Project design document form for CDM project activities

(Version 06.0)

Complete this form in accordance with the Attachment "Instructions for filling out the project design document form for CDM project activities" at the end of this form.

PROJECT DESIGN DOCUMENT (PDD)	
Title of the project activity	Dois Arcos Landfill Gas Project Activity
Version number of the PDD	04
Completion date of the PDD	05/08/2015
Project participant(s)	GNR Dois Arcos Valorização de Biogás S.A.
Host Party	Brazil
Sectoral scope and selected methodology(ies), and where applicable, selected standardized baseline(s)	13 - Waste handling and disposal ACM0001 – "Flaring or use of landfill gas" (version 15.0.0)
Estimated amount of annual average GHG emission reductions	60,283 tCO_2e

SECTION A. Description of project activity

A.1. Purpose and general description of project activity

The primary objective of the Dois Arcos Landfill Gas Project Activity is to avoid methane emissions from the Dois Arcos Landfill by capturing the landfill gas (LFG), upgrading and using it to supply natural gas (NG) off-site consumers. Any LFG excess is flared. GNR DOIS ARCOS VALORIZAÇÃO DE BIOGÁS S.A., the project activity implementer, understands that flaring shall be always the very last option of any CDM project related to LFG destruction.

The proposed CDM project activity is not a CPA that has been excluded from a registered CDM PoA as a result of erroneous inclusion of CPAs. The project activity has an installed capacity of 1,200 Nm^3/h (raw gas)[1], resulting in 60,283 tCO_2e/year emission reductions. By the end of the first crediting period, the project is expected to reduce 421,978 tCO_2e. Currently, the project is constructed and the renewable natural gas (RNG)/biomethane is delivered by trucks to the final consumer up to the NG pipeline construction, which is expected to occur in December 2015.

The LFG used in the project is from a municipal solid waste (MSW) landfill located in Sao Pedro da Aldeia, around 120 km east from Rio de Janeiro municipality, Southeastern region of Brazil. The landfill is owned and operated by Dois Arcos Gestao de Residuos (DAGR) since March 2008. The landfill has been developed in two main cells: cell 1 operated for approximately one year (from March 2008 to March 2009) and cell 2 is currently active, which is projected to operate up to 2018. A future disposal cell (cell 3) is projected to be active from 2018 to 2025.

Figure 1 – View of Dois Arcos landfill

Previously to the implementation of the proposed CDM Project Activity, no active collection of LFG took place at the project site. On the contrary, only a small portion of LFG was destructed through a passive venting system[2]. The wells used in the passive venting system were shallow and very inefficient even for just venting. Therefore, LFG flow could not be controlled to avoid free methane emissions to the atmosphere.

[1] According to Greenlane® Biogas Upgrading System, rev. 3.

[2] Case 3 of ACM0001, *i.e.* no requirement to destroy methane and a LFG capture system exists.

An environmental benefit with the implementation of the project activity is the destruction of methane that otherwise would be emitted to the atmosphere, contributing for global warming. The majority CDM landfill projects in Brazil, burns and uses the LFG to generate electricity. The proposed CDM Project Activity is one of the first projects in Brazil that upgrades the LFG to substitute NG. For this reason, it faces several barriers regarding technology and trained personnel for construction and operation. Therefore, the proposed project activity contributes to environmental, social and economic sustainability, and thus, to sustainable development.

A.2. Location of project activity

A.2.1. Host Party

Brazil.

A.2.2. Region/State/Province etc.

Rio de Janeiro State.

A.2.3. City/Town/Community etc.

São Pedro da Aldeia municipality.

A.2.4. Physical/Geographical location

Dois Arcos is located in Rio de Janeiro state, 22º49'37.07'' S and 42º3'7.62''W[3].

[3] SCS Energy Assessment Report – Dois Arcos Landfill dated August 2012.

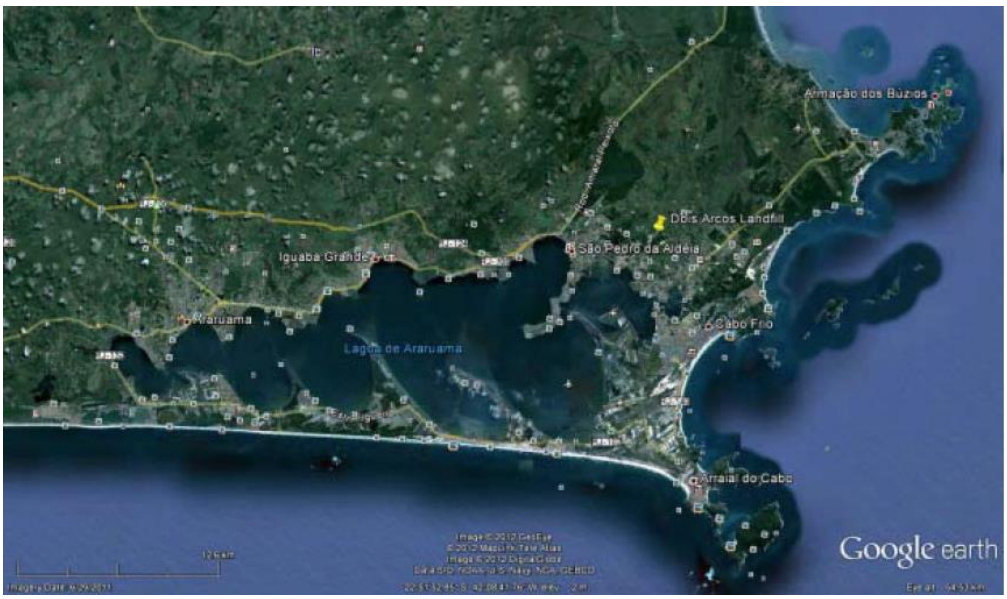

Figure 2 – Location of Dois Arcos landfill in Rio de Janeiro State

Source: Google Earth, 2014.

A.3. Technologies and/or measures

The implementation of the proposed CDM Project Activity comprises the following systems/stages:

Figure 3 – Stages of the proposed project activity

1. Collecting System

The Dois Arcos Landfill Project involves the installation of horizontal collectors and vertical wells, and the installation of wellheads on top to collect the LFG emitted directly to the atmosphere in the baseline. An example of wellhead and the detail of its construction are shown in the figure below.

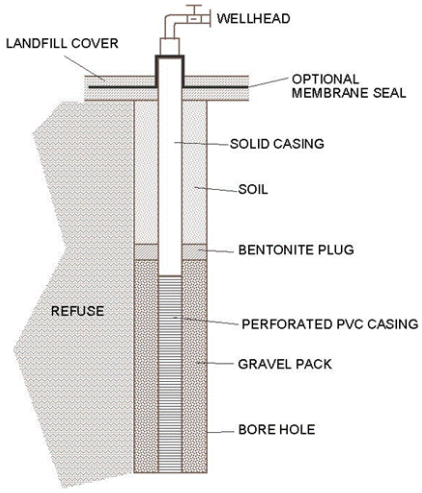

Figure 4 – Internal detail of a well and wellhead

Source: USEPA (1996)[4].

The use of the few existing wells is not recommended as they are quite shallow and not properly placed across the landfill surface. Wells shall guarantee the efficiency of the controlled drainage of the landfill as well as of the LFG collection. The quantity of wells is determined in the Executive Project, but it is subjected to adjustment depending on conditions observed during the project installation and commissioning.

Flow-control and monitoring wellheads will be employed at every gas extraction well, to allow precise regulation/adjustment of the gas flow at each well. Gas quality monitoring and flow adjustment is important to ensure that the system is "balanced" (*i.e.* gas extraction matches gas production so that atmospheric air is not introduced into the landfill).

In accordance with the SCS Report dated August 2012, a network of LFG header piping will be designed to connect the horizontal collectors and vertical extraction wells, and direct the LFG to the LFG processing plant or (if the plant is down or there is excess LFG) the blower and flaring station for methane destruction.

2. Upgrading gas facility

After collection, the LFG is compressed and goes to the upgrading gas facility, where the gas receives the proper treatment, where most of the non-methane gases will be removed from the stream. Then, as source of methane, LFG can be used to replace the consumption of Natural Gas.

The project activity is expected to have 2 (two) compressors and 3 (three) blowers installed. Up today, there are 2 compressors and 2 blowers installed at the project; the third blower is expected to be installed when cell 3 of the landfill start operations. The installed capacity of the upgrading system is of 1,200 Nm^3/h.

4 USEPA – United States Environmental Agency; *Turning a Liability into an Asset: a Landfill Gas-to-Energy Project Development Handbook*; LMOP – Landfill Methane Outreach Program, 1996.

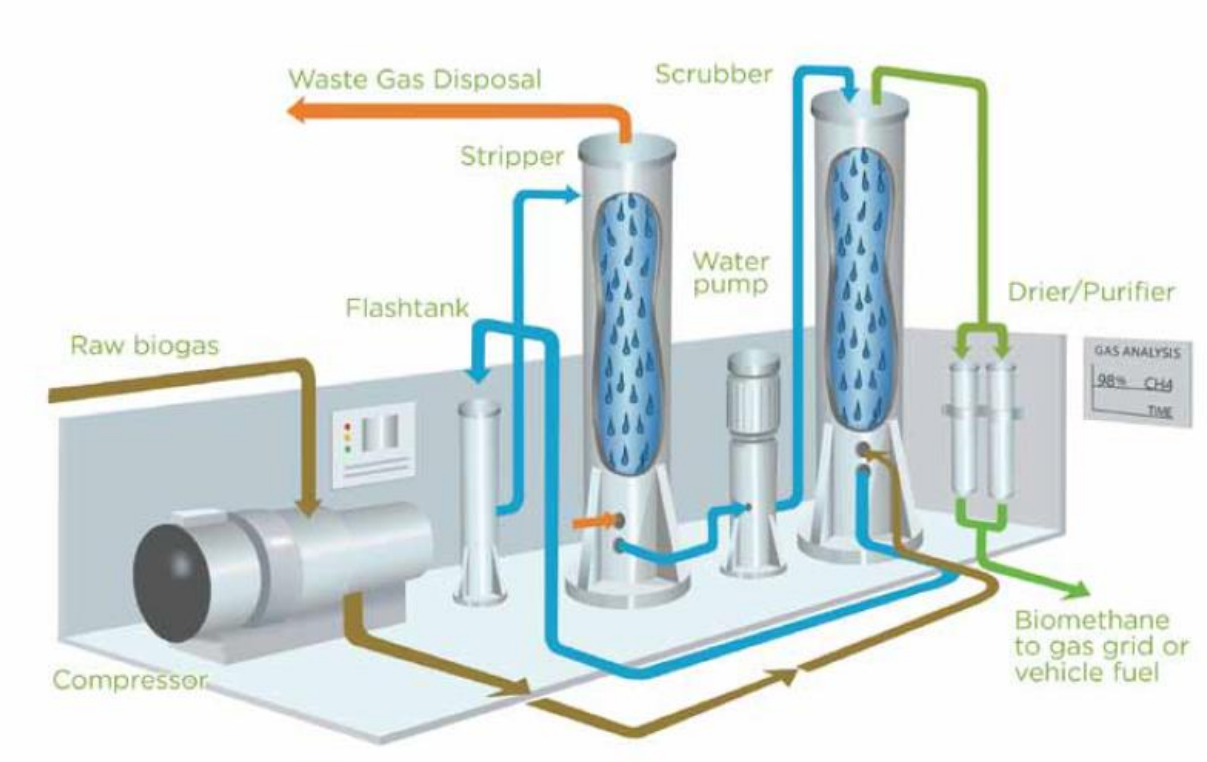

Figure 5 – Example of a purification system

Source: Greenlane data.

3. Flare System

Whenever LFG exceeds the processing capacity of the purification plant or it is not operational, the gas will be sent to the flaring system. The project activity has one open flare with a capacity of 1,400 Nm³/hour[5].

4. Transportation

The upgraded gas will be initially transported by trucks up to the construction of the NG distribution network pipeline at the project site. Since the NG pipeline is not implemented – expected to be implemented in the end of 2015 –, the upgraded gas is transported to consumers by trucks. As soon as the distribution system is implemented, transportation will be made through the NG distribution system.

