$	=	Is the weighted average density of fuel type *i* in year *y* (mass unit/volume unit of the fuel)
i	=	Are the fuel types combusted in process *j* during the year *y*

Option B: The CO_2 emission coefficient $COEF_{i,y}$ is calculated based on net calorific value and CO_2 emission factor of the fuel type *i*, as follows:

$$COEF_{i,y} = NCV_{i,y} \times EF_{CO2,i,y}$$ **Equation 36**

Where:

$COEF_{i,y}$	=	Is the CO_2 emission coefficient of fuel type *i* in year *y* (tCO_2/mass or volume unit)
$NCV_{i,y}$	=	Is the weighted average net calorific value of the fuel type *i* in year *y* (GJ/mass or volume unit)
$EF_{co2,i,y}$	=	Is the weighted average CO_2 emission factor of fuel type *i* in year *y* (tCO_2/GJ)
i	=	Are the fuel types combusted in process *j* during the year *y*

The CO_2 emission coefficient $COEF_{i,y}$ will be calculated using Option B of the Tool since the necessary data for Option A is not available.

Leakage

In accordance with the ACM0001, no leakage effects need to be accounted.

Emission Reduction

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y$$ **Equation 37**

Where:

ER_y	=	Emission reductions in year *y* (tCO_2e/MWh)
BE_y	=	Baseline emissions in year *y* (tCO_2e/MWh)
PE_y	=	Project emissions in year *y* (tCO_2e/MWh)

B.6.2. Data and parameters fixed ex ante

ACM0001: Flaring or use of landfill gas

Data / Parameter	OX_{top_layer}
Data unit	Dimensionless
Description	Fraction of methane that would be oxidized in the top layer of the SWDS in the baseline
Source of data	Consistent with how oxidation is accounted for in the methodological tool "*Emissions from solid waste disposal sites*"
Value(s) applied	0.1
Choice of data or Measurement methods and procedures	Default value used, according to ACM0001
Purpose of data	Calculation of baseline emission
Additional comment	-

Data / Parameter	η_{PJ}
Data unit	Dimensionless
Description	Efficiency of the LFG capture system that is be installed in the project activity
Source of data	Flare manufacturer and company which has been responsible for assembly and testing of the equipment at the landfill site
Value(s) applied	80%
Choice of data or Measurement methods and procedures	Based on the active LFG capture system installed in the project activity.
Purpose of data	Calculation of baseline emission
Additional comment	-

Project emissions from flaring

Data / Parameter	GWP_{CH4}
Data unit	tCO_2e/tCH_4
Description	Global warming potential of CH_4
Source of data	IPCC
Value(s) applied	25. Updated for the 2nd commitment period according to COP/MOP decisions[38]
Choice of data or Measurement methods and procedures	Default value used, according to IPCC Fourth Assessment Report: Climate Change 2007, item 2.10.2: Direct Global Warming Potentials, Table 2.14
Purpose of data	Calculation of baseline emission
Additional comment	-

Data / Parameter	$SPEC_{flare}$
Data unit	Temperature - °C Flow rate - Nm^3/h Maintenance schedule - number of days
Description	Manufacturer's flare specifications for temperature, flow rate and maintenance schedule
Source of data	Flare manufacturer

[38] PCC Fourth Assessment Report: Climate Change 2007, item 2.10.2: Direct Global Warming Potentials, Table 2.14, available at: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html, and in accordance with EB69, Annex 3 and decision 4/CMP.7, available at: http://cdm.unfccc.int/Reference/Standards/meth/reg_stan02.pdf.

<table>
<tr><td>Value(s) applied</td><td>-</td></tr>
<tr><td>Choice of data or Measurement methods and procedures</td><td><table>
<tr><td>Flare model</td><td>ZTOF® Enclosed – John Zink</td></tr>
<tr><td>Minimum flare temperature</td><td>760 ºC</td></tr>
<tr><td>Maximum flare temperature</td><td>982 ºC</td></tr>
<tr><td>Minimum and maximum inlet flow rate</td><td>Minimum flow: 858 Nm³/h
Maximum flow: 5,150 Nm³/h</td></tr>
<tr><td>Maximum duration in days between maintenance events</td><td>N/A[39]</td></tr>
</table></td></tr>
<tr><td>Purpose of data</td><td>Calculation of project emissions</td></tr>
<tr><td>Additional comment</td><td>-</td></tr>
</table>

Tool to determine the mass flow of a greenhouse gas in a gaseous stream

Data / Parameter	R_u
Data unit	$Pa.m^3/kmol.K$
Description	Universal ideal gas constant
Source of data	Methodological "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" version 03.0
Value(s) applied	8,314
Choice of data or Measurement methods and procedures	Default value used, according to methodological tool "*Project emissions from flaring*" version 02.0.0, table 1: Constants used in equations
Purpose of data	Calculation of baseline emission
Additional comment	-

<table>
<tr><td>Data / Parameter</td><td>MM_i</td></tr>
<tr><td>Data unit</td><td>kg/kmol</td></tr>
<tr><td>Description</td><td>Molecular mass of greenhouse gas i</td></tr>
<tr><td>Source of data</td><td>"Tool to determine the mass flow of a greenhouse gas in a gaseous stream"</td></tr>
<tr><td>Value(s) applied</td><td><table>
<tr><td>Compound</td><td>Structure</td><td>Molecular mass (kg/kmol)</td></tr>
<tr><td>Methane</td><td>CH_4</td><td>16.04</td></tr>
</table></td></tr>
<tr><td>Choice of data or Measurement methods and procedures</td><td>According to "Tool to determine the mass flow of a greenhouse gas in a gaseous stream"</td></tr>
<tr><td>Purpose of data</td><td>Calculation of baseline emissions</td></tr>
<tr><td>Additional comment</td><td>-</td></tr>
</table>

Data / Parameter	MM_k
Data unit	kg/kmol
Description	Molecular mass of gas *k*
Source of data	"*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*"

[39] The maximum duration in days between maintenance events by the equipment manufacturer is not available. Thus, the number of maintenance events completed in a determined year has been chosen considering preventive maintenance program which defines the frequency for checking flare equipment situation continuously every day.

Value(s) applied	Compound / Structure / Molecular mass (kg/kmol): Nitrogen / N_2 / 28.01
Choice of data or Measurement methods and procedures	According to "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*"
Purpose of data	Calculation of baseline emissions
Additional comment	-

Data / Parameter	MM_{H2O}
Data unit	kg/kmol
Description	Molecular mass of water
Source of data	"*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*"
Value(s) applied	18.0152
Choice of data or Measurement methods and procedures	According to "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*"
Purpose of data	Calculation of baseline emissions
Additional comment	-

Data / Parameter	P_{ref}
Data unit	Pa
Description	Atmospheric pressure at reference conditions
Source of data	Tool to determine the mass flow of a greenhouse gas in a gaseous stream
Value(s) applied	101,325
Choice of data or Measurement methods and procedures	Default value extracted from *"Tool to determine the mass flow of a greenhouse gas in a gaseous stream"*
Purpose of data	Calculation of project emissions
Additional comment	-

Data / Parameter	T_{ref}
Data unit	K
Description	Temperature at reference conditions
Source of data	Tool to determine the mass flow of a greenhouse gas in a gaseous stream
Value(s) applied	273.15
Choice of data or Measurement methods and procedures	Default value extracted from *"Tool to determine the mass flow of a greenhouse gas in a gaseous stream"*
Purpose of data	Calculation of project emissions
Additional comment	-

Emissions from solid waste disposal sites

Data / Parameter	$\varphi_{default}$
Data unit	-
Description	Default value for the model correction factor to account for model uncertainties
Source of data	Tool *"Emissions from solid waste disposal sites"*

Value(s) applied	0.75
Choice of data or Measurement methods and procedures	According to *“Emissions from solid waste disposal sites”*, the Application A was used because the landfill is an existing solid waste disposal site and in the project activity the methane emissions are being mitigated by capturing and flaring the methane (ACM0001).
Purpose of data	Calculation of baseline emission
Additional comment	-

Data / Parameter	OX
Data unit	-
Description	Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)
Source of data	Based on an extensive review of published literature on this subject, including the IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value(s) applied	0.1
Choice of data or Measurement methods and procedures	Default value used according to Tool *“Emissions from solid waste disposal sites”*
Purpose of data	Calculation of baseline emission
Additional comment	When methane passes through the top-layer, part of it is oxidized by methanotrophic bacteria to produce CO_2. The oxidation factor represents the proportion of methane that is oxidized to CO_2.This should be distinguished from the methane correction factor (MCF) which is to account for the situation that ambient air might intrude into the SWDS and prevent methane from being formed in the upper layer of SWDS.

Data / Parameter	F
Data unit	-
Description	Fraction of methane in the SWDS gas (volume fraction)
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value(s) applied	0.5
Choice of data or Measurement methods and procedures	Default value used according to Tool *“Emissions from solid waste disposal sites”*
Purpose of data	Calculation of baseline emission
Additional comment	Upon biodegradation, organic material is converted to a mixture of methane and carbon dioxide

Data / Parameter	$DOC_{f,default}$
Data unit	Weight fraction
Description	Default value for the fraction of degradable organic carbon (DOC) in MSW that decomposes in the SWDS
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value(s) applied	0.5
Choice of data or Measurement methods and procedures	The default value was used for type Application A). according to Tool *“Emissions from solid waste disposal sites”*
Purpose of data	Calculation of baseline emission
Additional comment	This factor reflects the fact that some degradable organic carbon does not degrade, or degrades very slowly, in the SWDS. This default value can be used for Application A.

Data / Parameter	$MCF_{default}$
Data unit	-
Description	Methane correction factor
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value(s) applied	1.0
Choice of data or Measurement methods and procedures	The project activity is an anaerobic managed solid waste disposal site with controlled placement of waste (i.e. waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and is include: (i) cover material; (ii) mechanical compacting and (iii) levelling of the waste.
Purpose of data	Calculation of baseline emission
Additional comment	-

<table>
<tr><td>Data / Parameter</td><td>DOC_j</td></tr>
<tr><td>Data unit</td><td>-</td></tr>
<tr><td>Description</td><td>Fraction of degradable organic carbon in the waste type j (weight fraction)</td></tr>
<tr><td>Source of data</td><td>IPCC 2006 Guidelines for National Greenhouse Gas Inventories (adapted from Volume 5, Tables 2.4 and 2.5)</td></tr>
<tr><td>Value(s) applied</td><td>
<table>
<tr><th>Waste type j</th><th>DOCj (% wet waste)</th></tr>
<tr><td>Wood and wood products</td><td>43%</td></tr>
<tr><td>Pulp, paper and carboard (other than sludge)</td><td>40%</td></tr>
<tr><td>Food, food waste, beverages and tobacco (other than sludge)</td><td>15%</td></tr>
<tr><td>Textiles</td><td>24%</td></tr>
<tr><td>Garden, yard and park waste</td><td>20%</td></tr>
<tr><td>Glass, plastic, metal, other inert waste</td><td>0%</td></tr>
</table>
</td></tr>
<tr><td>Choice of data or Measurement methods and procedures</td><td>IPCC default value for municipal solid waste (MSW) disposal site is applied.</td></tr>
<tr><td>Purpose of data</td><td>Calculation of baseline emission</td></tr>
<tr><td>Additional comment</td><td>-</td></tr>
</table>

Data / Parameter	k_j
Data unit	1/yr
Description	Decay rate for waste type *j*
Source of data	2006 IPCC Guidelines for National Greenhouse Gas Inventories

<table>
<tr><td>Value(s) applied</td><td>
<table>
<tr><th colspan="2" rowspan="2">Waste type j</th><th>Tropical (MAT > 20º C)</th></tr>
<tr><th>Wet (MAP > 1,000mm)</th></tr>
<tr><td rowspan="2">Slowly degrading</td><td>Pulp, paper, cardboard (other than sludge), textiles</td><td>0.07</td></tr>
<tr><td>Wood, wood products and straw</td><td>0.035</td></tr>
<tr><td>Moderately degrading</td><td>Other (non-food) organic putrescible garden and park waste</td><td>0.17</td></tr>
<tr><td>Rapidly degrading</td><td>Food, food waste, sewage sludge, beverages and tobacco</td><td>0.40</td></tr>
</table>
</td></tr>
<tr><td>Choice of data or Measurement methods and procedures</td><td>IPCC default value for anaerobic managed solid waste disposal site is applied.</td></tr>
<tr><td>Purpose of data</td><td>Calculation of baseline emissions</td></tr>
<tr><td>Additional comment</td><td>Used for projection of methane avoidance. The Brazil's climate database was provided by EMBRAPA, and historical data from 1961 to 1990 for the municipality of Manaus was used.</td></tr>
</table>

<table>
<tr><td>Data / Parameter</td><td>Waste composition</td></tr>
<tr><td>Data unit</td><td>%</td></tr>
<tr><td>Description</td><td>Waste composition</td></tr>
<tr><td>Source of data</td><td>Landfill internal data</td></tr>
<tr><td>Value(s) applied</td><td>
<table>
<tr><th colspan="2">Composition of waste</th></tr>
<tr><td>A) Wood and wood products</td><td>6.31%</td></tr>
<tr><td>B) Pulp, paper and carboard (other than sludge)</td><td>23.47%</td></tr>
<tr><td>C) Food, food waste, beverages and tobacco (other than sludge)</td><td>35.84%</td></tr>
<tr><td>D) Textiles</td><td>0.00%</td></tr>
<tr><td>E) Garden, yard and park waste</td><td>0.00%</td></tr>
<tr><td>F) Glass, plastic, metal, other inert waste</td><td>34.39%</td></tr>
</table>
</td></tr>
<tr><td>Choice of data or Measurement methods and procedures</td><td>Internal report</td></tr>
<tr><td>Purpose of data</td><td>Calculation of baseline emission</td></tr>
<tr><td>Additional comment</td><td>Used for projection of methane avoidance</td></tr>
</table>

Tool to calculate the emission factor for an electricity system

Data / Parameter	$EF_{grid,BM,2016}$
Data unit	tCO_2/MWh
Description	Build margin emission factor for the grid in year y
Source of data	Brazilian DNA. Available at: <http://www.mctic.gov.br/mctic/opencms/textogeral/emissao_despacho.html>.
Value(s) applied	0.1581 (*ex ante* estimate for year 2016)

Choice of data or Measurement methods and procedures	The ex-ante calculation vintage of this parameter was chosen as per the procedures of the "*Tool to calculate the emission factor for an electricity system*".
Purpose of data	Calculation of project emissions
Additional comment	For methodological choices details, please refer to Appendix 4.

Data / Parameter	$EF_{grid,OM-adj,y}$
Data unit	tCO_2/MWh
Description	Simple adjusted operating margin CO_2 emission factor in year *y*
Source of data	Brazilian DNA. Available at: <http://www.mctic.gov.br/mctic/opencms/textogeral/emissao_ajustado.html>.
Value(s) applied	0.4979
Choice of data or Measurement methods and procedures	The ex-ante calculation vintage of this parameter was chosen as per the procedures of the "*Tool to calculate the emission factor for an electricity system*".
Purpose of data	Calculation of project emissions
Additional comment	For methodological choices details, please refer to Appendix 4.

B.6.3. Ex ante calculation of emission reductions

>> **Emission reduction**

Baseline emission calculation

The total of methane generation at the site has been estimated based on the waste tonnage of the landfill using the first order decay model presented in the "Emissions from solid waste disposal sites" and considering the following equation as mentioned previously.

Ex-ante estimation of $F_{CH4,PJ,y}$

The assumptions used to calculate $F_{CH4,PJ,y}$ are:

- Methane content in LFG = 50% (default value);
- LFG collection efficiency = 80% (Based on estimation of methane generation in the Manaus landfill);
- Density of methane = 0.716 kg/m^3 (as per tool "*Project emissions from flaring*").

The landfill gas collection and utilization system captures only a portion of the generated landfill gas. Thus, an estimate of 80% LFG collection was applied to the estimate of LFG produced, under assumption that generated LFG is composed of 50% methane.

The *ex ante* estimation of the $F_{CH4,PJ,y}$ is presented below:

$$F_{CH4,PJ,y} = \eta_{PJ} \times BE_{CH4,SWDS,y} / GWP_{CH4}$$ **Equation 38**

Where:

$F_{CH4,PJ,y}$	=	Amount of methane in the LFG which is flared and/or used in the project activity in year *y* (tCH_4/yr)
$BE_{CH4,SWDS,y}$	=	Amount of methane in the LFG that is generated from the SWDS in the baseline scenario in year *y* (tCO_2e/yr)
η_{PJ}	=	Efficiency of the LFG capture system that will be installed in the project activity
GWP_{CH4}	=	Global warming potential of CH_4 (tCO_2e/tCH_4)

The table below illustrates the ex-ante estimation of $F_{CH4,PJ,y}$ by the project activity during the second crediting period.

Table 4 – Ex ante estimation of $F_{CH4,PJ,y}$.

Year	$F_{CH4,PJ,y}$ (tCH_4/yr)
08/07/2018	12,198
2019	25,557
2020	25,871
2021	26,245
2022	26,656
2023	27,085
2024	27,524
07/07/2025	14,340

Determination of $F_{CH4,BL,y}$

As discussed in the Section B.6.1 of this PDD, $F_{CH4,BL,y} = 0$.

Baseline emissions of methane from the SWDS ($BE_{CH4,y}$)

The equation of the $BE_{CH4,y}$ is:

$$BE_{CH4} = \left(\left(1 - OX_{top\_layer}\right) \times F_{CH4,PJ,y} - F_{CH,BL,y}\right) \times GWP_{CH4}$$ **Equation 39**

Where the OX_{top_layer} = 0.1 (default value) and $F_{CH4,PJ,y}$ and $F_{CH4,BL,y}$ are calculated above. The results are presented below:

Table 5 – Baseline emissions of methane from the SWDS ($BE_{CH4,y}$)

Year	$BE_{CH4,y}$ (tCO_2/yr)
08/07/2018	274,456
2019	575,027

2020	582,088
2021	590,508
2022	599,761
2023	609,406
2024	619,292
07/07/2025	322,646

<u>**Baseline emissions associated with electricity generation ($BE_{EC,y}$)**</u>

The ex-ante calculation is:

$$BE_{EC,y} = \sum_{j} EC_{BL,k,y} * EF_{EL,k,y} * (1 + TDL_{k,y})$$

Equation 40

As explained above, $EF_{EL,j/k/l,y} = EF_{grid,CM,y}$. Thus, the $EF_{grid,CM,y}$ = 0.2430 tCO_2/MWh.

Table 6 - Baseline emissions associated with electricity generation ($BE_{EC,y}$)

Year	$EC_{BL,k,y}$ (MWh/yr)	$BE_{EC,y}$ (tCO_2/yr)
08/07/2018	0	0
2019	0	0
2020	0	0
2021	0	0
2022	40,823	11,517
2023	54,707	15,434
2024	68,591	19,351
07/07/2025	41,850	11,807

The equation of the baseline emission calculation is:

$$BE_y = BE_{CH4,y} + BE_{EC,y}$$

Equation 41

The result is:

Table 7 – Total baseline emissions of the project activity.