5. Monitoring system

All stages mentioned above will be monitored through meters, gas analyzers and control panels. Detailed description of the monitoring system is presented in section B.7.3 of this PDD.

Despite the LFG projects have great potential in Brazil, technology is under development in the country. Therefore, the project activity has been facing barriers due to technology and trained personnel availability and high costs. Technology to be employed at the project comes from abroad, mainly from the United States and Europe. Hence, technology transfer occurs from countries with strict environmental requirements and environmentally sound technologies.

[5] John Zink Biogas Flare System manual - Sales Order: 9137837.

A.4. Parties and project participants

Party involved (host) indicates host Party	Private and/or public entity(ies) project participants (as applicable)	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
Brazil (host)	GNR Dois Arcos Valorização de Biogás S.A. (private entity)	No

A.5. Public funding of project activity

There is no public funding from Parties included in Annex I Parties involved in this CDM Project Activity.

SECTION B. Application of selected approved baseline and monitoring methodology and standardized baseline

B.1. Reference of methodology and standardized baseline

Dois Arcos Project Activity applies the ACM0001 methodology – "*Flaring or use of landfill gas*" (version 15.0.0). ACM0001 refers to the following tools:

(a) The methodological tool "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)[6];

(b) The methodological tool "Emissions from solid waste disposal sites" (version 07.0)[7];

(c) "Combined tool to identify the baseline scenario and demonstrate additionality" (version 05.0.0)[8];

(d) The methodological tool "Project emissions from flaring" (version 02.0.0)[9];

(e) "Tool to calculate baseline, project and/or leakage emissions from electricity consumption" (version 01)[10];

(f) "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion" (version 02)[11];

(g) "Tool to determine the remaining lifetime of equipment" (version 01)[12];

(h) "Tool to determine the baseline efficiency of thermal or electric energy generation systems" (version 01)[13];

(i) "Tool to determine the mass flow of a greenhouse gas in a gaseous stream" (version 02.0.0)[14];

[6] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-11-v3.0.1.pdf

[7] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-04-v7.pdf

[8] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v5.0.0.pdf

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

[10] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-05-v1.pdf

[11] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-03-v2.pdf

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

[13] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-09-v1.pdf

(j) The methodological tool "Project and leakage emissions from transportation of freight" (version 01.1.0)[15].

Furthermore, the project activity uses the "Tool to calculate the emission factor for an electricity system" (version 4.0) in order to calculate project emissions due to electricity consumption from the grid.

Please note that "Tool to determine the baseline efficiency of thermal or electric energy generation systems" and the "Tool to determine the remaining lifetime of equipment" are not applicable to the project activity, and therefore they are not used. Similarly, the methodological tool "Assessment of the validity of the original/current baseline and update of the baseline at the renewal of the crediting period" is not used, since this PDD corresponds to the first crediting period of the proposed CDM Project Activity.

B.2. Applicability of methodology and standardized baseline

The proposed project activity is according to the applicability conditions of ACM0001 as described below:

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

The proposed project activity consists on the installation of a new LFG capture system in an existing SWDS, where 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 LFG was vented only and not used.

(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; and/or

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

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

The project activity consists of using the captured gas for consumers through NG distribution network (option iii). The transportation by trucks (option iv) during 2015 is a temporary solution for the upgraded gas transportation up to the construction of the NG pipeline. The excess of LFG is flared.

[14] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-08-v2.0.0.pdf

[15] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.1.0.pdf

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

The implementation of the proposed CDM 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 increase.

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.

The baseline scenario is the partial or total atmospheric release of the gas (usual practice of the Dois Arcos Landfill Project Activity management, option (a) above). Please refer to Section B.4 for details.

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 Dois Arcos Landfill Project does not make use other CDM approved methodology. Furthermore, the management of the Dois Arcos 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.

Besides the ACM0001 methodology applicability conditions, the project activity shall assess the applicability of the following tools:

— The methodological tool "**Emissions from solid waste disposal sites**"

This tool provides procedures to calculate baseline, project or leakage emissions of methane from solid waste disposed or prevented from disposal at a SWDS. In the case of Dois Arcos, application A applies to the project:

"The CDM project activity mitigates methane emissions from a specific existing SWDS. Methane emissions are mitigated by capturing and flaring or combusting the methane. The methane is generated from waste disposed in the past, including prior to the start of the CDM project activity. In these cases, the tool is only applied for an ex- ante estimation of emissions in the CDM-PDD. The emissions will then be monitored during the crediting period (e.g. measuring the amount of methane captured from the SWDS)".

— The "**Combined tool to identify the baseline scenario and demonstrate additionality**" is used in order to assess the project additionality.

This tool is only applicable to methodologies for which the potential alternative scenarios available to the project developer cannot be implemented in parallel to the proposed project activity. As described in section B.4, the alternative scenarios to the project developer cannot be implemented in parallel to the proposed project activity. Therefore, this tool is applicable to Dois Arcos in order to assess the project additionality.

— The methodological tool "**Project emissions from flaring**"

This tool provides procedures to calculate project emissions from flaring of a residual gas in open or enclosed flares. This tool is applicable to the flaring of flammable greenhouse gases where:

- Methane is the component with the highest concentration in the flammable residual gas; and
- The source of the residual gas is coal mine methane or a gas from a biogenic source (*e.g.* biogas, landfill gas or wastewater treatment gas).

The flammable residual gas is LFG (gas from biogenic source), which is composed by CH_4, H_2S, CO_2 and N_2, among other components. By default, the methodology adopts that the default fraction of methane in the LFG which is 50%. Therefore, it can be assumed that methane is the component with the highest concentration in the LFG. In this sense, both applicability conditions of the tool are met.

— "**Tool to calculate baseline, project and/or leakage emissions from electricity consumption**"

This tool provides procedures to estimate the baseline, project and/or leakage emissions associated with the consumption of electricity. The tool is only applicable if one of the scenarios applies to sources of electricity consumption:

Scenario A: Electricity consumption from the grid;

Scenario B: Electricity consumption from (an) off-grid fossil fuel fired captive power plant(s);

Scenario C: Electricity consumption from the grid and (a) fossil fuel fired captive power plant(s).

In the case of the proposed project activity, scenario A is applicable. However, in the future, scenarios B and/or C can also be applied considering intermittences of electricity supply identified during the project commissioning. Therefore, this tool is applicable to Dois Arcos project.

— "**Tool to calculate baseline, project and/or leakage emissions from fossil fuel consumption**"

This tool shall be used in cases where CO_2 emissions from fossil fuel combustion are calculated based on the quantity of fuel combusted and its properties. In the case of Dois Arcos, this tool is applicable since is expected the use of gas liquefied petroleum (GLP) for ignition of the flare and diesel oil for the transportation of upgraded gas by trucks in the first years of the project operation.

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

This tool is applicable for the determination of the mass flow of greenhouse gas *i* (CO_2, CH_4, N_2O, SF_6 or a PFC) in the gaseous stream in time interval *t*. Typical application of this tool is methodologies which flow and composition of residual, flared gases or exhaust gases are

measured for the determination of baseline or project emissions. Therefore, this tool is applicable to Dois Arcos project.

— Methodological tool "**Project and leakage emissions from transportation of freight**"

This tool is applicable to project activities which involve freight transportation by road, which transportation is not the main activity. Note that this tool is not applicable if transportation is the main source of greenhouse gases emissions, except for the case of emissions from freight transportation by rail.

In the case of Dois Arcos, trucks are used to transport the upgraded gas from the project site to off-site consumers in the first year of the project operation up to the implementation of NG pipeline. Since transportation is not the main activity or main source of GHG emissions, this tool is applicable and may be used to the proposed project activity.

Furthermore, the "**Tool to calculate the emission factor for an electricity system**" is used as referred in the "**Tool to calculate baseline, project and/or leakage emissions from electricity consumption**".

This tool provides procedures for the calculation of the CO_2 emission factor of the grid. The tool is not applicable if the project electricity system is located partially or totally in an Annex I country. The National Interconnected Electricity System ("SIN" from the Portuguese Sistema Interligado Nacional) is not located in an Annex I country and, therefore, this tool is applicable to Dois Arcos project.

B.3. Project boundary

Source		GHGs	Included?	Justification/Explanation
Baseline scenario	Emissions from decomposition of waste at the SWDS site	CH_4	Yes	The major source of emissions in the baseline
		N_2O	No	N_2O emissions are small compared to CH_4 emissions from SWDS. This is conservative
		CO_2	No	CO_2 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	No	Excluded. Power generation is not 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	Excluded. Heat generation is not 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 the use of natural gas	CO_2	No	Excluded for simplification. This is conservative
		CH_4	Yes	Major emission source if supply of LFG through a natural gas distribution network or using trucks is included in the project activity
		N_2O	No	Excluded for simplification. This is conservative
Project scenario	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	CO_2	Yes	May be an important emission source

	electricity consumption due to the project activity	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	CO_2	Yes	May be an important emission source
		CH_4	Yes	May be an important emission source
		N_2O	No	Emissions are considered negligible

According to the ACM0001 methodology the project boundary includes *the* site where the LFG is captured (Dois Arcos 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, sites where the LFG is flared/used consists of the collection system, biogas upgrading facility, pipeline (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 activity;*

In the case of the proposed CDM Project Activity, the boundary includes all power generation sources connected to the Brazilian National Grid, since electricity will also be consumed from the grid. On May 26th, 2008, the Brazilian Designated Authority published Resolution #8[16] 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.

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

Not applicable since electricity generation to the grid is not included in the project activity.

- *Heat generation equipment or sources which are supplying heat in the baseline that is displaced by heat generated by captured LFG in the project activity; and*

Not applicable since heat is not included in the project activity.

- *The transportation of the compressed/liquefied LFG from the biogas processing facility to consumers;*

The proposed CDM Project Activity generates upgraded gas to consumers by trucks up to December 2015, when the GN distribution system is implemented. Since the project is expected to be registered under CDM in January 2016, the scenario with the gas transportation by trucks is not expected to occur during the project crediting period.

The figure below is a representation of the project boundary.

[16] Comissão Interministerial de Mudança Global do Clima (CIMGC). Available at: <http://www.mct.gov.br/upd_blob/0024/24719.pdf>.

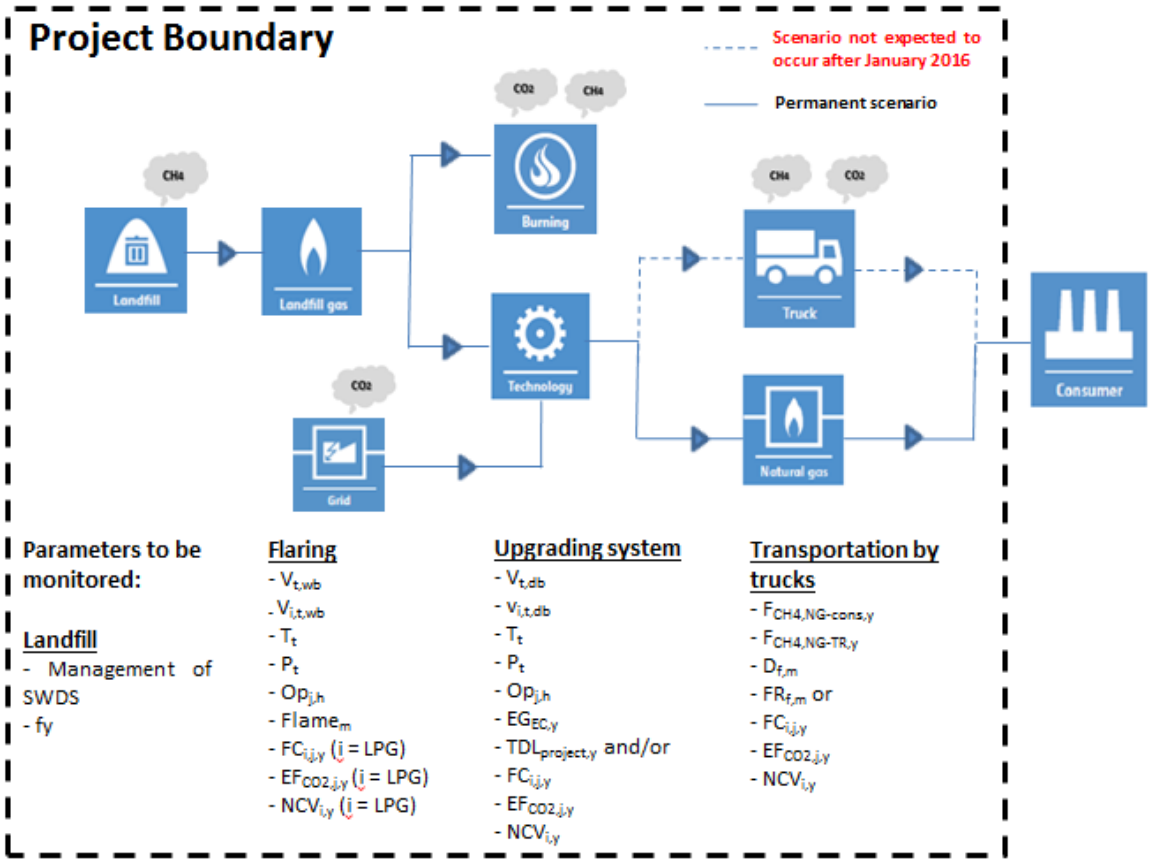

Figure 6 – Simplified diagram of the Project Boundary[17]

B.4. Establishment and description of baseline scenario

According with ACM0001 the procedures of the latest version of the "Combined tool to identify the baseline scenario and demonstrate additionality" is to be applied when selecting the most plausible baseline scenario.