Year	$BE_{CH4,y}$	$BE_{EC,y}$	BE_y

	(tCO$_2$/yr)	(tCO$_2$/yr)	(tCO$_2$/yr)
08/07/2018	274,455	0	274,455
2019	575,027	0	575,027
2020	582,087	0	582,087
2021	590,507	0	590,507
2022	599,760	11,517	611,277
2023	609,405	15,434	624,839
2024	619,291	19,351	638,642
07/07/2025	322,645	11,807	334,452

Emission Factor calculation

The Brazilian DNA is responsible for calculating the OM and BM emission factor in Brazil. It uses the method b) Simple adjusted OM.

As mentioned above the average $EF_{OM\ simple,\ 2014\text{-}2016}$ is 0.4979 tCO_2/MWh and the $EF_{grid,BM,2016}$ is 0.1581 tCO_2/MWh.

Considering the Option 1 was chosen for the proposed project in the first crediting period, for the second crediting period the build margin emission factor was updated based on the most recent information available (2016).

Calculate the combined margin emissions factor

The default weights are as follows: w_{OM} = 0.25 and w_{BM} = 0.75, fixed for the second crediting period. That gives:

EF_{2016} = 0.4979 x 0.25 + 0.1581 x 0.75 = 0.2430 tCO_2/MWh

The combined margin CO_2 emission factor will be fixed during the second crediting period.

Project Emissions

According to "*Tool to calculate baseline, project and/or leakage emissions from electricity consumption*", the project emission from consumption of electricity will be from two sources:

- $PE_{EC1,y}$ - Grid (Brazilian interconnected electric system);
- $PE_{EC2,y}$ - Diesel generator(s) (off-grid captive power plant).

$PE_{EC,y} = PE_{EC1,y} + PE_{EC2,y}$

$PE_{EC1,y}$ - Project emission from the grid

In the project activity, the annual electricity consumption from the grid is estimated around 830 MWh/year. However, this variable will be monitored during the whole crediting period.

In the option A1 of the "*Tool to calculate baseline, project and/or leakage emissions from electricity consumption*", states that a value of the combined margin emission factor ($EF_{grid,CM,y}$) may be used as the emission factor ($EF_{ELj/k/l,y}$). Therefore, a value of 0.2743 tCO_2/MWh will be used.

Finally the technical transmission and distribution losses ($TDL_{j,y}$) value has been assumed to be 16.1%, according to National Energy Balance 2017 for the year 2016[40]. Table below summarizes the project emissions resulting from electrical consumption in the plant.

Table 8 – Electricity consumption from the grid resulting due to the project activity.

Year	$EC_{PJ1,y}$ (MWh/yr)	$PE_{EC1,y}$ (tCO_2/yr)
08/07/2018	400	113
2019	830	265
2020	830	265
2021	830	265
2022	0	0
2023	0	0
2024	0	0
07/07/2025	0	0

For the second crediting period, considering the electricity generation is estimated to start on 01/01/2022, it was considered only electricity consumption since 08/07/2018 to 31/12/2021.

$PE_{EC2,y}$ - Project emission from diesel generator(s)

The diesel generator consumption will be around 220 MWh/year during phase 1 (from 2018 to 2021) and for the phase 2 (from 2022 to 2025) it is no consumption of diesel by the diesel generator since the electricity will be generated through LFG in order to supply the LFG plant internal needs. The emission factor from the diesel generator(s) is 1.3 tCO_2/MWh. The following table represents the project emissions from the use of the standby generator over the crediting period. Table below presents the project emissions associated with fossil fuel combustion at the project site.

[40] National Energy Balance 2017 (base year 2016), page 30. Available at: <https://ben.epe.gov.br/downloads/S%C3%ADntese%20do%20Relat%C3%B3rio%20Final_2017_Web.pdf>.

Table 9 - Electricity consumption from the grid resulting due to the project activity.

Year	$EC_{PJ2,y}$ (MWh/yr)	$PE_{EC2,y}$ (tCO_2/yr)
08/07/2018	106	138
2019	220	286
2020	220	286
2021	220	286
2022	0	0
2023	0	0
2024	0	0
07/07/2025	0	0

$PE_{FC,y}$ - Project emission from consumption of fossil fuels due to the project activity, for purpose other than electricity generation

Based on monitored values of the project activity for 2017 year of 78 kg/yr of LPG for the parameter $FC_{i,j,y}$ has been used. The emission factor is 0.00305 tCO_2/kg. The following table represents the project emissions from the use of LPG over the crediting period.

Table 10 – LPG consumption due to the project activity.

Year	$FC_{i,j,y}$ (mass or volume unit /yr)	$PE_{FC,y}$ (tCO_2/yr)
08/07/2018	37.61	0.115
2019	78	0.238
2020	78	0.238
2021	78	0.238
2022	78	0.238
2023	78	0.238
2024	78	0.238
07/07/2025	39.96	0.122

Leakage

No leakage effects need to be accounted under methodology ACM0001.

Emission Reduction

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y$$ **Equation 42**

Where:

ER_y	=	Emission reductions in year *y* (tCO_2e/MWh)
BE_y	=	Baseline emissions in year *y* (tCO_2e/MWh)
PE_y	=	Project emissions in year *y* (tCO_2e/MWh)

Table 11 – Emission reductions due the project activity.

Year	BE_y (tCO_2/yr)	PE_y (tCO_2/yr)	ER_y (tCO_2/yr)
08/07/2018	274,455	251	274,203
2019	575,027	521	574,506
2020	582,087	521	581,566
2021	590,507	521	589,986
2022	611,277	0	611,277
2023	624,839	0	624,839
2024	638,642	0	638,642
07/07/2025	334,452	0	334,451

B.6.4. Summary of ex ante estimates of emission reductions

Year*	Baseline emissions (t CO_2e)	Project emissions (t CO_2e)	Leakage (t CO_2e)	Emission reductions (t CO_2e)
2018	274,455	251	0	274,203
2019	575,027	521	0	574,506
2020	582,087	521	0	581,566
2021	590,507	521	0	589,986
2022	611,277	0	0	611,277
2023	624,839	0	0	624,839
2024	638,642	0	0	638,642
2025	334,452	0	0	334,451
Total	**4,231,286**	**1,814**	**0**	**4,229,470**
Total number of crediting years	7			
Annual average over the crediting period	604,469	259	0	604,210

*The crediting period starts on 08/07/2018 up to 07/07/2025

B.7. Monitoring plan

B.7.1. Data and parameters to be monitored

Baseline, project and/or leakage emission from electricity consumption and monitoring of electricity generation

Data / Parameter	TDL_y
Data unit	-
Description	Average technical transmission and distribution losses in the grid in year *y* for the voltage level at which electricity is obtained from the grid at the project site.
Source of data	National Energy Balance
Value(s) applied	16.1%[41]
Measurement methods and procedures	For (a): TDLj/k/l,y should be estimated for the distribution and transmission networks of the electricity grid of the same voltage as the connection where the proposed CDM project activity is connected to. The technical distribution losses should not contain other types of grid losses (e.g. commercial losses/theft). The distribution losses can either be calculated by the project participants or be based on references from utilities, network operators or other official documentation
Monitoring frequency	Annually. In the absence of data from the relevant year, most recent figures should be used, but not older than 5 years
QA/QC procedures	-
Purpose of data	(b) Calculation of project emissions or actual net GHG removals by sinks
Additional comment	-

<table>
<tr><td>Data / Parameter</td><td>$EC_{PJ1,y} = EG_{EC1,y}$</td></tr>
<tr><td>Data unit</td><td>MWh/y</td></tr>
<tr><td>Description</td><td>Quantity of electricity consumed from the grid by the project activity during the year y</td></tr>
<tr><td>Source of data</td><td>Measurement from Project participants.</td></tr>
<tr><td>Value(s) applied</td><td><table>
<tr><th>Year</th><th>$EC_{PJ1,y}$</th></tr>
<tr><td>2018</td><td>400</td></tr>
<tr><td>2019</td><td>830</td></tr>
<tr><td>2020</td><td>830</td></tr>
<tr><td>2021</td><td>830</td></tr>
<tr><td>2022</td><td>0</td></tr>
<tr><td>2023</td><td>0</td></tr>
<tr><td>2024</td><td>0</td></tr>
<tr><td>2025</td><td>0</td></tr>
</table></td></tr>
<tr><td>Measurement methods and procedures</td><td>Continuously measured by electricity meters for the grid electricity consumption as per the “Methodological tool: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation” and methodology ACM0001.</td></tr>
<tr><td>Monitoring frequency</td><td>Continuously</td></tr>
<tr><td>QA/QC procedures</td><td>As per the “Methodological tool: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation”.</td></tr>
<tr><td>Purpose of data</td><td>(b) Calculation of project emissions or actual net GHG removals by sinks</td></tr>
</table>

[41] National Energy Balance 2017 (base year 2016), page 30. Available at: <https://ben.epe.gov.br/downloads/S%C3%ADntese%20do%20Relat%C3%B3rio%20Final_2017_Web.pdf>.

Additional comment	The data will be archived throughout the crediting period and two years thereafter.