STEP 0: Demonstration that the proposed project activity is the First-of-its-kind

Not applicable to the proposed CDM Project Activity.

STEP 1: Identification of alternative scenarios.

The realistic and credible alternatives scenarios to the proposed CDM Project Activity were identified following the recommendations of the "Combined Tool for the demonstration and assessment of additionality" and ACM0001 methodology.

Step 1a: Define alternative scenarios to the proposed CDM project activity

According with this Sub-step, it's necessary to identify realistic and credible alternatives available to the project participants, which cannot be implemented in parallel to the proposed project activity and that provide outputs or services comparable with the proposed CDM project activity. Considering that the project consists of capture the LFG and supplying it to consumers, the

[17] 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

following alternatives are identified for the destruction of the LFG in the absence of the project activity:

- *LFG1*: Project Activity undertaken without being registered as a CDM Project Activity (capture, flare and/or use of LFG),
- *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. Continuation of the fossil NG supply to the distribution network[18];
- *LFG3*: LFG generation is partially avoided because part of the organic fraction of the solid waste is recycled and not disposed in the SWDS;
- *LFG4*: LFG generation is partially avoided because part of the organic fraction of the solid waste is treated aerobically and not disposed in the SWDS;
- *LFG5*: LFG generation is partially avoided because part of the organic fraction of the solid waste is incinerated and not disposed in the SWDS.

Once the proposed CDM Project Activity does not foresee either the production of heat or electricity, no scenarios for those components are applicable.

Step 1b: Consistency with mandatory laws and regulations

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 adequate environmental final destination of the solid waste. However, the Policy does not foreseen 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[19].

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 Dois Arcos 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	Yes	---

[18] In the case of supply of LFG to a natural gas distribution network and distribution of compressed/liquefied using trucks, the baseline is assumed to be the supply with natural gas, as indicated in the methodology.

19 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 10/04/2010.

undertaken without being registered as a CDM Project Activity		
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. Continuation of the fossil NG supply to the distribution network;	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
LFG3: LFG generation is partially avoided because part of the organic fraction of the solid waste is recycled and not disposed in the SWDS	Yes	▪ There is no law which restricts the use of the organic fraction of the waste to be recycled and not disposed in the SWDS
LFG4: LFG generation is partially avoided because part of the organic fraction of the solid waste is treated aerobically and not disposed in the SWDS;	Yes	▪ There is no law which restricts the use of the organic fraction of the waste to be treated aerobically and not disposed in the SWDS
LFG5: LFG generation is partially avoided because part of the organic fraction of the solid waste is incinerated and not disposed in the SWDS.	Yes	▪ There is no law which restricts the incineration of organic wastes in Brazil

Outcome of Sub-Step 1b: all alternatives comply with local laws/regulations and none of them are mandatory.

STEP 2: Barrier analysis

Step 2a. Identify barriers that would prevent the implementation of alternative scenarios

The proposed use of LFG from the Dois Arcos Landfill Project is a pioneer initiative in Brazil. The majority of projects of LFG capture in the country have been undertaken considering only the CDM revenues and none of them has been developed so far considering the LFG upgrading for off-site consumption.

- *Barriers due to prevailing practice:*

According to the latest official statistics on urban solid waste in Brazil ("PNSB 2008" from the Portuguese Pesquisa Nacional de Saneamento Básico 2008) – the most recent information available from the Brazilian Institute of Geography and Statistics (IBGE) –, the country produces 259,547 tons of waste per day. Table 1 shows the final destination of the waste per municipality, according to PNSB 2008.

Table 1 - Daily amount of urban solid waste collected/received, by final destination unit in 2008

Districts according to size (population)	Daily amount of urban solid waste collected/received in t/day								
	Total	Units of collected waste final destination							
		Open Dump	Open dumps in Flooded Areas	Controlled Landfill	Sanitary Landfill	Composting	Recycling	Incineration	Other
Brazil	*259,547*	*45,710 (17.6%)*	*46 (0.02%)*	*40,695 (15.7%)*	*167,636 (64.6%)*	*1,635 (0.63%)*	*3,122 (1.2%)*	*67 (0.03%)*	*636 (0.25%)*

Source: IBGE, Diretoria de Pesquisas, Departamento de População e Indicadores Sociais, Pesquisa Nacional de Saneamento Básico 2008.

Note: This table was adapted from the original table from PNSB2008

Only few of the existing Brazilian landfills have installed a collecting and flaring LFG system. The majority of landfills operate with natural emission of LFG to the atmosphere, usually through concrete built wells. According to the "Brazilian Atlas of Greenhouse Gas Emissions and Energetic Potential in the Residues Destination"[20] published by ABRELPE in 2013, there are 22 (twenty-two) LFG projects whose encompass electricity generation and only 1 (one) predicts the upgrading of biogas to NG distribution system. To the project developers' knowledge, the identified project similar to Dois Arcos is Gramacho landfill, which is also a CDM project activity (ref. 9087)[21]. All the 23 projects identified in the ABRELPE study are CDM projects. Detailed information regarding operational landfills in the country with a forced LFG collection system is presented below in the Common Practice analysis section.

The existing landfills operate with passive emission of methane to the atmosphere, as controlled landfill gas collection and destruction is neither mandated by laws/regulations nor by local environmental regulations and GHG emission reduction policies. The most relevant law of the sector is Brazil's new National Solid Waste Policy (http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm), ratified by the President on 02/08/2010 after 19 years under discussion, which does not requires the LFG to be captured and/or flared.

Step 2 b. Eliminate alternative scenarios which are prevented by the identified barriers

Alternative	Barriers due to prevailing practice

[20] ABRELPE (2013). Atlas Brasileiro de Emissões de GEE e Potencial Energético na Destinação de Resíduos Sólidos. Report supported by US Environmental Protection Agency (EPA) and the Global Methane Initiative. Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais – ABRELPE. ABRELPE is an association founded in 1976 and is the representative International Solid Waste Association (ISWA) in Brazil.

[21] Gramacho Landfill Gas Project <https://cdm.unfccc.int/Projects/DB/DNV-CUK1356155404.95/view>.

LFG1: Project Activity undertaken without being registered as a CDM Project Activity	This alternative is not realistic as no LFG project in Brazil was implemented without the CDM revenues.
LFG2: Continuation of the landfill operation and LFG atmospheric release of the landfill gas 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. Continuation of the fossil NG supply to the distribution network;	This barrier does not prevent the implementation of this alternative, as it is the business as usual scenario (please refer to Sub-Step 2 a).
LFG3: LFG generation is partially avoided because part of the organic fraction of the solid waste is recycled and not disposed in the SWDS	Considering the actual situation of waste disposal in Brazil this barrier prevents the implementation of this alternative; only 1.2% of the waste generated in Brazil is recycled. Thus, this alternative would face a prevailing practice barrier.
LFG4: LFG generation is partially avoided because part of the organic fraction of the solid waste is treated aerobically and not disposed in the SWDS	Considering the actual situation of waste disposal in Brazil this barrier prevents the implementation of this alternative; only 0.62% of the waste generated in Brazil is sent to composting. Thus, this alternative would face a prevailing practice barrier.
LFG5: LFG generation is partially avoided because part of the organic fraction of the solid waste is incinerated and not disposed in the SWDS.	Considering the actual situation of waste disposal in Brazil this barrier prevents the implementation of this alternative; only 0.02% of the waste generated in Brazil is incinerated. Thus, this alternative would face a prevailing practice barrier.

As presented in the table above, the prevailing practice barrier would prevent the implementation of all alternatives, except for the release of the methane generated to the atmosphere, BAU scenario. Therefore LFG2 is considered as the baseline scenario.

CDM incentives will help alleviate the barriers identified for the proposed project above and also the investment barrier (Please refer to Step 3 below).

STEP 3: Investment analysis

On 17/12/2012, the capital contribution for the implementation of Dois Arcos project activity was approved. This event was decisive for the project developer's decision to implement the project. Therefore, this date demonstrates the timing of the investment decision and is considered as the project "starting date", since it is the first real action that demonstrates that the project would be implemented. Detailed description of the project timeline is presented in section C.1.1.

Therefore, the investment analysis was conducted based on data valid and applicable at the time of the investment decision; the financial indicator identified for the project activity is the Project's Internal Rate of Return (IRR). The IRR of the project without CDM revenues was compared to the appropriate benchmark of the sector, which is the Weighted Average Cost of Capital (WACC).

Weighted Average Cost of Capital (WACC)

The weighted-average cost of capital (WACC) is a rate used to discount business cash flows and takes into consideration the cost of debt and the cost of equity of a typical investor in the sector of the project activity. The benchmark can be applied to the cash flow of the project as a discount rate when calculating the net present value (NPV) of the same, or simply by comparing its value to the internal rate of return (IRR) of the project (in accordance with the "Guidelines on the Assessment of Investment Analysis", version 5, as referred in the Additionality Tool, paragraph 12). The WACC considers that shareholders expect compensation towards the projected risk of investing resources in a specific sector or industry in a particular country.

The WACC calculation is based on parameters that are standard in the market, considers the specific characteristics of the project type, and is not linked to the subjective profitability expectation or risk profile of this particular project developer. This is due the fact that any corporate entity would be able to obtain the public concession to implement that project. Therefore, the use of a sectoral benchmark is applicable as per the guidance provided in the "Guidelines on the Assessment of Investment Analysis" as referred in the Additionality Tool, paragraph 13.

The WACC of the sector considered is of 2012 – *i.e.* the date of the investment decision – and is equal to 10.28%. This value was calculated through the formula below:

$$WACC = Wd \times Kd + We \times Ke$$

We and **Wd** are, respectively, the weights of equity and debt typically observed at the sector. In accordance with the "Guidelines on the assessment of investment analysis" (paragraph 18), 50% debt (**Wd**) and 50% (**We**) equity are assumed as a default value.

Kd is the cost of debt. Unlike markets where most commercial players and companies approach private lenders for loans, most Brazilian companies investing in the infrastructure sector expect to get funds from the Brazilian Development Bank ("BNDES" from the Portuguese Banco Nacional de Desenvolvimento Econômico e Social). BNDES, a governmentally backed entity, is the major provider of long-term loans in the country, which are scarcely provided by commercial banks, and in general, these entities do not have competitive rates compared to the BNDES. BNDES provides several type of financing lines available to companies through BNDES presented at its website: <http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Produtos/>. The most suitable financial line to the proposed project activity is the "BNDES Automático" and then, interests rates of the **Kd** calculation are based on this financing line.

Furthermore, the marginal tax rate (**t**) is multiplied by the Cost of debt and then by the debt to total cost of capital ratio to ascertain the debt portion of the WACC formula. In the case of Brazil,

this tax factor could either be 34% (actual profit) or 0% (presumed profit). This is decided by the specific type of project and tax regime under which it sits. For the Presumed Profit eligibility, corporate entities revenues must be under Forty eight million Reais per year (Article #13, Law #9.718/1998)[22]. In the case of the proposed project activity, the 0% tax factor applies for the investment decision.

The nominal rate achieved for debt is used to calculate nominal WACC, which is used to discount nominal cash flow projections. In order to achieve the nominal cash flow rate in *Reais* (BRL), the inflation targeting figure (d) for Brazil is reduced from the nominal figure achieved. The (d) is obtained from the Brazilian Central Bank (www.bcb.gov.br) and has experienced very little variance in the past 5 years.

Kd is calculated through the following equation:

$$Kd = [1 + (a+b+c) \times (1-t)]/(1+d) -1$$

Values used in the cost of debt calculation are presented in Table 2 below.

Table 2 – Cost of debt (Kd) calculation

Cost of Debt (Kd)	
(a) Financial cost[23]	6.03%
(b) BNDES Spread[24]	1.00%
(c) BNDES tax[25]	0.1%
(d) Credit Risk Rate[26]	4.18%
(a+b+c) Pre-Cost of Debt	11.31%
(t) Marginal tax rate[27]	0%
(d) Inflation forecast[28]	4.50%
After tax Cost of Debt	6.52%p.a

According to the table above, **Kd** is of 6.52%.

Ke is the cost of equity. As per option b) provided in the paragraph 15 of Annex5, EB62, it was estimated using the best financial practices through the Capital Asset Pricing Model - CAPM

[22] Publicly available in Portuguese at http://www.receita.fazenda.gov.br/legislacao/leis/Ant2001/lei971898.htm.

[23] 5-year historical data of TJLP (Long term Interest Rate). Available at: <http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Produtos/BNDES_Automatico/mpme.html>.

[24] BNDES remuneration available at: <http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Produtos/BNDES_Automatico/mpme.html>

[25] BNDES financial intermediation tax available at: <http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Produtos/BNDES_Automatico/mpme.html>

[26] Remuneration / intermediation of accredited financial institution. The reference of data is based on the credit risk rate from BNDES. Since BNDES has more competitive rates than local commercial banks, this value is very conservative. Available at: <http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Produtos/FINEM/meio_ambiente.html>.

[27] Available at: http://www.receita.fazenda.gov.br/Aliquotas/ContribCsll/Aliquotas.htm http://www.receita.fazenda.gov.br/Aliquotas/ContribPj.htm

[28] Brazilian inflation targeting available at: <http://www.bcb.gov.br/pec/metas/InflationTargetingTable.pdf>.

(mentioned as an appropriate method to determine benchmarks in guidance 14, Annex 5, EB62). This method considers the risk associated in investing in the Brazil.

The following equation is used to calculate the **Ke**:

$$Ke = [(1+ Rf) /(1+ \pi')-1] + \beta \times (Rm-Rf) + Rc$$

Rf stands for the risk free rate. The risk-free rate used for **Ke** calculation was a long term bond rate. This bond was issued by the US government. In order to adjust the risk-free rate (**Rf**) to the inflation adjusted rate, the expected inflation rate (for the United States) (**π'**) is reduced. The inflation is calculated based on the treasury through spot TIPS (Treasury Inflation Protected Securities) which are readily quoted in the market.

Beta, or **β,** stands for the average sensitivity of comparable companies in that industry to movements in the underlying market. **β** derives from the correlation between returns of US companies from the sector and the performance of the returns of the US market. **β** has been adjusted to the leverage of Brazilian companies in the sector, reflecting both structural and financial risks. **β** adjusts the market premium to the sector.

(Rm–Rf) represents the market premium, or higher return, expected by market participants in light of historical spreads attained from investing in equities versus risk free assets such as government bond rates, investors require a higher return when investing in private companies. The market premium is estimated based on the historical difference between the S&P 500 returns and the long term US bonds returns. The spread over the risk-free rate is the average of the difference between those returns.

Note that in the formula above there is the factor EMBI+ (Emerging Markets Bond Index Plus), considers as the country risk premium, **Rc**. This factor accounts for the country or sovereign risk embedded in the debt of a country. Assuming that relative to the US risk-free debt market EMBI+ is 0, then Brazil's EMBI+ would calculate for the added or reduced risk relative of Brazils debt markets to the US.

Justification for the EMBI+ addition to the risk-free rate lies in the vast differences between the United States in such factors as credit risk, inflation history, politics, debt markets, and more. Ignoring these differences would result in the incorrect application of relevant environmental factors in the decision-making process of an investor in Brazil.

Values used in the cost of equity calculation are presented in Table 3 below.

Table 3 – Cost of equity (Ke) calculation

Cost of Equity (Ke) – CAPM	
(Rf) Risk-free rate[29]	3.42%
(Rm) Equity risk premium[30]	5.88%
(Rc) Estimated country risk premium[31]	2.38%
(β) Adjusted industry beta[32]	1.71%
(π') US expected inflation[33]	1.77%

[29] The Federal Reserve: http://www.federalreserve.gov/

[30] http://pages.stern.nyu.edu/~adamodar/

[31] www.ipeadata.gov.br

[32] http://pages.stern.nyu.edu/~adamodar/

[33] The Federal Reserve: http://www.federalreserve.gov/

Cost of Equity with Brazilian Country Risk (p.a.)	14.04%p.a.

According to the table above, Ke is of 14.04%. Plugging these numbers into WACC formulae we obtain:

WACC = 50% x 6.52% + 50% x 14.04% = 10.28%

Each assumption made and all data used to estimate the benchmark has been presented to the DOE. The spreadsheet used for calculation of the WACC is available with the Project Participants and has also been provided to the DOE. For complete reference of the data used to estimate the benchmark please refer to this spreadsheet, which is also attached to this PDD.

Financial Indicator, Internal rate of return (IRR)

As mentioned above, the financial indicator identified for Dois Arcos Landfill Project Activity is the project Internal Rate of Return (IRR). Dois Arcos cash flow over its lifetime shows that the project IRR is 4.80%.

The table presented below provides a list of the main input values considered for the IRR calculation as well as the source of the information used.

Table 4 – Parameters considered for the project IRR calculation

Parameter	***Value***	**Justification/source of information used**
Average of upgraded gas (MMBTU)	265,118	SCS Asssessment Report nr. 06212012.00 - Dois Arcos.
Upgraded gas price (US$/MMBTU)	US$ 9.01/MMBTU plus taxes (PIS/COFINS/ICMS) = US$ 11.51/MMBTU	The Mines and Energy Ministry (“MME” from the Portuguese Ministério de Minas e Energia)./ Natural Gas Department - Monthly reports of natural gas industry. Reference of taxes used is described below.
Average during the assessment period of operational costs (US$/year)	US$ 1,731,370/year	SCS Asssessment Report nr. 06212012.00 - Dois Arcos. Operation costs considered in the project cash flow are composed by the following costs: • Power costs: US$ 3.89/MMBTU average during the assessment period • Operation and maintenance (O&M): US$ 1.89/MMBTU average during the assessment period • Property tax and insurance: US$ 150,000/year • General and administrative: US$ 50,000/year
Investment (US$)	US$ 6,581,250	SCS Asssessment Report nr. 06212012.00 - Dois Arcos.
CSLL and IR taxes	CSLL: 12% x social taxes 9% = 1.08% IR: 8% x 25 % = 2%	Assumed income for social/income tax is based on the Brazilian regulations, which is public available information: • CSLL is the social tax (from the Portuguese Contribuição Social sobre Lucro Líquido): Law # 8,981, January 20th, 1995 • IR is the income tax (from the Portuguese Imposto de Renda): Law # 9,430, December 27th, 1996

PIS and COFINS taxes	PIS: 0.65% COFINS: 3.00%	Revenues tax is based on the Brazilian regulations, which is public available information: • PIS is tax of the Employees' Profit Participation Program (from the Portuguese Programa de Integração Social): at http://www.portaltributario.com.br/tributos/pis.htm • COFINS is the tax for social security financing (from the Portuguese Contribuição para o Financiamento da Seguridade Social): at http://www.receita.fazenda.gov.br/legislacao/leis/2003/lei10833.htm
ICMS tax	18%	Sales revenues tax is based on the Brazilian regulations, which is public available information: ICMS is the tax on the circulation of goods and services (from the Portuguese Imposto sobre Circulação de Mercadorias e Serviços) to be collected by states: The State Secretariat of Finance of Rio de Janeiro: Decree# 27,427/00 (RICMS/00) date November 17th, 2000[34].
Lifetime (years)	15 years	The SCS Asssessment Report nr. 06212012.00 - Dois Arcos presents an assessment period of 15 years. According to the declaration from the upgrade system manufacturer, the equipment has 20 year lifetime. Therefore, the fair value was included in the end of the assessment period following §3 of Annex 5, EB62. The 20-year assessment period is also according to the default period established in §3.

As can be seen, the calculated project IRR LFG1/P1 is 4.80% which demonstrates the project is not economically attractive/is below the benchmark of 10.28%. The project cash flow is available with the Project Participants and was presented to the DOE.

Sensitivity analysis

In order to perform the sensitivity analysis of the proposed project activity, the following parameters were altered:

- Variation in the upgraded gas price in + 10%;
- Variation in the upgraded gas generation in +10%;
- Variation in investment / CAPEX in - 10%;
- Variation of the operational costs in - 10%.

Table 5 - The following table summarizes the IRRs resulting from the application of the different hypotheses

Variations	Initial value	Revised value	Units	IRR
Variation in the upgraded gas price in + 10%	11.51	12.66	US$/MMBTU	8.87%

[34] Information available at: <http://www.fazenda.rj.gov.br/sefaz/faces/menu_structure/legislacao/legislacao-estadual-navigation/coluna2/RegulamentoDoICMS?_afrLoop=91271095541000&datasource=UCMServer%23dDocName%3A80968&_afrWindowMode=0&_adf.ctrl-state=1020sw0x39_4#TITULO_I>.

Variation in the upgraded gas generation in +10%	265,118	291.630	MMBTU/year	8.87%
Variation in investment / CAPEX in - 10%	6,581,250	5,923,125	US$	5.95%
Variation of the operational costs in - 10%	1,731,370	1,558,233	US$/year	7.92%

As shown in the Table above, the project IRR remains negative when the above parameters fluctuated within the range of -10% and +10%. According to the sensitivity analysis, even with ± 10% variations of the financial key parameters, the project IRR is still negative considering the benchmark of 10.28%.

It is important to note that the average of the Brazilian inflation in 2012 was 5.84%[35]. The use of 10% of variation in costs and revenues of the project activity, around two times the 2012 inflation rate, is a very conservative approach.

According to the "Guidelines on the assessment of investment analysis", whenever a scenario results in an IRR higher than the benchmark, an assessment on the probability of the respective occurrence shall be presented. Although none of the scenarios presented above the IRR reaches or surpasses the benchmark, the Project Participants also conducted the sensitivity analysis by altering each parameter until the IRR reaches the benchmark (10.28%) and analyzed the probability of the occurrence of these scenarios[36]. Results of this sensitivity analysis are presented in the table below:

Table 6 – Sensitivity analysis 2

Scenario	Initial value	Revised value	Units	% change
(a) Increase in the upgraded gas price	11.51	13.09	US$/MMBTU	13.8%
(b) Increase in the upgraded gas generation	265,118	301,572	MMBTU/year	13.8%
(c) Reduction in investment	6,581,250	4,195,547	US$	36.3%
(d) Reduction in operational costs	1,731,370	1,414,529	US$/year	18.3%

The probability of the occurrence of these scenarios is presented below:

(a) Increase in the upgraded gas price

The upgraded gas price considered in the project cash flow is US$ 9.01/MMBTU plus Brazilian taxes, resulting in US$ 11.51/MMBTU. The considered value is based on historical data of the natural gas (NG) price available in the Monthly Reports of the Mines and Energy Ministry ("MME" from the Portuguese Ministério de Minas e Energia) / Natural Gas Department. Therefore, data since the 1st Monthly Report issued was considered, which covers a 5.6 year-period of analysis.