Data / Parameter	$EC_{PJ2,y} = EG_{EC2,y}$
Data unit	MWh/y
Description	Quantity of electricity consumed from diesel generator by the project activity during the year y
Source of data	Measurement from Project participants.
Value(s) applied	**Year** / **$EC_{PJ2,y}$**: 2018 – 106; 2019 – 220; 2020 – 220; 2021 – 220; 2022 – 0; 2023 – 0; 2024 – 0; 2025 – 0
Measurement methods and procedures	Continuously measured by electricity meters for the diesel generators as per "*Methodological tool: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*" and ACM0001 methodology.
Monitoring frequency	Continuously
QA/QC procedures	As per the "*Methodological tool: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*".
Purpose of data	(b) Calculation of project emissions or actual net GHG removals by sinks
Additional comment	The data will be archived throughout the crediting period and two years thereafter.

Year	**$EC_{PJ2,y}$**
2018	106
2019	220
2020	220
2021	220
2022	0
2023	0
2024	0
2025	0

ACM0001: Flaring or use of landfill gas --- Version 18.0

Data / Parameter	Management of SWDS
Data unit	-
Description	Management of SWDS
Source of data	Use different sources of data: - Original design of the landfill; - Technical specifications for the management of the SWDS; - Local or national regulations.
Value(s) applied	-
Measurement methods and procedures	Project participants should refer to the original design of the landfill to ensure that any practice to increase methane generation have been occurring prior to the implementation of the project activity. Any change in the management of the SWDS after the implementation of the project activity should be justified by referring to technical or regulatory specifications.
Monitoring frequency	Annually
QA/QC procedures	-
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	-

Data / Parameter	$EG_{PJ,y} = EC_{BL,k,y}$
Data unit	MWh
Description	Amount of electricity generated using LFG by the project activity in year y
Source of data	Electricity meter

Value(s) applied	<table><tr><th>Year</th><th>$EG_{PJ,y}$</th></tr><tr><td>2018</td><td>0</td></tr><tr><td>2019</td><td>0</td></tr><tr><td>2020</td><td>0</td></tr><tr><td>2021</td><td>0</td></tr><tr><td>2022</td><td>40,823</td></tr><tr><td>2023</td><td>54,707</td></tr><tr><td>2024</td><td>68,591</td></tr><tr><td>2025</td><td>41,850</td></tr></table>
Measurement methods and procedures	Monitor net electricity generation by the project activity using LFG
Monitoring frequency	Continuous
QA/QC procedures	Electricity meter will be subject to regular (in accordance with stipulation of the meter supplier) maintenance and testing to ensure accuracy. The readings will be double checked by the electricity distribution company.
Purpose of data	b) Calculation of project emissions or actual net GHG removals by sinks
Additional comment	This parameter is required for calculating baseline emissions associated with electricity generation ($BE_{EC,y}$) using the "*Methodological tool: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*". The electricity generation from biogas generator (CHP300) is not monitored and will be considered 0 (zero), therefore certified emissions reductions will not be requested for this activity

Data / Parameter	$O_{pj,h}$
Data unit	-
Description	Operation of the equipment that consumes the LFG
Source of data	Measurements by Project participant using a device integrated with the operational software at the landfill gas plant.
Value(s) applied	n/a
Measurement methods and procedures	For each equipment unit j using the LFG monitor that the plant is operating in hour h by the monitoring any one or more of the following three parameters: (a) Temperature. Determine the location for temperature measurements and minimum operational temperature based on manufacturer's specifications of the burning equipment. Document and justify the location and minimum threshold in the PDD; (b) Flame. Flame detection system is used to ensure that the equipment is in operation; (c) Products generated. Monitor the generation of steam for the case of boilers and air-heaters and glass for the case of glass melting furnances. This option is not applicable to brick kilns. $O_{pj,h}$ = 0 when: (a) One of more temperature measurements are missing or below the minimum threshold in hour h (instantaneous measurements are made at least every minute); (b) Flame is not detected continuously in hour h (instantaneous measurements are made at least every minute); (c) No products are generated in the hour h. Otherwise, $O_{pj,h}$ = 1
Monitoring frequency	Once per minute
QA/QC procedures	The calibration of this equipment is not applicable since it is a device integrated with the operational software at the landfill gas plant.
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	-

Tool to determine the mass flow of a greenhouse gas in a gaseous stream

Data / Parameter	$V_{t,db}$
Data unit	m^3/h
Description	Volumetric flow of the gaseous stream in time interval t on a dry basis
Source of data	Measurements by Project participants using a flow meter(s)
Value(s) applied	n/a
Measurement methods and procedures	The volumetric flow rate of the residual gas which is sent to each individual flare, LFG engines in the hour h will be measured by the installed flow meters with digital recordable electronic signal, according to the "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*", the measurement option in the project activity will be: • Option (A) dry basis: when the temperature of gaseous stream is lower than 60ºC (333.15 K) at the flow measurement point; • Option (B) wet basis: when the temperature of gaseous stream is higher than 60º C (333.15 K) at the flow measurement point.
Monitoring frequency	Continuous recorded and hourly aggregated
QA/QC procedures	Periodic calibration against a primary device provided by an independent accredited laboratory is mandatory. The calibration frequency of this monitoring equipment should be in accordance with manufacturer's specifications.
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	This parameter will be monitored only in case Option A of the "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" is applied for the determination of $F_{CH4,flared,y}$ and $F_{CH4,EL,y}$

Data / Parameter	$V_{t,wb}$
Data unit	m^3/h
Description	Volumetric flow of the gaseous stream in time interval t on a wet basis
Source of data	Measurements by Project participants using a flow meter
Value(s) applied	n/a
Measurement methods and procedures	The volumetric flow rate of the residual gas which is sent to each individual flare, LFG engines in the hour h will be measured by the installed flow meters with digital recordable electronic signal, according to the "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*", the measurement option in the project activity will be: • Option (A) dry basis: when the temperature of gaseous stream is lower than 60ºC (333.15 K) at the flow measurement point; • Option (B) wet basis: when the temperature of gaseous stream is higher than 60ºC (333.15 K) at the flow measurement point.
Monitoring frequency	Continuous recorded and hourly aggregated
QA/QC procedures	Periodic calibration against a primary device provided by an independent accredited laboratory is mandatory. The calibration frequency of this monitoring equipment should be in accordance with manufacturer's specifications.
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	This parameter will be monitored only in case Options B or C of the "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" is applied for the determination of $F_{CH4,flared,y}$ and $F_{CH4,EL,y}$

Data / Parameter	$v_{i,t,db}$
Data unit	m^3 gas i/m^3 dry gas
Description	Volumetric fraction of greenhouse gas *i* in a time interval t on a dry basis
Source of data	Measurements by Project Participants using gas analyser (onsite measurements)
Value(s) applied	50%
Measurement methods and procedures	Continuous gas analyser operating in dry basis. Volumetric flow measurement should always refer to the actual pressure and temperature.
Monitoring frequency	Continuous recorded and hourly aggregated

QA/QC procedures	Calibration should include zero verification with an inert gas (e.g. N_2) and at least one reading verification with a standard gas (single calibration gas or mixture calibration gas). All calibration gases must have a certificate provided by the manufacturer and must be under their validity period.
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	This parameter will be monitored only in case Option A of the tool "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" is applied for the determination of $F_{CH4,flared,y}$ and $F_{CH4,EL,y}$

Data / Parameter	$v_{i,t,wb}$
Data unit	m³ gas *i*/m³ wet gas
Description	Volumetric fraction of greenhouse gas *i* in a time interval t on a wet basis
Source of data	Measurements by Project Participants using gas analyser (onsite measurements)
Value(s) applied	50%
Measurement methods and procedures	Continuous gas analyser operating in dry basis. Volumetric flow measurement should always refer to the actual pressure and temperature.
Monitoring frequency	Continuous recorded and hourly aggregated.
QA/QC procedures	Calibration should include zero verification with an inert gas (e.g. N_2) and at least one reading verification with a standard gas (single calibration gas or mixture calibration gas). All calibration gases must have a certificate provided by the manufacturer and must be under their validity period.
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	This parameter will be monitored only in case Option A of the tool "*Tool to determine the mass flow of a greenhouse gas in a gaseous stream*" is applied for the determination of $F_{CH4,flared,y}$ and $F_{CH4,EL,y}$

Data / Parameter	T_t
Data unit	K
Description	Temperature of the gaseous stream in time interval t
Source of data	Measurements by Project participant using a temperature meter
Value(s) applied	n/a
Measurement methods and procedures	Thermoresistance with digital recordable electronic signal will be used. The accuracy and uncertainty of the monitoring instrument will be in accordance with manufacturer specifications.
Monitoring frequency	Continuous
QA/QC procedures	Periodic calibration against a primary device provided by an independent accredited laboratory is mandatory. The calibration frequency of this monitoring equipment should be according to the manufacturer's specifications
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	Provided all parameters are converted to normal conditions during the monitoring process, this parameter may not be needed except for moisture content determination and therefore it should be metered only when performing such measurements (with same frequency). However, if the applicability condition related to the gaseous stream flow temperature being below 60ºC is adopted, this parameter must be monitored continuously to assure the applicability condition is met.

Data / Parameter	P_t
Data unit	Pa
Description	Pressure of the gaseous stream in time interval t
Source of data	Measurements by Project participant using a pressure meter
Value(s) applied	n/a

Measurement methods and procedures	Instruments with recordable electronic signal (analogical or digital) will be used. Examples include pressure transducers, etc. The accuracy and uncertainty of the monitoring instrument will be in accordance with manufacturer specifications.
Monitoring frequency	Continuous
QA/QC procedures	Periodic calibration against a primary device must be performed periodically and records of calibration procedures must be kept available as well as the primary device and its calibration certificate. Pressure transducers (either capacitive or resistive) must be calibrated monthly. In case the pressure meter is not a capacitive or resistive pressure transducer, the calibration frequency of this monitoring equipment should be according to the manufacturer's specifications.
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	Provided all parameters are converted to normal conditions during the monitoring process, this parameter may not be needed except for moisture content determination and therefore it should be metered only when performing such measurements (with same frequency)

Data / Parameter	Status of biogas destruction device
Data unit	-
Description	Operational status of biogas destruction devices
Source of data	Provided by project participants
Value(s) applied	n/a
Measurement methods and procedures	Monitoring and documenting may be undertaken by recording the energy production from methane captured or the operation of the flare by means of a flame detector to demonstrate the actual destruction of methane, unless a different method is specified in the underlying methodology/tool. Emission reductions will not accrue for periods in which the destruction device is not operational.
Monitoring frequency	Continuous
QA/QC procedures	-
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	For flame detector devices refer to the methodological tool "*Project emissions from flaring*"

Data / Parameter	$P_{H2O,t,Sat}$
Data unit	Pa
Description	Saturation pressure of H_2O at temperature T_t in time interval t
Source of data	Provided by project participants
Value(s) applied	n/a
Measurement methods and procedures	This parameter is solely a function of the gaseous stream temperature Tt and can be found at reference [1] for a total pressure equal to 101,325 Pa
Monitoring frequency	-
QA/QC procedures	-
Purpose of data	(a) Calculation of baseline emissions or baseline net GHG removals by sinks
Additional comment	[1] Fundamentals of Classical Thermodynamics; Gordon J. Van Wylen, Richard E. Sonntag and Borgnakke; 4º Edition 1994, John Wiley & Sons, Inc.

Methodological tool "*Project emissions from flaring*"

Data / Parameter	$V_{i,RG,m}$
Data unit	-
Description	Volumetric fraction of component i in the residual gas on a dry basis in the minute m where i = CH4, CO, CO2, O2, H2, H2S, NH4, N2
Source of data	Measurements by project participants using a continuous gas analyser

Value(s) applied	50%
Measurement methods and procedures	Measurement may be made on either dry or wet basis. If value is made on a wet basis, then it shall be converted to dry basis for reporting
Monitoring frequency	Continuously. Values to be averaged on a minute basis
QA/QC procedures	Analysers must be periodically calibrated according to the manufacturer's recommendation. A zero check and a typical value check should be performed by comparison with a standard certified gas
Purpose of data	Determination of the flare efficiency
Additional comment	As a simplified approach, project participants may only measure the content CH4, CO and CO2 of the residual gas and consider the remaining part as N2. Monitoring of this parameter is only applicable in case of enclosed flares and continuous monitoring of the flare efficiency (as the case of the purpose project activity)

Data / Parameter	$V_{RG,m}$
Data unit	m^3
Description	Volumetric flow of the residual gas on a dry basis at reference conditions in the minute *m*
Source of data	Measurements by project participants using a flow meter
Value(s) applied	-
Measurement methods and procedures	Instruments with recordable electronic signal (analogical or digital)
Monitoring frequency	Continuously. Values to be averaged on a minute basis
QA/QC procedures	Flow meters are to be periodically calibrated according to the manufacturer's recommendation
Purpose of data	Determination of the flare efficiency
Additional comment	-

Data / Parameter	$M_{RG,m}$
Data unit	kg
Description	Mass flow of the residual gas on a dry basis at reference conditions in the minute m
Source of data	-
Value(s) applied	-
Measurement methods and procedures	Instruments with recordable electronic signal (analogical or digital)
Monitoring frequency	Continuous, values to be averaged on a minute basis
QA/QC procedures	Periodic calibration against a primary device provided by an independent accredited laboratory is mandatory. Calibration and frequency of calibration is according to manufacturer's specifications
Purpose of data	Determination of the flare efficiency
Additional comment	-

Data / Parameter	$v_{O2,EG,m}$
Data unit	-
Description	Volumetric fraction of O_2 in the exhaust gas on a dry basis at reference conditions in the minute *m*
Source of data	Measurements by project participants using a continuous gas analyser
Value(s) applied	-
Measurement methods and procedures	Extractive sampling analysers with water and particulates removal devices or in situ analysers for wet basis determination. The point of measurement (sampling point) shall be in the upper section of the flare (80% of total flare height). Sampling shall be conducted with appropriate sampling probes adequate to high temperatures level (e.g. inconel probes)
Monitoring frequency	Continuously. Values to be averaged on a minute basis

QA/QC procedures	Analysers must be periodically calibrated according to the manufacturer's recommendation. A zero check and a typical value check should be performed by comparison with a standard gas
Purpose of data	Determination of the flare efficiency
Additional comment	-

Data / Parameter	$fc_{CH4,EG,m}$
Data unit	mg/m^3
Description	Concentration of methane in the exhaust gas of the flare on a dry basis at reference conditions in the minute *m*
Source of data	Measurements by project participants using a continuous gas analyser
Value(s) applied	-
Measurement methods and procedures	Extractive sampling analysers with water and particulates removal devices or in situ analyser for wet basis determination. The point of measurement (sampling point) shall be in the upper section of the flare in order that the sampling is of the gas after consumption has taken place (80% of total flare height). Sampling shall be conducted with appropriate sampling probes adequate to high temperatures level (e.g. inconel probes)
Monitoring frequency	Continuously. Values to be averaged on a minute basis
QA/QC procedures	Analysers must be periodically calibrated according to manufacturer's recommendation. A zero check and a typical value check should be performed by comparison with a standard gas
Purpose of data	Determination of the flare efficiency
Additional comment	Measurement instruments may read ppmv or % values. To convert from ppmv to mg/m3 simply multiply by 0.716. 1% equals 10 000 ppmv

Data / Parameter	$Flame_m$
Data unit	Flame on or Flame off
Description	Flame detection of flare in the minute m
Source of data	Project Participant
Value(s) applied	-
Measurement methods and procedures	Measurements by project participants using a continuous Ultra Violet flame detector
Monitoring frequency	Once per minute. Detection of flame recorded as a minute that the flame was on, otherwise recorded as a minute that the flame was off
QA/QC procedures	Equipment shall be maintained and calibrated in accordance with manufacturer's recommendations
Purpose of data	Calculation of baseline and project emissions when the flame is on[42].
Additional comment	-

Data / Parameter	$Maintenance_y$
Data unit	Calendar dates
Description	Maintenance events completed in year y
Source of data	Project participants
Value(s) applied	-
Measurement methods and procedures	Record the date that maintenance events were completed in year y. Records of maintenance logs must include all aspects of the maintenance including the details of the person(s) undertaking the work, parts replaced, or needing to be replaced, source of replacement parts, serial numbers and calibration certificates
Monitoring frequency	Daily

[42] When the flame is off, neither baseline nor project emissions occurs since the LFG is not combusted and instead released to the atmosphere.

QA/QC procedures	Records must be kept in a maintenance log for two years beyond the life of the flare
Purpose of data	Calculation of baseline and project emissions when the flame is on[43].
Additional comment	Monitoring of this parameter is required for the case of enclosed flares and the project participant selects Option B to determine flare efficiency. These dates are required so that they can be compared to the maintenance schedule to check that maintenance events were completed within the minimum time between maintenance events specified by the manufacturer ($S_{PEC,flare}$).

Data / Parameter	$T_{EG,m}$
Data unit	ºC
Description	Temperature in the exhaust gas of the enclosed flare in minute *m*
Source of data	Measurements by project participants
Value(s) applied	-
Measurement methods and procedures	Measure the temperature of the exhaust gas stream in the flare by a Type N thermocouple. A temperature above 760ºC indicates that a significant amount of gases are still being burnt and that the flare is operating. Data will be recorded continuously and values will be averaged hourly or at a shorter time interval.
Monitoring frequency	Once per minute
QA/QC procedures	Thermocouples will be replaced or calibrated every year.
Purpose of data	(b) Calculation of project emissions or actual net GHG removals by sinks
Additional comment	-

Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion

Data / Parameter	$FC_{i,j,y}$
Data unit	kg/yr
Description	Quantity of fuel type *i* combusted in process *j* during the year *y*
Source of data	Sales of receipt
Value(s) applied	78
Measurement methods and procedures	Use either mass or volume meters. In cases where fuel is supplied from small daily tanks, rulers can be used to determine mass or volume of the fuel consumed, with the following conditions: The ruler gauge must be part of the daily tank and calibrated at least once a year and have a book of control for recording the measurements (on a daily basis or per shift); • Accessories such as transducers, sonar and piezoelectronic devices are accepted if they are properly calibrated with the ruler gauge and receiving a reasonable maintenance; • In case of daily tanks with pre-heaters for heavy oil, the calibration will be made with the system at typical operational conditions.
Monitoring frequency	Continuously
QA/QC procedures	The consistency of metered fuel consumption quantities should be cross-checked by an annual energy balance that is based on purchased quantities and stock changes. Where the purchased fuel invoices can be identified specifically for the CDM project, the metered fuel consumption quantities should also be cross-checked with available purchase invoices from the financial records.
Purpose of data	Calculation of project emissions from fossil fuel combustion in process
Additional comment	-

Data / Parameter	$NCV_{i,y}$
Data unit	GJ/kg

[43] When the maintenance is being carried out, neither baseline nor project emissions occurs since the LFG is not combusted and released to the atmosphere.