Considering an increase in the NG price of 13.8% to the IRR reaches the benchmark, the NG price would be US$ 13.09/MMBTU. However, there is a tendency of a reduction in the NG price considering the *shale gas* offer. The *shale gas* has introduced new parameters for the NG price by

[35] Information available at: <http://g1.globo.com/economia/noticia/2013/01/inflacao-oficial-fecha-2012-em-584-aponta-ibge.html>.

[36] Variation required during the CDM validation of the Project. Please refer to the PPs response in CAR 4 of the Validation Protocol.

reducing it and unlinking it with the petroleum price (GOMES, 2011)[37]. The unexpected shale gas offer in the US market has surprised international markets, including Brazil, which had intention of exporting gas to US after pre-salt consolidation.

Table 7 – Projection of NG price in Brazil: based on the 75% competitiveness hypothesis[38]

Year	Fuel oil (US$ / MBtu)	NG (75% fuel oil) (US$ / MBtu)
2012	14.77	11.08
2013	14.49	10.64
2014	13.59	10.19
2015	12.81	9.61
2016	11.78	8.84
2017	10.95	8.21
2018	10.24	7.68
2019	9.59	7.20
2020	9.49	7.12
2021	9.50	7.12

Source: PDE 2021 (EPE, 2012)

Considering the increase of gas offer with the shale gas and pre-salt basins discovered in Brazil, it is expected an increase in the NG offer and, consequently, a reduction in the NG price. Therefore, an increase in the NG price of 13.8% to the IRR reaches the benchmark would not be reasonable in the project making context and it is not expected to occur.

(b) Increase in the upgrade gas generation

The estimated upgrade gas generation considered in the project cash flow is based on the SCS Assessment Report dated August 2012 considering 1,200 Nm^3/h installed capacity.

Considering an increase of 13.8% in the gas generation to the IRR reaches the benchmark, the average of upgraded gas generation would be 301,572 MMBTU/yr. However, the installed capacity of the upgrade system is 1,200 Nm^3/h as checked during the site visit. Although the LFG generation could increase considering the increase in the waste deposited in Dois Arcos landfill, the upgraded gas generation for selling is limited to the maximum capacity of the upgrade gas system, which would require more investment in equipment. Therefore, an increase of 13.8% in the upgrade gas generation is not reasonable in the project context and is not expected to occur.

Furthermore, the project activity has been conceived for the gas selling and, therefore, it cannot be inefficient and should be implemented as effectively as possible. For this reason, the figure used by the Project Participants is not underestimated.

(c) Reduction in investment cost

[37] Brazilian Market Study of Natural Gas in the Contexto f Shale Gas (in a free translation from the Portuguese Estudo do Mercado Brasileiro de Gás Natural Contextualizado ao Shale Gas). Rio Grande do Sul University, 2011.

[38] 75% - Energetic equivalence in US$/MBtu.

Investment considered in the project cash flow is based on the SCS Assessment Report dated August 2012. SCS Energy is a third-party engineering company contracted by the project developer to perform technical and financial analysis of the project activity implementation. According to the SCS Assessment Report, the investment required for the project activity implementation results in approximately US$ 6.6 MM. A reduction of 36.3% in the project investment to the IRR reaches the benchmark would result in approximately US$ 4.2 MM.

Since there are no similar projects to Dois Arcos in Brazil (energetic use of LFG, except for those which generates electricity considering CDM revenues), the PPs analyzed developed countries which have experienced this type of technology. According to "Landfill Gas Energy Project Development Handbook" published by the Government of Vermont[39], the estimated investment cost for direct-use gas project is around US$ 4.6 MM, which includes LFG collection system, flare, gas compression and treatment for the end user's equipment, gas pipeline and condensate management system for removing condensate along the pipeline.

However, according to Bacon and Besant-Jones (1998) study, real investments in developing countries are usually higher than the original estimative[40]. The study indicates that although the ratio of actual to estimated cost can be smaller than one (indicating actual investment smaller than estimated), less than 10% of the analyzed projects had investments lower than those forecasted. One of the conclusions is that "*the estimated values were significantly biased below actual values*". In fact, the currently estimated investment required for Dois Arcos implementation is in R$ 18MM (around US$ 7.5MM) as presented in the quarterly report for shareholders dated June 2014. Therefore, the current estimated investment for Dois Arcos implementation is 13.6% higher than the estimated figure considered in project cash flow at the time of the investment decision.

In conclusion, the investment considered in the project cash flow is based on a reliable documented evidence (a third-party contracted by the project developer) and very conservative in spite of the project is innovative in the country. For this reason, a 36.3% reduction in project investment is not reasonable in the project context, which in fact it is not expected to occur.

(d) Reduction in operational costs

Operational costs presented in the project cash flow are composed of commodities, operation and maintenance, labor, office expenses, electric power, property tax, insurance, general and administrative. Total operational costs result in around US$ 1.7 MM/year as presented in the SCS Assessment Report dated August 2012. A reduction in the project costs until the IRR reaches the benchmark would result in a decrease of 18.3% from the estimated operational costs, *i.e.* US$ 1.4 MM/year.

As mentioned in item (c), there are no similar projects to Dois Arcos in Brazil and, therefore, reference for costs involved in the project is based on a developed country literature. According to "Landfill Gas Energy Project Development Handbook" published by the Government of Vermont[41], the estimated O&M cost for direct-use gas project is around US$ 408,089/yr, which is similar to Dois Arcos project, *i.e.* US$ 500,239/yr average. Since this type of technology is not developed in the Host Country, costs are usually higher considering training course, specialized services, repair

[39] Available at: <http://psb.vermont.gov/sites/psb/files/docket/7523/Discovery/GMPFirstRound/NewGMP/REV_GMP-1_19%20LMOP%20-%20pdh_chapter4.pdf>.

[40] R. W. Bacon and J. E. Besant Jones (1998). Estimating construction costs and schedules – Experience with power generation projects in developing countries. Energy Policy, vol. 26, no 4, pp 317-333.

[41] Available at: <http://psb.vermont.gov/sites/psb/files/docket/7523/Discovery/GMPFirstRound/NewGMP/REV_GMP-1_19%20LMOP%20-%20pdh_chapter4.pdf>.

of equipment, and others, whose need to be imported from Annex I countries. Therefore, estimated O&M costs considered for Dois Arcos project are reasonable and conservative.

Unfortunately, the project is not operational yet and reference of other costs that composted the annual Opex – as property tax, insurance, power cost, general, administrative – were not found in literature. However, the PPs stress that data considered in project cash flow was made available by a third-party company contracted by the project developer in order to assess the technical and financial feasibility of Dois Arcos project. Therefore, a reduction of 18.3% is not a reasonable scenario in the context of the project activity and is not expected to occur.

Outcome: All information used in this sensitivity analysis is based on official data and was presented to DOE during the project validation. The IRR of Dois Arcos project activity without being registered as a CDM project is below the benchmark, evidencing that project activity is not financially attractive for the investor even when parameters change in favour of the project.

STEP 4: Common practice analysis

The Combined tool establishes that for those CDM project activities consisting of one of the measures that are listed in the definitions section of the tool, the approach presented in *Step 4a* shall be used. The measures listed in the tool are:

(a) Fuel and feedstock switch;

(b) Switch of technology with or without change of energy source (including energy efficiency improvement as well as use of renewable energies);

(c) Methane destruction;

(d) Methane formation avoidance.

The proposed CDM Project Activity matches option (c) since it consists of destructing the methane contained in the landfill[42]. Therefore, the approach provided in the *Step 4a* is to be used.

Step 4a: The proposed CDM project activity(s) applies measure(s) that are listed in the definitions section above

In accordance with the combined tool, the stepwise approach presented below shall be applied since the proposed CDM Project Activity consists of one of the measures listed in its definitions section.

Sub-step 4a(1): Calculate the applicable output range as +/-50% of the design output or capacity of the proposed project activity.

Output is defined in the "Guidelines on common practice" as *goods or services with comparable quality, properties and application areas (e.g. clinker, lighting, residential cooking)*.

The proposed CDM Project Activity aims at supplying methane from the LFG displacing the use of natural gas. Therefore, the output is the total LFG collected and upgraded for off-site consumers.

The project activity is projected to have an installed capacity of 1,200Nm^3/h, *i.e.* 10,512,000 Nm^3/year (at full capacity). Thus, the applicable range is 5,256,000Nm^3/year and 15,768,000Nm^3/year.

[42] Analogously to the example provided in the Annex 8 of the EB 62.

Sub-step 4a(2): In the applicable geographical area, identify all plants that deliver the same output or capacity within the applicable output range, calculated in Step 1, as the proposed project activity and have started commercial operation before the start date of the project. Note their number N_{all}. Registered CDM project activities and projects activities undergoing validation shall not be included in this step.

The "Guidelines on common practice" states that the *applicable geographical area covers the entire Host Country as a default*. Therefore, Brazil is identified as the applicable geographical area for the purpose of conducting the common practice analysis.

The starting date of the proposed CDM Project Activity is December 17th, 2012. Therefore, all landfill that have started collecting LFG and upgrading to off-site consumers before this date have to be assessed.

According to "2012 Management Diagnosis of Municipal Solid Waste" (in a free translation from the Portuguese "Diagnóstico do Manejo do Resíduos Sólidos Urbanos 2012") prepared by the Brazilian Ministry of the Cities, there are 765 solid waste disposal sites in the Host Country distributed in open dump, composting, recycling, sanitary and controlled landfills. However, it was not identified any landfill which collects LFG and upgrades it to natural gas quality.

According to the "Brazilian Atlas of Greenhouse Gas Emissions and Energetic Potential in the Residues Destination"[43] published by ABRELPE in 2013, there are 22 (twenty-two) LFG projects whose encompass electricity generation and only 1 (one) predicts the upgrading of biogas to NG distribution system. Therefore, N_{all} = 1.

However, to the project developers' knowledge, the identified project similar to Dois Arcos is Gramacho landfill, which is also a CDM project activity (ref. 9087)[44].

Therefore, N_{all} = 0, since there are no projects similar to the proposed project activity and, all projects which involves LFG for energetic use proposes are related to electricity generation and are also CDM project activities. According to the most recent information available from ABRELPE, the 23 projects identified are also CDM projects.

Sub-step 4a(3): Within the plants identified in Step 2, identify those that apply technologies different to the technology applied in the proposed project activity. Note their number N_{diff}.

Since N_{all} = 0, N_{diff} = 0.

Sub-step 4a(4): Calculate factor $F=1-N_{diff}/N_{all}$, representing the share of plants using a technology similar to the technology used in the proposed project activity in all plants that deliver the same output or capacity as the proposed project activity. The proposed project activity is regarded as common practice within a sector in the applicable geographical area if both the following conditions are fulfilled:

(a) The factor F is greater than 0.2; and

(b) $N_{all}-N_{diff}$ is greater than 3.

[43] ABRELPE (2013). Atlas Brasileiro de Emissões de GEE e Potencial Energético na Destinação de Resíduos Sólidos. Report supported by US Environmental Protection Agency (EPA) and the Global Methane Initiative. Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais – ABRELPE. ABRELPE is an association founded in 1976 and is the representative International Solid Waste Association (ISWA) in Brazil.

[44] Gramacho Landfill Gas Project <https://cdm.unfccc.int/Projects/DB/DNV-CUK1356155404.95/view>.

From the above, there are no projects similar to Dois Arcos project activity. Hence, the conditions of *sub-step4a(4)* are met and the project is additional.

Outcome of Step 4: the proposed project activity is not a common practice in the Host Country and, therefore, it is additional.

B.5. Demonstration of additionality

The additionality of the proposed project activity has been demonstrated using the *"Combined Tool to identify the baseline scenario and demonstrate additionality",* in line with the requirements of ACM0001. Please refer to section B.4. above for details.