Description	Weighted average net calorific value of fuel type i in year y (i = LPG)
Source of data	c) Regional or national default values
Value(s) applied	0.0465
Measurement methods and procedures	-
Monitoring frequency	Review appropriateness of values annually
QA/QC procedures	Verify if the value is within the uncertainty range of the IPCC default values as provided in Table 1.2, Vol. 2 of the 2006 IPCC Guidelines. If the values fall below this range collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The laboratories in a), b) or c) should have SO17025 accreditation or justify that they can comply with similar quality standards.
Purpose of data	Calculation of project emissions from fossil fuel consumption for the flare ignition.
Additional comment	Option c) is used since a liquid fuel is considered and is based on well documented reliable sources (i.e. Brazilian Energy Balance). Information used with the purpose of calculating expected emission reductions is in accordance with the values provided in 2006 IPCC Guidelines.

Data / Parameter	$EF_{CO2,I,y}$
Data unit	tCO_2/GJ
Description	Weighted average CO2 emission factor of fuel type i in year y (i = LPG)
Source of data	d) IPCC default values at the upper limit of the uncertainty at 95% confidence interval as provided in Table 1.2 of Chapter 1 of Vol.2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories
Value(s) applied	0.0656
Measurement methods and procedures	Not applicable since IPCC default value is used.
Monitoring frequency	Any future revisions of the IPCC Guidelines should be taken into account.
QA/QC procedures	Not applicable since IPCC default value is used.
Purpose of data	Calculation of project emissions from fossil fuel consumption for the flare ignition
Additional comment	-

B.7.2. Sampling plan

>> Not applicable.

B.7.3. Other elements of monitoring plan

>> The monitoring plan is done according to the methodology ACM0001, the applicable tools, as well as per the the CDM Project Standard for Project Activities. Details are available in section B.7.1 above.

All continuously measured parameters (LFG flow, CH_4 concentration, flare temperature, flare operating hours, engine operating hours, and engine electrical output) are recorded electronically via a datalogger, located within the site boundary which have the capability to aggregate and print the collected data at the frequencies as specified above. It is the responsibility of the Site Operator to provide all requested data logs which is stored over the duration of the reporting period at the Site office. The data logs are summarized into emission reduction calculation summaries prior to

each verification. This task is completed by CRA and reported directly to the DOE. These logs are available as required by the DOE in order to prove the operational integrity of the Project.

Since May 26, 2019 a biogas generated was installed at Manaus Landfill, using a small amount of biogas that could go straight to the flare to generate energy.

Because the monitoring of this gas is not being carried out, the conservative procedure was elaborated as follows since May 26, 2019:

- The electricity generation from biogas will be considered 0 (zero) therefore certified

emission reductions will not be requested for this activity.

1. Introduction and Objectives

The two primary purposes of the monitoring plan are:

- To collect the necessary system data required for the determination the emissions reductions; and
- To demonstrate successful compliance with established operating and performance criteria to verify the emission reductions and generate the respective CERs.

The operational data that is collected and used to support the periodic verification report, required CER auditing. The monitoring plan discussed herein is designed to meet or exceed the UNFCCC requirements (approved monitoring methodology ACM0001 ver. 18).

The routine system monitoring program required for the determination of the emission reductions is discussed in section 2 below, while the additional system data that is collected to ensure the safe, correct and efficient operation of the LFG management system is discussed in section 3.

2. Training of monitoring personnel

Before commencement of the O&M phase, Conestoga-Rovers & Associates Capital Limited (CRA) conducted trainings and quality control programs to ensure that good management practices are carried out and implemented by all project operating personnel in terms of record-keeping, equipment calibration, overall maintenance, and procedures for corrective action. Operation manuals are developed for the operating personnel. The procedures for filing data and calculations to be performed by the LFG utilization operator is included in a daily log to be placed in the main control room.

3. Monitoring Work Program

The LFG monitoring program is a relatively simple, straight forward program designed to collect system operating data required to safely operate the system and for the verification of CERs. This data is collected in real time and provides continuous record that is easy to monitor, review, and validate. The following sections outline and discuss the following key elements of the monitoring program:

- Flow measurement;
- Gas quality measurements;
- Uncombusted methane;
- Electrical Consumption;
- Project electricity output;
- Regulatory requirements;
- Data records; and
- Data assessment and reporting.

3.1. Flow Measurement

Following ACM0001, one flow meter was installed during Phase 1 (flaring) on the piping, straight before the flares.

The flow of LFG collected by the system and subsequently utilized or flared are measured via individual flow measuring devices suitable for measuring the velocity and volumetric flow of a gas. One common example is an annubar. The flow measurements are taken within the piping itself, and the flow sensors are connected to transmitters that are capable of collecting and sending continuous data to a recording device such as a datalogger.

The flow sensors are calibrated according to a specified temperature and composition of the gas, thus the flow actually measured must be corrected to according to actual temperature, pressure, and composition, thus density, of the gas measured. The equipment selected allows dynamic compensation for these parameters, normalized to a standard temperature, pressure, and gas composition. For reporting purposes, the flows are generally required to be normalized to 0°C and 1.01325 bar at standard gas composition of 50% methane and carbon dioxide each by volume.

The accuracy of a flow meter is dependent on the design of the equipment, and the specific type of sensor used, however equipment is available that will provide a minimum accuracy of +/- 2% by volume. The equipment selected for the site utilizes a continuous monitoring system as defined in ACM0001, which measures once every minute and aggregates flow data approximately once every hour.

3.2. Gas Quality

The two parameters that are most pertinent to the validation of CERs, as well as the safe and efficient operation of the system are the concentration of methane and oxygen in the gas stream delivered for utilization or diverted to flaring. These two parameters are measured via a common sample line that is run to the main collection system piping, and measured in real time by two separate sensors, one each for methane and oxygen, installed as per ACM0001.

Regular calibration of the equipment is especially important, as the accuracy of the methane and oxygen sensors is greatest within the expected range of the gas stream to be measured. Equipment is readily available that will provide an accuracy of at least +/- 1% by volume. The equipment selected for the site aggregates gas compositions approximately once every 1 minute as per the definition of a continuous monitoring system in ACM0001.

3.3. Uncombusted Methane

The efficiency of the enclosed flares is measured in each minute per the methodological tool "*Project emissions from flaring*".

3.4. Electrical Consumption

Electricity consumption will be continuously monitored by electricity meters. Monthly electrical bills charged to the project are monitored and considered as the actual energy consumption for the project.

3.5. Project Electricity Output

The generated electricity supplied to the grid by the project activity is continuously measured by an electricity meter and respective data is electronically recorded.

3.6. LPG purchased

The mass of LPG purchased by the project developer will be continuously monitored through the invoices issued by the LPG supplier.

3.7. Diesel purchased

Quantities of diesel used for the standby generator will be continuously monitored and will be recorded via receipts and additional information is delivered from the fuel company. In case of lack of information, IPCC guidelines will be used.

3.8. Regulatory Requirements

Regulatory requirements relating to LFG projects are annually evaluated by investigating municipal, state and national regulations pertaining to LFG. This is done through consultation with the appropriate regulatory bodies, ongoing discussion with regulators, and monitoring of publications delineating upcoming legislative changes governing landfills and LFG.

4. Data records and storage

Data collected from each of the parameter sensors is transmitted directly to an electronic database from which the CER volume calculations may be carried out. A hard copy backup or reports of the data may be printed as required or recorded in Portable Document Format (PDF).

Backup of the electronic data is conducted on a 2-3 minute intervals, as described above.

4.1. Data Assessment and Reporting

Assessment of the flow and composition data described above coupled with the operating hours of the engines/flare and engines/flare destruction efficiencies are used to determine the quantity of CERs to be generated. For electricity generation offsets, the appropriate emission factors will be applied.

The destruction efficiency of the flare is a function of the internal combustion temperature and resident holding time, which are generally measured by the flare system controller and recorded for auditing purposes. Extensive technical documentation is available that documents the destructive efficiency of the enclosed drum flares that will be used, subject to the flow rate and combustion temperature verification. Destruction efficiency will also be assessed periodically through measurement of uncombusted methane emissions.

As discussed in Section 2.1, flow data is normalized to standard temperature, pressure, and composition for reporting purposes. The data will be compiled and assessed to produce the required quantification and validation. The periodic monitoring report will contain the data required for the verification of the CERs, and additionally may contain operational data from the collection system and flaring system described below to illustrate that the system is well maintained and operating at peak efficiency. Records of regular maintenance performed will also be a component of the annual report.

5. Related monitoring and project performance review

CRA will conduct an additional operational monitoring of the LFG collection system to check the project performance and ensure that the system is being operated both correctly and efficiently. Periodic adjustments to the extraction wells will be required to optimize the collection system effectiveness. LFG collection field adjustments will be made based upon a review of the well performance history considered within the context of the overall LFG collection field operation in order to maximize the collection of methane balanced against minimization of any oxygen in the system that could introduce unsafe operating conditions. Monitoring at each extraction well/trench will consist of the following parameters: valve position, individual well/trench flow, individual well/trench vacuum, and composition of the gas collected, i.e., methane, carbon dioxide, and oxygen, using a portable measuring device.

6. Emergency procedures

As a precautionary measure, the Landtec® system is plugged to a battery-based uninterruptible power supply (UPS) to avoid data loss due to power failures. As a backup is produced and stored off-site from the main recording system, no more than 2 to 3 minutes of data at a time would ever be lost due to a system malfunction.