CDM Prior Consideration and continuing and real actions to secure the CDM status

According to the "*Glossary of CDM Terms*" (EB66, Annex 63) the start date of the CDM Project Activity corresponds to "*the earliest date at which either the implementation or construction or real action of a CDM project activity or PoA begins*".

The identified starting date of the proposed project activity is 17/12/2012, which corresponds to the date when the approval of the capital contribution for the implementation of the proposed project occurred. For details on how the project starting date was identified, please refer to Section C.1.1.

With regards to the demonstration of the prior consideration of the CDM, the "*Clean Development Mechanism Project Standard*", requires that the CDM consideration must be demonstrated by those projects for which the identified start date *is prior to the date of publication of the PDD for the global stakeholder consultation*.

In addition, paragraph 7 of the "Project Cycle Procedure establishes that "*For project activities with a start date on or after 2 August 2008, the project participants shall notify the designated national authority(ies) (DNAs) of the host Party(ies) of the project activity and the secretariat in writing of the commencement of the project activity and their intention to seek the CDM status within 180 days of the start date of the project activity as defined in the "Glossary of CDM terms", by using the "Prior consideration of the CDM form" (F-CDM-PC). Such notification is not necessary if:*

(a) *A PDD regarding the project activity has been published for global stakeholder consultation in accordance with paragraph 16 below; or (…)".*

The proposed CDM Project Activity notified both the CDM EB and the Brazilian DNA of its intention to seek the registration on 27/03/2013. The confirmation of receipt from those entities is available with Project Participants and was sent to the DOE.

B.6. Emission reductions

B.6.1. Explanation of methodological choices

Baseline Emissions (BE_y)

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_2/yr);

$BE_{HG4,y}$ = Baseline emissions associated with heat generation in year *y* (tCO_2/yr);

$BE_{NG,y}$ = Baseline emissions associated with natural gas use in year *y* (tCO_2/yr).

Baseline emissions associated with heat generation in year *y* ($BE_{HG,y}$) and electricity generation in year *y* ($BE_{EC,y}$) are not applicable to the proposed project activity and, therefore, they are zero.

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[45].

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

Where,

$BE_{CH4,y}$ = Baseline emissions of methane 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) (default value of 0.1)

$F_{CH4,PJ,y}$ = Amount of methane in the LFG which is flared and/or used in the project activity in year *y* (tCH_4/yr)

$F_{CH4,BL,y}$ = 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) (default value of 25)

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

NBR 13896/97, consisting of the technical standard published by ABNT (Brazilian Association of Technical Standards - *Associação Brasileira de Normas Técnicas*), sets out the requirements for development of design, implementation and operation of landfills aiming at minimizing gaseous emissions and promoting its capture and correct management. However, its use is not mandatory and the norm neither specifies the amount of methane to be destroyed nor the system that shall be put in place. In addition, there is no federal/state/local law requiring the destruction of the methane.

[45] $OX_{top\text{-}layer}$ 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.

Previously to the implementation of the proposed CDM Project Activity there was a passive system and methane was burned in an uncontrolled manner (Figure 7). Hence, to the understanding of the project participants, Case 1 is applicable to Dois Arcos Landfill Project (*i.e.*, no technical requirement to destroy methane and no existing LFG capture and destruction system). However, based on the MP clarifications received[46], Case 3 is applicable in this case, *i.e* no requirement to destroy methane exists and a LFG capture system exists.

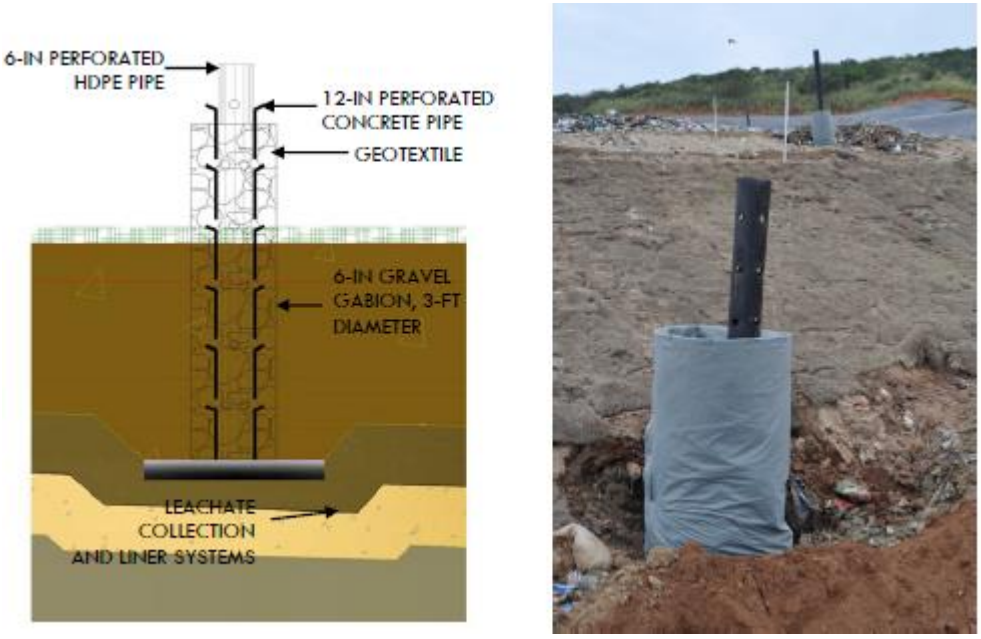

Figure 7 – Existing wells at the project site previously to the implementation of the CDM Project Activity (Source: SCS Report).

In accordance with the ACM0001 methodology, under *Case 3*, $F_{CH4,BL,y}$ = $F_{CH4,BL,sys,y}$ and, since there is no monitored or historic data on the amount of methane that was captured in the year prior to the implementation of the project situation (option C), the following equation applies:

$$F_{CH4,BL,sys,y} = 0.2 \times F_{CH4,PJ,y}$$ **Equation 3**

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 the natural gas distribution network, 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 4**

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*

[46] AM_CLA_0265 - Procedure to determine the amount of methane that would have been captured and destroyed (by flaring) in the baseline ($F_{CH4,BL,y}$). Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/clarifications/90436

(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 and/or to the trucks in year *y* (tCH_4/yr)

In the case of the project activity, $F_{CH4,HG,y}$ and $F_{CH4,EL,y}$ are zero since neither heat nor electricity will be generated using the biogas.

The *ex-post* determination of $F_{CH4,NG,y}$ is calculated using the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream". Since the proposed project activity is under commissioning and it is not known if temperature/pressure will be monitored in all metering points, the PDD presents the most possible scenario for biogas and methane monitoring. In spite of the options chosen at the time of the project verification, monitoring will be followed according to ACM0001 and the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream".

Then, the most plausible scenario for calculating $F_{CH4,NG,y}$ is **Option A** of the Tool (*i.e.* mass flow biomethane and volumetric fraction of methane measured in dry basis). Then, $F_{CH4,NG,y} = F_{i,t}$.

While considering this option, it is necessary to demonstrate that the gaseous stream is dry by:

(a) Measuring the moisture content of the gaseous stream ($C_{H2O,t,db,n}$) and demonstrate that this is less or equal to 0.05 kg H_2O/m^3 dry gas; or

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

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 corresponding option available in the tool should be applied instead.

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

And:

$$\rho_{i,t} = \frac{P_t \times MM_i}{R_u \times T_t}$$ **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 (m^3 wet gas/h);

$v_{i,t,db}$ = Volumetric fraction of greenhouse gas *i* in the gaseous stream in time interval *t* on a dry basis (m^3 gas *i* /m^3 dry gas);

$\rho_{i,t}$ = Density of greenhouse gas *i* in the gaseous stream in time interval t (kg gas *i*/m^3 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 (Pa.m^3/kmol.K);

T_t = Temperature of the gaseous stream in time interval *t* (K).

$F_{CH4,flared,y}$ is determined as the difference between the amount of methane supplied to the flare(s) and any methane emissions from the flare(s), as follows:

$$F_{CH4,flared,y} = F_{CH4,sent\_flare,y} - \frac{PE_{flare,y}}{GWP_{CH4}}$$ **Equation 7**

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).

$F_{CH4,sent\_flare,y}$ is determined directly using the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream". Following the simplification approach provided by the tool, which is also allowed by ACM0001 methodology, the volumetric fraction of only the gases *k* that are greenhouse gases and are considered in the emission reduction calculation in the underlying methodology are to be monitored. In the context of the proposed project activity, the only gas that is to be monitored is the methane (CH_4). The difference to 100% will be considered as pure nitrogen.

For calculating $F_{CH4,sent\_flare,y}$, **Option C** of the Tool is the most plausible scenario (*i.e.*, LFG and volumetric fraction of methane measured in wet basis). Then, $F_{CH4,sent\_flare,y} = F_{i,t}$.

$$F_{i,t} = V_{t,wb,n} \times v_{i,t,wb} \times \rho_{i,n}$$ **Equation 8**

And:

$$\rho_{i,n} = \frac{P_n \times MM_i}{R_u \times T_n}$$ **Equation 9**

Where:

$F_{i,t}$ = Mass flow of greenhouse gas *i* in the gaseous stream in time interval *t* (kg gas/h);

$V_{t,wb,n}$ = Volumetric flow of the gaseous stream in time interval *t* on a wet basis at normal conditions (m^3 wet gas/h);

$v_{i,t,wb}$ = Volumetric fraction of greenhouse gas *i* in the gaseous stream in time interval *t* on a wet basis (m^3 gas *i* /m^3 wet gas);

$\rho_{i,n}$ = Density of greenhouse gas *i* in the gaseous stream at normal conditions (kg gas *i*/m^3 wet gas *i*);

P_n = Absolute pressure at normal conditions (Pa);

T_n = Temperature at normal conditions (K);

MM_i = Molecular mass of greenhouse gas *i* (kg/kmol);

R_u = Universal ideal gases constant (Pa.m^3/kmol.K).

The following equation should be used to convert the volumetric flow of the gaseous stream from actual conditions to normal conditions of temperature and pressure:

$$V_{t,wb,n} = V_{t,wb} \times [(T_n / T_t) \times (P_t / P_n)]$$ **Equation 10**

Where:

$V_{t,wb,n}$ = Volumetric flow of the gaseous stream in a time interval *t* on a wet basis at normal conditions (m^3 wet gas/h);

$V_{t,wb}$ = Volumetric flow of the gaseous stream in time interval *t* on a wet basis (m^3 wet gas/h);

P_t = Pressure of the gaseous stream in time interval *t* (Pa);

T_t = Temperature of the gaseous stream in time interval *t* (K);

P_n = Absolute pressure at normal conditions (Pa);

T_n = Temperature at normal conditions (K).

It is important mentioning that the upgraded gas that does not reach specifications to be delivered in the NG pipeline will be flared. For the determination of biogas resulted from the upgrade system return that will be flared, Option A is the most plausible scenario to be applied (volume flow of biomethane and volumetric flow of methane measured in dry basis) following equations 5 and 6 above.

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

An *ex-ante* estimative is required to calculate the baseline emissions. According to ACM0001, it shall be determined as follows:

$$F_{CH4,PJ,y} = \eta_{PJ} \cdot BE_{CH4,SWDS,y}/GWP_{CH4} \quad \textbf{Equation 11}$$

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, this is considered as 60% as presented in SCS Assessment Report 06212012.00 dated August 2012;

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 following guidance should be taken into account when applying the tool:

- f_y in the tool shall be assigned a value of 0 because the amount of LFG that would have been captured and destroyed is already accounted for in $\boldsymbol{F_{CH4,BL,y}}$;
- In the tool, x begins with the year that the SWDS started receiving wastes (*e.g.* the first year of SWDS operation); and
- Sampling to determine the fractions of different waste types is not necessary because the waste composition can be obtained from previous studies (obtained from data from COMLURB).

Application A of the Tool is used (*i.e. the project activity mitigates methane emissions from a specific existing SWDS-solid waste disposal site*). A yearly selection has been chosen as the Dois Arcos landfill started receiving wastes in 2008.

The amount of methane that would in the absence of the project activity be generated from disposal of waste at the solid waste disposal site ($BE_{CH4,SWDS,y}$) is calculated with a multi-phase model. The calculation is based on a first order decay (FOD) model.

$$BE_{CH\$,SWDS,y} = \varphi y \times (1-f_y) * GWP_{CH_4} * (1-OX) * \frac{16}{12} * F * DOC_{f,y} * MCFy * \sum_{x=1}^{y} \sum_{j} W_{j,x} * DOC_j \times e^{-k_j(y-x)} * \left(1-e^{-k_j}\right) \quad \textbf{Equation 12}$$

Where,

$BE_{CH4,SWSD,y}$ = Baseline methane emissions occurring in year y generated from waste disposal at the solid waste disposal site (SWDS) during a period ending in year y (tCO_2e/y)

φ = Model correction factor to account for model uncertainties (default value of 0.75), Option 1 in the Tool has been selected, value as per Table 3 of the Tool.

f = 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. As this is already accounted for in $\boldsymbol{F_{CH4,BL,y}}$, "*f*" in the Tool shall be assigned a value of 0.

GWP_{CH4} = Global Warming Potential (GWP) of methane, valid for the relevant commitment period (default value of 25)

OX = Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste) (default value of 0.1)

F = Fraction of methane in the SWDS gas (volume fraction) (default value of 0.5)

$DOC_{f,y}$ = Fraction of degradable organic carbon (DOC) that decomposes under the specific conditions occurring in the SWSD for year y (weight fraction) (default value of 0.5).

MCF_y = Methane correction factor for year y (default value for anaerobic managed solid waste disposal sites of 1.0)

$W_{j,x}$ = Amount of solid waste type j disposed or prevented from disposal in the SWDS in the year *x* (t)

DOC = Fraction of degradable organic carbon (by weight fraction) in the waste type *j* (default value based on the waste type)

k_j = Decay rate for the waste type *j* (1/yr) (default value based on waste type and temperature)

j = Type of residual waste or types of waste in the MSW

x = Years in the time period in which waste is disposed at the SWSD, extending from the first year in the time period (x=1) to year (x = y)

y = Year for which methane emissions are calculated (considering a consecutive period of 12 months)

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

$BE_{NG,y}$ is estimated as follows:

$$BE_{NG,y} = 0.0504 \times F_{CH4,NG,y} \times EF_{CO2,NG,y} \quad \textbf{Equation 13}$$

Where,

$BE_{NG,y}$ = Baseline emissions associated with natural gas use in year *y* (t CO_2/yr);

$EF_{CO2,NG,y}$ = Average CO_2 emission factor of natural gas in the natural gas network or in trucks in year *y* (tCO_2/TJ);

$F_{CH4,NG,y}$ = Amount of methane in the LFG which is sent to the natural gas distribution network or in trucks in year *y* (tCH_4/yr).

$EF_{CO2,NG,y}$ is determined using the "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion".

Project Emissions (PE_y)

According to ACM0001, sources of project emissions are calculated based on the equation below:

$$PE_y = PE_{EC,y} + PE_{FC,y} + PE_{DT,y} \quad \textbf{Equation 14}$$

Where,

$PE_{EC,y}$ = Emissions from consumption of electricity due to the project activity in year *y* (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* (tCO_2/yr);

$PE_{DT,y}$ = Emissions from the distribution of compressed/liquefied LFG using trucks, in year *y* (tCO_2/yr).

$PE_{DT,y}$ is zero, since up to the starting date of the crediting period of the project, the NG distribution system will be constructed. However, if delays in the construction occur, $PE_{DT,y}$ monitoring will be conducted in accordance with the methodology.

Furthermore, the PPs included in the equation above project emissions from flaring ($PE_{flare,y}$) following the methodological tool "Project emission from flaring".

Emissions from consumption of electricity ($PE_{EC,y}$)

The project emissions from electricity consumption ($PE_{EC.y}$) will be calculated following the procedures set out by the "Tool to estimate the baseline, project and/or leakage emissions from electricity consumption". During the crediting period, electricity is expected to be used from the grid for the operation of the plant (process and administrative). Therefore, Option **A.1** of the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption" is used. Under this option, project emissions from consumption of electricity from the grid are calculated based on the power consumed by the project activity and the emission factor of the grid, adjusted for transmission losses, using the following formula:

$$\mathrm{PE}_{\mathrm{EC,\,grid,y}} = \sum_{\mathrm{j}} \mathrm{EC}_{\mathrm{PJ,\,j,\,y}} \times \mathrm{EF}_{\mathrm{EL,\,j,\,y}} \times \left(1 + \mathrm{TDL}_{\mathrm{j,\,y}}\right) \quad \textbf{Equation 15}$$

Where,

$PE_{EC,grid,y}$ = Project emissions from electricity consumption from the grid by the project activity during the year *y* (tCO_2/year);

$EC_{PJ,y}$ = Quantity of electricity consumed by the project electricity consumption source *j* in year *y* (MWh)

$EF_{EL, j, ,y}$ = Emission factor for electricity generation for source *j* in year (tCO_2/MWh)

$TDL_{j, y}$ = Average technical transmission and distribution losses for providing electricity to source *j* in year *y*

j = Sources of electricity consumption in the project

Electricity sources *j* corresponds to all the sources of electricity consumed for the operation of the LFG capture system, for the processing and upgrading of the LFG, for transportation of the LFG to the flare, for the compression of the LFG into the natural gas network, etc. For the *ex-ante* estimation of electricity consumed, the installed power of the active LFG collection system and LFG upgrading facility equipment was used.

Regarding $TDL_{j, y}$, the "Tool to estimate the baseline, project and/or leakage emissions from electricity consumption" provides the use of data available within the Host Country, if available, or a default value of 20%. $TDL_{j,y}$, is publicly available by the Brazilian Power Regulatory Agency ("ANEEL" from the Portuguese Agência Nacional de Energia Elétrica) for each power utility. The power utility responsible for electricity supply at the project site is AMPLA Energia e Serviços S/A and, therefore, ANEEL data shall be used at the time of the project verification. For *ex-ante* estimative, the default data provided by the tool is used.

The Emission Factor was calculated according with the "Tool for calculation of emission factor for electricity systems". The Tool considers the determination of the emission factor for the grid to which the project activity is connected as the core data to be determined in the baseline scenario. Thus $EF_{EL ,y} = EF_{grid,CM,y}$.

The Emission Factor is calculated as the *Combined Margin (CM)*, comprised by two components: the *Built Margin (BM)* and the *Operation Margin (OM)*. The BM evaluates the contribution of the power plants which would have been built if the project plant would not have been implemented. The OM evaluates the contribution of the power plants which would have been dispatched in the absence of the project activity.

The "Tool for calculation of emission factor for electricity systems" presents the following steps to calculate the Emission Factor:

- **STEP 1** - Identify the relevant electricity systems

According to the tool, "*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. If such delineations are not available, project participants should define the project electricity system and any connected electricity system and justify and document their assumptions in the CDM-PDD*".

The Brazilian DNA published Resolution #8, issued on 26th May, 2008, 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.

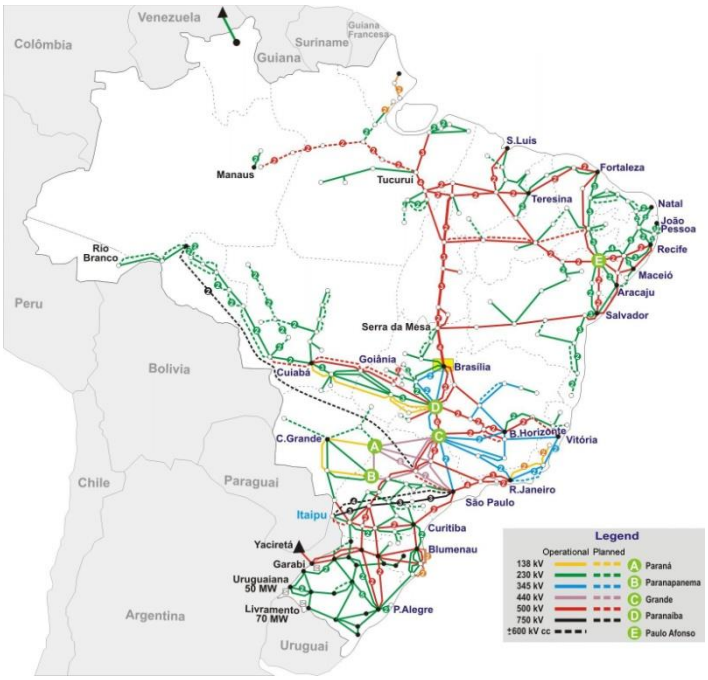

Figure 8: Brazilian Interconnected System. (*Source:* Electric System National Operator)

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

  Option I of the tool is chosen, which is to include only grid power plants in the calculation.

- **STEP 3 -** Select a method to determine the operating margin (OM).

The calculation of the operating margin emission factor ($EF_{grid,OM,y}$) is based on one of the following methods:

(a) Simple OM, or

(b) Simple adjusted OM, or

(c) Dispatch data analysis OM, or

(d) Average OM.

The simple operating margin can only be used where low-cost/must-run resources[47] constitute less than 50% of total grid generation in: 1) average of 5 most recent years, or 2) based on long-term normalities for hydroelectricity production. Table 8 shows the share of hydroelectricity in the total electricity production for the Brazilian interconnected system. The results show the non-applicability of the simple operating margin to the proposed CDM Project Activity.

[47] Low operating cost and must run resources typically include hydro, geothermal, wind, low-cost biomass, nuclear and solar generation.

Table 8 - Share of hydroelectricity generation in the Brazilian interconnected system, 2007 to 2011

Year	Share of hydroelectricity (%)
2009	93.27%
2010	88.77%
2011	91.18%
2012	85.86%
2013	78.77%

Source: *ONS: Histórico de Geração. Available at <http://www.ons.org.br/historico/geracao_energia.aspx>.*

The fourth alternative, an average operating margin, is an oversimplification and does not reflect in any way the impact of the project activity on the operating margin. The use of the dispatch data analysis method is only applicable to the *ex-post* vintage for determining the emission factor, which is not the vintage chosen by the project participants. Therefore, the simple adjusted operating margin will be used to determine the grid emission factor.

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 was submitted to the DOE for validation in the first quarter of 2014. Therefore, data from 2011, 2012 and 2013 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:

$$EF_{grid,OM-adj,y} = (1-\lambda_y) \cdot \frac{\sum_m EG_{m.y} \times EF_{EL,m,y}}{\sum_m EG_{m.y}} + \lambda_y \cdot \frac{\sum_k EG_{k,y} \times EF_{EL,k,y}}{\sum_k EG_{k,y}} \qquad \textbf{Equation 16}$$

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 *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 17**

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 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 ONS, which is an official source, as recommended by the tool. ONS is a non-profit corporate entity, founded on 26 August 1998, and is responsible for coordinating and controlling the operation of generation and transmission facilities in the Brazilian Interconnected System (SIN) under supervision and regulation of the ANEEL[48].

- **STEP 5** - Calculate the build margin (BM) emission factor

In terms of vintage, **option 1** was chosen. In this sense, the build margin was calculated using the most recent information available on units already built for sample group *m* at the time of PDD submission to the DOE, *i.e.* 2013.

[48] http://www.ons.org.br/institucional/modelo_setorial.aspx?lang=en

The sample group of power units *m* used to calculate the build margin was determined following the procedure provided by the tool and BM emission factor shall be calculated based on the equation below:

$$EF_{grid,BM,y} = \frac{\sum mEG_{m,y} \times EF_{EL,m,y}}{\sum mEG_{m,y}} \qquad \textbf{Equation 18}$$

Where,

$EF_{grid,BM,y}$ = Build margin CO_2 emission factor in year y (tCO_2/MWh)

$EG_{m,y}$ = Net quantity of electricity generated and delivered to the grid by power unit m in year y (MWh)

$EF_{EL,m.y}$ = CO_2 emission factor of power unit m in year y (tCO_2/MWh)

m = Power units included in the build margin

y = Most recent historical year for which electricity generation data is available

The sample group of power units *m* used to calculate the build margin was identified following the procedure provided by the tool. The result is discussed below and is presented in detail in the spreadsheet supplied to the DOE which is also attached to the PDD.