All data will be collected through a Landtec® Field Analytical Unit (FAU) and will be transmitted to a Landtec® Field Server Unit (FSU), which records the data on-site and automatically sends it via a "always-on" Internet connection to an off-site server for storage and off-site back-up. All collected data is available for viewing, report generation, and retrieval through a Web interface, the EnviroComp™ Reporting System (ECRS), which can be accessed from anywhere an Internet connection is available. The plant Manager will check daily the records. In addition, it was developed an Emergency Plan including others types of emergencies such as fire and work accidents.

7. Calibration

All the measurement instruments will be subject to regular calibration as per manufacturer's specifications. The regular check and calibration will be made to the operators. The plant Manager will be responsible for checking the equipment's proper working order, as well as checking and storing up the calibration certificates and records. Calibration certificates will be kept for all the equipments until two years after the end of the crediting period.

SECTION C. Start date, crediting period type and duration

C.1. Start date of project activity

>>08/07/2011

C.2. Expected operational lifetime of project activity

>>25y-0m

C.3. Crediting period of project activity

C.3.1. Type of crediting period

>> Renewable

C.3.2. Start date of crediting period

>>08/07/2018

C.3.3. Duration of crediting period

>>07y-0m

SECTION D. Environmental impacts

D.1. Analysis of environmental impacts

>> Not applicable.

D.2. Environmental impact assessment

>> Not applicable.

SECTION E. Local stakeholder consultation

E.1. Modalities for local stakeholder consultation

>> Not applicable.

E.2. Summary of comments received

>> Not applicable.

E.3. Consideration of comments received

>> Not applicable.

SECTION F. Approval and authorization

Federative Republic of Brazil
Interministerial Commission in Global Climate Change

Letter of Authorization

TO: TUMPEX – EMPRESA AMAZONENSE DE COLETA DE LIXO LTDA. (PROJECT PARTICIPANT)
CONESTOGA-ROVERS&ASSOCIATES CAPITAL LIMITED (PROJECT PARTICIPANT)
ENTERPA ENGENHARIA LTDA (PROJECT PARTICIPANT)
CONESTOGA-ROVERS E ASSOCIADOS ENGENHARIA LTDA.(PROJECT PARTICIPANT)

Date: April 2nd, 2013

1. As President of the Interministerial Commission on Global Climate Change, the Designated National Authority for the Clean Development Mechanism under the Kyoto Protocol, I hereby confirm that:

(i) The Federative Republic of Brazil ratified the United Nations Framework Convention on Climate Change on February 28th, 1994 and the Kyoto Protocol on August 23rd, 2002;

(ii) The Federative Republic of Brazil participates voluntarily in the CDM;

(iii) That **Conestoga-Rovers e Associados Engenharia Ltda**. is authorized by this Commission to participate on the project activity registered by the CDM Executive Board as 4211 "Manaus Landfill Gas Project".

2. By providing this authorization, the Commission does not wish to interfere in any decision regarding the certified emission reduction units to be generated by this project.

Yours sincerely,

MARCO ANTONIO RAUPP
Minister of Science, Technology and Innovation of the Federative Republic of Brazil
President of the Interministerial Commission on Global Climate Change

Nordic Environment Finance Corporation
Fabianinkatu 34, P.O.Box 241
FI-00171 Helsinki
Finland

Oslo, 27.06.2014

Your ref.:	Our ref. :	Contact person:
Heli Sinkko	2013/3678	André Aasrud

Written approval of voluntary participation

Nordic Environment Finance Corporation has informed us that they are a project participant in the following Clean Development Mechanism (CDM) project:

- Manaus Landfill Gas (CDM ref#4211)

The Norwegian Environment Agency, being the Norwegian Designated National Authority (DNA) under the CDM, hereby declares that:

(i) Norway ratified the Kyoto Protocol on 30th May 2002;
(ii) Norway participates voluntarily in the Clean Development Mechanism;

This written approval constitutes authorisation, according to the CDM modalities and procedures, of the Nordic Environment Finance Corporations participation in the above mentioned CDM programme of activities.

In providing this written approval, Norway's DNA has not considered those matters that fall within the competence of:

1. The Host Party for the CDM project;
2. the Designated Operational Entity contracted by the CDM project;
3. the CDM Executive Board.

Signed on behalf of Norway's Designated National Authority for the CDM,

Best regards,
Norwegian Environment Agency

Audun Rosland
Director of the Climate Department

Trine Berntzen
Acting Head of Section for Emission Trading

Postal address : PO Box 5672, Sluppen, N-7485 Trondheim | **Tel**: +47 73 58 05 00 | **Fax**: +47 73 58 05 01
E-mail: post@miljodir.no | **Internet**: www.environmentagency.no | **VAT.No.**: 999 601 391
Visiting address Oslo: Strømsveien 96, N-0663 Oslo | **Visiting address Trondheim**: Brattørkaia 15, N-7010 Trondheim

Appendix 1. Contact information of project participants

Organization name	Conestoga Rovers e Associados Engenharia Ltda.
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Contact person	Flavia Pileggi

Organization name	Nordic Environment Finance Corporation
Country	Finland
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Telephone	+358 10 6180664
Fax	+358 10 6180651
E-mail	helle.lindegaard@nefco.fi
Website	www.nefco.org
Contact person	Helle Lindegaard

Appendix 2. Affirmation regarding public funding

This project is not a diversion of ODA from an Annex 1 country.

No public funding was and will be used in the present project.

Appendix 3. Applicability of methodologies and standardized baselines

This section is intentionally left blank. For details please refer to sections B.4, B.6.1 and B.6.3. above.

Appendix 4. Further background information on ex ante calculation of emission reductions

The "*Tool to calculate the emission factor for an electricity system*" indicates that the emission factor of the grid is determined by the following six steps:

1. Identify the relevant electricity systems;

2. Choose whether to include off-grid power plants in the project electricity system;

3. Select a method to determine the operating margin (OM);

4. Calculate the operating margin emission factor according to the selected method;

5. Calculate the build margin (BM) emission factor;

6. Calculate the combined margin (CM) emission factor.

Step 1: Identify the relevant electricity systems

While determining the electricity emission factors, the project electricity system shall be defined. According to the "*Tool to calculate the emission factor for an electricity system*", if the DNA of the host country has published a delineation of the project electricity system and connected electricity systems, these delineations should be used (Option 1).

The Brazilian DNA published a Resolution #08, issued on 26th May, 2008[44], defines the Brazilian Interconnected Grid as a single system that covers all the five macro-geographical regions of the country (North, Northeast, South, Southeast and Midwest). Hence this figure will be used to calculate the baseline emission factor of the grid.

[44] Available at: <http://www.mctic.gov.br/mctic/export/sites/institucional/arquivos/publicacao/clima/Resolucao_n_8_de_26_de_maio_de_2008.pdf>. Accessed on 20/08/2017.

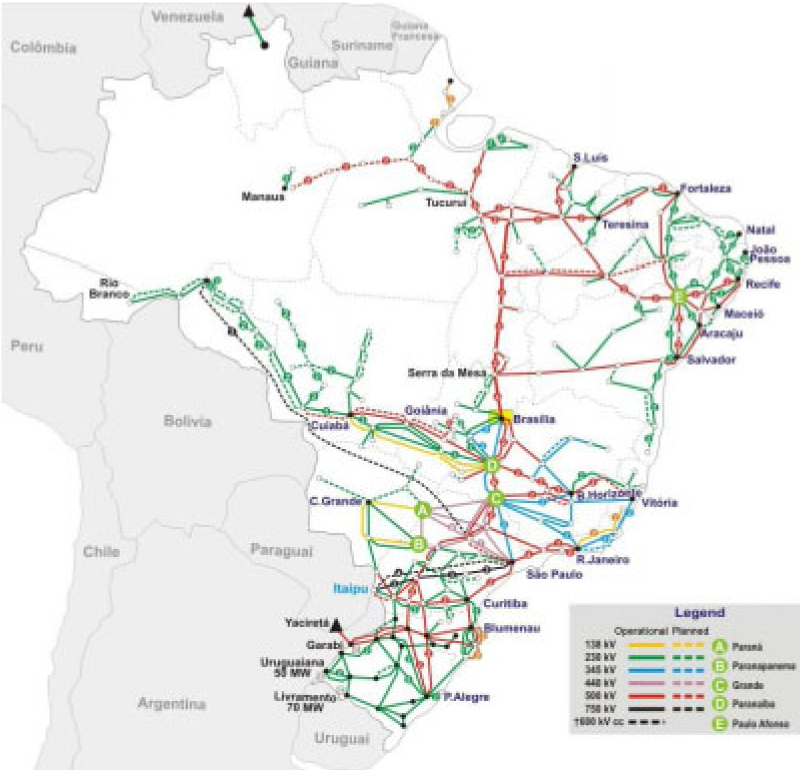

Figure 8 – Brazilian Interconnected System.

Source: Electric System National Operator.

Step 2. Choose whether to include off-grid power plants in the project electricity system (optional)

Project participants may choose between the following two options to calculate the operating margin and build margin emission factor:

Option I: Only grid power plants are included in the calculation;

Option II: Both grid power plants and off-grid power plants are included in the calculation.

The Brazilian DNA is responsible for calculating the emission factors and it did not include off-grid power plants in the calculation, therefore Option I is used.

Step 3: Select a method to determine the operating margin (OM)

Calculate the Operating Margin emission factor ($EF_{grid,OM,y}$) based on one of the following our methods:

(a) Simple OM;

(b) Simple adjusted OM;

(c) Dispatch Data Analysis OM;

(d) Average OM.

The $EF_{grid,OM,y}$ is given by the Brazilian DNA and calculated under the method: *Simple adjusted OM*[45].

Further, the ex-ante data vintage is the chosen to estimate the operating margin. Hence, in accordance with the methodology, the emission factor is determined once at the validation stage, thus no monitoring and recalculation of the emissions factor during the crediting period is required. For grid power plants, use a 3-year generation-weighted average, based on the most recent data available at the time of submission of the CDM-PDD to the DOE for validation.

The PDD will be submitted to the DOE for validation in October 2017. Therefore, data from 2014, 2015 and 2016 are to be used to determine this parameter (most recent available data). In accordance with the explanation provided above in STEP 2, off-grid power plants are not considered in the grid emission factor calculation.

Step 4: Calculate the operating margin emission factor according to the selected method

According to the tool "*the simple adjusted OM emission factor ($EF_{grid,OM-adj,y}$) is a variation of the simple OM, where the power plants / units (including imports) are separated in low-cost/must-run power sources (k) and other power sources (m)*".

The simple adjusted OM was calculated based on the net electricity generation and a CO_2 emission factor for each power unit – i.e. similarly to Option A of the simple OM method – as follows:

$$EF_{grid,OM-adj,y} = (1-\lambda_y) \cdot \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}} + \lambda_y \cdot \frac{\sum_k EG_{k,y} \times EF_{EL,k,y}}{\sum_k EG_{k,y}}$$

Equation 43

Where,

$EF_{grid,OM-adj,y}$	=	Simple adjusted operating margin CO_2 emission factor in year *y* (tCO_2/MWh);
λ_y	=	Factor expressing the percentage of time when low-cost/must-run power units are on the margin in year *y*;
$EG_{m,y}$	=	Net quantity of electricity generated and delivered to the grid by power unit m in year *y* (MWh);
$EG_{k,y}$	=	Net quantity of electricity generated and delivered to the grid by power unit

[45] The OM emission factor calculation and explanation documents can be found on MCTIC website: http://www.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/textogeral/emissao_ajustado.html

		k in year y (MWh);
$EF_{EL,m,y}$	=	CO_2 emission factor of power unit m in year y (tCO_2/MWh);
$EF_{EL,k,y}$	=	CO_2 emission factor of power unit k in year y (tCO_2/MWh);
m	=	All grid power units serving the grid in year y except low-cost/must-run power units;
k	=	All low-cost/must run grid power units serving the grid in year y;
y	=	The relevant year as per the data vintage chosen in Step 3.

Determination of $EF_{EL,m,y}$

Considering that only data on electricity generation and the fuel types used in each of the power units was available, the emission factor was be determined based on the CO_2 emission factor of the fuel type used and the efficiency of the power unit, as per **Option A2** of the simple OM method. The following formula was used:

$$EF_{EL,m,y} = \cdot \frac{EF_{CO2,m,i,y} \cdot 3.6}{\eta_{m,y}}$$ **Equation 44**

Where,

$EF_{EL,m,y}$	=	CO_2 emission factor of power unit m in year y (tCO_2/MWh);
$EF_{CO2,m,I,y}$	=	Average CO_2 emission factor of fuel type i used in power unit m in year y (tCO_2/GJ);
$\eta_{m,y}$	=	Average net energy conversion efficiency of power unit m in year y (ratio);
m	=	All grid power units serving the grid in year y except low-cost/must-run power units;
y	=	The relevant year as per the data vintage chosen in Step 3.

Determination of $EG_{m,y}$

Information used to determine this parameter was supplied by the Brazilian DNA[46].

Step 5. Calculate the build margin (BM) emission factor

The Brazilian DNA is responsible for calculating the BM emission factor in Brazil. In terms of data vintage, project participants can choose between one of the following two options:

[46] Available at: <http://www.mctic.gov.br/mctic/opencms/textogeral/emissao_ajustado.html>.

Option 1: For the first crediting period, calculate the build margin emission factor ex-ante based on the most recent information available on units already built for sample group m at the time of CDM-PDD submission to the DOE for validation. For the second crediting period, the build margin emission factor should be updated based on the most recent information available on units already built at the time of submission of the request for renewal of the crediting period to the DOE. For the third crediting period, the build margin emission factor calculated for the second crediting period should be used. This option does not require monitoring the emission factor during the crediting period.

Option 2: For the first crediting period, the build margin emission factor should be updated annually, ex- post, including those units built up to the year of registration of the project activity or, if information up to the year of registration is not yet available, including those units built up to the latest year for which information is available. For the second crediting period, the build margin factor shall be calculated ex- ante, as described in option 1 above. For the third crediting period, the build margin emission factor calculated for the second crediting period should be used.

The Option 1 was chosen for the proposed project in the first crediting period. Hence, for the second crediting period the build margin emission factor was updated based on the most recent information available by the Brazilian DNA (2016)[47]. Thus, $EF_{grid,BM,2016}$ = 0.1581 tCO_2/MWh.

Step 6: Calculate the Combined Margin emission factor

The combined margin calculation is based on method (a) provided by the tool, as follows:

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times w_{OM} + EF_{grid,BM,y} \times w_{BM}$$ **Equation 45**

Where:

$EF_{grid,BM,y}$	=	Build margin CO_2 emission factor in year *y* (in tCO_2/MWh)
$EF_{grid,OM,y}$	=	Operating margin CO_2 emission factor in year *y* (in tCO_2/MWh)
w_{OM}	=	Weighting of operating margin emissions factor (in %)
w_{BM}	=	Weighting of build margin emissions factor (in %)

According with the Tool, default weights are as follows: w_{OM} = 0.25 and w_{BM} = 0.75. As mentioned above, the *ex-ante* approach is used.

[47] Available at: <http://www.mctic.gov.br/mctic/opencms/textogeral/emissao_despacho.html>.

Appendix 5. Further background information on monitoring plan

This section is intentionally left blank. Detailed information is described in sections B.7.1 and B.7.2 above.

Appendix 6. Summary report of comments received from local stakeholders

This section is intentionally left blank. For details please refer to section E above.

Appendix 7. Summary of post-registration changes

A correction in the registered PDD was approved in August 12th, 2013 (PRC reference- 4211-001). This correction consists of the revise in the formula presented under section B.6.1 to determine the quantity of moles of O_2 required for a complete oxidation of one kg of residual gas in hour h adds the last element by toichiometric mistake.

Permanent changes to the registered monitoring plan, or permanent deviation of monitoring from the applied methodologies, standardized baselines, or other methodological regulatory documents

Due to the installation of the biogas generator in May 2019, the monitoring of gas that is no longer being flared is not being carried out, the conservative procedure will be elaborated as follows since May 26, 2019:
The electricity generation from biogas will be considered 0 (zero) therefore certified emission reductions will not be requested for this activity.

Changes to project design

In May 2019, a biogas generator was installed that was not foreseen in the project design. The generator started operating on May 26, 2019 using a small amount of biogas that could go straight to the flare to generate energy. The CHP300 biogas generator has a consumption of 74 Nm3 / h @ 170 kW, according to the manufacturer's manual.

The actual changes proposed to the registered CDM project activity do not affects the following items:

(a) The applicability and application of the applied methodology ACM0001, the applied standardized baseline and the other applied methodological regulatory documents with which the project activity has been registered;

(b) The compliance of the monitoring plan with the applied methodology, the applied standardized baseline and the other applied methodological regulatory documents;

(c) The level of accuracy and completeness in the monitoring of the project activity compared with the requirements contained in the registered monitoring plan;

(d) The additionality of the project activity; and

(e) The scale of the project activity

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Document information

Version	*Date*	*Description*
11.0	31 May 2019	Revision to: • Ensure consistency with version 02.0 of the "CDM project standard for project activities" (CDM-EB93-A04-STAN); • Make editorial improvements.
10.1	28 June 2017	Revision to make editorial improvement.
10.0	7 June 2017	Revision to: • Improve consistency with the "CDM project standard for project activities" and with the PoA-DD and CPA-DD forms; • Make editorial improvement.
09.0	24 May 2017	Revision to: • Ensure consistency with the "CDM project standard for project activities" (CDM-EB93-A04-STAN) (version 01.0); • Incorporate the "Project design document form for small-scale CDM project activities" (CDM-SSC-PDD-FORM); • Make editorial improvement.
08.0	22 July 2016	EB 90, Annex 1 Revision to include provisions related to automatically additional project activities.
07.0	15 April 2016	Revision to ensure consistency with the "Standard: Applicability of sectoral scopes" (CDM-EB88-A04-STAN) (version 01.0).
06.0	9 March 2015	Revision to: • Include provisions related to statement on erroneous inclusion of a CPA; • Include provisions related to delayed submission of a monitoring plan; • Provisions related to local stakeholder consultation; • Provisions related to the Host Party; • Make editorial improvement.

Version	*Date*	*Description*
05.0	25 June 2014	Revision to: • Include the Attachment: Instructions for filling out the project design document form for CDM project activities (these instructions supersede the "Guidelines for completing the project design document form" (Version 01.0)); • Include provisions related to standardized baselines; • Add contact information on a responsible person(s)/ entity(ies) for the application of the methodology (ies) to the project activity in B.7.4 and Appendix 1; • Change the reference number from F-CDM-PDD to CDM-PDD-FORM; • Make editorial improvement.
04.1	11 April 2012	Editorial revision to change version 02 line in history box from Annex 06 to Annex 06b.
04.0	13 March 2012	Revision required to ensure consistency with the “Guidelines for completing the project design document form for CDM project activities” (EB 66, Annex 8).
03.0	26 July 2006	EB 25, Annex 15
02.0	14 June 2004	EB 14, Annex 06b
01.0	03 August 2002	EB 05, Paragraph 12 Initial adoption.

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