(a) Identify the set of five power units, excluding power units registered as CDM project activities, that started to supply electricity to the grid most recently ($SET_{5\text{-}units}$) and determine their annual electricity generation ($AEG_{SET\text{-}5\text{-}units}$, in MWh);

From the most recent consolidated information the SET5-units are: Termopernambuco, UHE Jirau, UTE Tambaqui, T. Ponta Negra and UTE Aparecida. The electricity generated by these set of plants ($AEG_{SET\text{-}5\text{-}units}$) in 2013 was 1,440,999MWh.

(b) Determine the annual electricity generation of the project electricity system, excluding power units registered as CDM project activities (AEG_{total}, in MWh). Identify the set of power units, excluding power units registered as CDM project activities, that started to supply electricity to the grid most recently and that comprise 20% of AEG_{total} (if 20% falls on part of the generation of a unit, the generation of that unit is fully included in the calculation) ($SET_{\geq 20\%}$) and determine their annual electricity generation ($AEG_{SET\text{-}\geq 20\%}$, in MWh);

Not considering the CDM project activities, in 2013, the Brazilian electricity System generated (AEGtotal) 487,520,106MWh. A large number of plants comprise 20% of AEGtotal. This information (SET≥20%) can be checked in the calculation spreadsheet attached to this PDD. The annual electricity generation of SET≥20%, corresponding to the parameter AEGSET-≥20%, is 97,504,021MWh.

(c) From $SET_{5\text{-}units}$ and $SET_{\geq 20\%}$ select the set of power units that comprises the larger annual electricity generation (SET_{sample}); Identify the date when the power units in SET_{sample} started to supply electricity to the grid. If none of the power units in SET_{sample} started to supply electricity to the grid more than 10 years ago, then use SET_{sample} to calculate the build margin. Ignore steps (d), (e) and (f).

From data presented in items (a) and (b), it can be observed that $SET_{\geq 20\%}$ is greater than $SET_{5\text{-}units}$. Therefore, SET_{sample} corresponds to $SET_{\geq 20\%}$. The oldest plant comprised in SET_{sample} started

to supply electricity to the grid in May 2002. Hence, steps *(d), (e)* and *(f)* of the tool are applicable.

(d) Exclude from SET_{sample} the power units which started to supply electricity to the grid more than 10 years ago. Include in that set the power units registered as CDM project activity, starting with power units that started to supply electricity to the grid most recently, until the electricity generation of the new set comprises 20% of the annual electricity generation of the project electricity system (if 20% falls on part of the generation of a unit, the generation of that unit is fully included in the calculation) to the extent is possible. Determine for the resulting set ($SET_{sample-CDM}$) the annual electricity generation ($AEG_{SET-sample-CDM}$, in MWh);

Plants which have started to supply electricity to the grid more than 10 years ago were excluded. Six registered CDM Projects were included in the SET_{smaple}. The electricity generation by resultant set of plants, corresponds to the parameter $AEG_{SET-sample-CDM}$, is 7,756,515MWh.

If the annual electricity generation of that set is comprises at least 20% of the annual electricity generation of the project electricity system (i.e. $AEG_{SET-sample-CDM} \geq 0.2 \times AEG_{total}$), then use the sample group $SET_{sample-CDM}$ to calculate the build margin. Ignore steps (e) and (f).

From the results presented above, $AEG_{SET-sample-CDM}$ is lower than AEG_{total}. Then, steps (e) and (f) were applied.

(a) Include in the sample group $SET_{sample-CDM}$ the power units that started to supply electricity to the grid more than 10 years ago until the electricity generation of the new set comprises 20% of the annual electricity generation of the project electricity system (if 20% falls on part of the generation of a unit, the generation of that unit is fully included in the calculation);

(b) The sample group of power units m used to calculate the build margin is the resulting set ($SET_{sample-CDM->10yrs}$).

Power plants that started to supply electricity to the grid more than 10 years ago were included. The resultant set $SET_{sample-CDM->10yrs}$ is identified in the grid emission factor calculation spreadsheet.

The build margin was calculated following the same approach described above in Step 4, and considered the set of plants identified above. As mentioned previously, this parameter will be validated since the *ex-ante* option was chosen.

- **STEP 6** – Calculate the combined margin (CM) emissions factor

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

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times w_{OM} + EF_{grid,BM,y} \times w_{BM} \quad \textbf{Equation 19}$$

Where,

$EF_{grid,BM,y}$ = Build margin CO_2 emission factor in year y (tCO_2/MWh);

$EF_{grid,OM,y}$ = Operating margin CO_2 emission factor in year y (tCO_2/MWh);

w_{OM} = Weighting of operating margin emissions factor (%);

w_{BM} = Weighting of build margin emissions factor (%).

According with the Tool, values adopted for w_{OM} and w_{BM} were equal to 0.5 for each one during the 1st crediting period. As mentioned above, the *ex-ante* approach is used.

In the future, it may be possible that a generator could be installed at the plant site considering the high variation of electricity supply where the project is located. In this case, project emissions from the use of fuel to produce electricity will be considered in the $PE_{FC,y}$ calculation following the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption".

Emissions from consumption of fossil fuels ($PE_{FC,y}$)

In order to calculate project emissions resulting from combustion of fossil fuels, the "Tool to calculate project or leakage emissions from fossil fuel combustion" shall be used. During the crediting period, it is expected the use of Liquefied Petroleum Gas (LPG) ignition of the flare. Project emissions related to this source are estimated using the following formulae:

$$PE_{FC,j,y} = \sum_{i} FC_{i,j,y} \times COEF_{i,y} \quad \textbf{Equation 20}$$

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 proposed project activity is expected to use LPG for the ignition of the flare. 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. As per 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:

$$COEF_{i,y} = NCV_{i,y} \times EF_{CO2,i,y} \quad \textbf{Equation 21}$$

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*

If a fossil fuel generator is installed at the project site for electricity generation, fuel consumption will be also monitored following equations above.

Emissions from the distribution of compressed/liquefied LFG using trucks ($PE_{DT,y}$)

The project emissions from the distribution of compressed/liquefied LFG using trucks ($PE_{DT,y}$) is determined by the sum of emissions arising from the transportation of LFG using trucks and possible leaks during the transportation, as follows:

$$PE_{DT,y} = PE_{TR,y} + PE_{leaks,y}$$ **Equation 22**

Where,

$PE_{DT,y}$ = Project emissions from the distribution of compressed/liquefied LFG using trucks, in year *y* (tCO_2/yr)

$PE_{TR,y}$ = Emissions from the transportation of compressed/liquefied LFG using trucks, in year y (tCO_2/yr)

$PE_{leaks,y}$ = Emissions from CH_4 leaks during the transportation of compressed/liquefied LFG, in year y (tCO_2/yr)

The upgraded gas transportation by trucks is a temporary solution until the NG distribution construction, which is expected to occur up to December 2015. Therefore, the $PE_{DT,y}$ is not expected to occur in the project scenario, since the starting date of the crediting period is January 2016. However, if delays occur for the NG pipeline construction, $PE_{DT,y}$ and related parameters will be monitored following the methodology.

Emissions from the transportation of LFG ($PE_{TR,y}$)

For the calculation of the emissions of the distribution of LFG using trucks, the methodological tool "Project and leakage emissions from transportation of freight" shall be used. In the case of the proposed project activity, Option A or B can be used as follows:

Option A:

Monitoring fuel consumption based on the amount of fuel consumed by the vehicles, project emissions are determined using the latest version of the "Tool to calculate project or leakage CO2 emissions from fossil fuel combustion". The following guidance is given for applying the tool:

(a) Parameter $PE_{FC,j,y}$ in the tool corresponds to the parameter $PE_{TR.m}$ or $LE_{TR,m}$ in this tool;
(b) Element process j corresponds to the combustion of fuels in the vehicles;
(c) If biofuels are used, then the corresponding CO2 emission factor of the fossil fuels that would most likely be used in the absence of the use of biofuels should be used.3 If biofuel blends are consumed, then the CO2 emission factor of the fossil fuel used in the blend shall be used, as a conservative simplification.

Option B:

Using conservative values while applying the following equation:

$$PE_{TR,m} = D_{f,m} \times FR_{f,m} \times EF_{CO2,f} \times 10^{-6}$$ **Equation 23**

Where,

$PE_{TR,m}$ = Project emissions from transportation of freight monitoring period *m* (t CO_2)

$D_{f,m}$ = Return trip distance between the origin and destination of freight transportation activity *f* in monitoring period *m* (km)

$FR_{f,m}$ = Total mass of freight transported in freight transportation activity *f* in monitoring period *m* (t)

$EF_{CO2,f}$ = Default CO_2 emission factor for freight transportation activity *f* (g CO_2/t km)

f = Freight transportation activities conducted in the project activity in monitoring period *m*

Emissions from CH4 leaks during the transportation

$$PE_{leaks,y} = GWP_{CH4} \times (F_{CH4,NGTR,y} - F_{CH4,NG-cons,y}) \quad \textbf{Equation 24}$$

Where,

$PE_{leaks,y}$ = Emissions from CH_4 leaks during the transportation of compressed/ liquefied LFG, in year y (tCO_2/yr)

GWP_{CH4} = Global Warming Potential of CH_4

$F_{CH4,NG\ TR,y}$ = Amount of methane in the LFG which is sent to trucks in year y

$F_{CH4,NG-cons,y}$ = Amount of methane in the LFG which is delivered to consumers using trucks in year y (tCH_4/yr)

Furthermore, emissions from flaring were calculated as follows:

Project emissions from flaring

The project has an open flare and, then, project emissions from flaring will be calculated following the steps of the methodological tool "Project emissions from flaring" as follows:

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

The mass flow of methane in the residual gaseous stream in the minute *m* ($F_{CH4,m}$) will be determined using the procedures set out by the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream".

$F_{CH4,m}$, 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* ($F_{CH4,RG,m}$). This parameter corresponds to $F_{CH4,flared,y}$. Therefore, the same methodological approaches apply to both parameters (Option C of the tool described above).

However, the upgraded gas, which does not reach quality specifications to be delivered into the NG pipeline, will be flared. In this case, Option A of the tool will be applied as explained above. Please refer to methodological explanations for the ex-post determination of $F_{CH4,sent\_flare,y}$ and monitoring equipment in section B.7.3.

STEP 2: Determination of flare efficiency

The Dois Arcos Landfill Project will install one open flare. Therefore, in accordance with the methodological tool, the flare efficiency in the minute *m* ($\eta_{flare,m}$) is 50% when the flame is detected in minute *m* ($Flame_m$), otherwise $\eta_{flare,m}$ is 0%.

STEP 3: Calculation of project emissions from flaring

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

$$PE_{flare,y} = GWP_{CH_4} \times \sum_{m=1}^{525600} F_{CH4,RG,m} \times \left(1 - \eta_{flare,m}\right) \times 10^{-3} \quad \textbf{Equation 25}$$

Where,

$PE_{flare,y}$ = Project emissions from flaring of the residual gas stream in year *y* (tCO_2e)

GWP_{CH4} = Global Warming Potential (tCO_2e/tCH_4) valid for the commitment period

$F_{CH4,RG,m}$ = Mass flow of methane in the residual gas in the minute *m* (kg)

$\eta_{flare,m}$ = Flare efficiency in the minute *m*

Leakage

According to ACM0001, there is no need to account for leakage.

Emission reductions

Emission reductions will be calculated using the formula below:

$$ER_y = BE_y - PE_y \quad \textbf{Equation 26}$$

Where,

ER_y = Emission reductions during the year *y* (tCO_2e)

BE_y = Baseline emissions in year *y* (tCO_2e)

PE_y = Project emissions in year *y* (tCO_2e)

B.6.2. Data and parameters fixed ex ante

ACM0001 – Flaring or use of landfill gas

Data / Parameter	OX_{top_layer}
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	As per the ACM0001.
Purpose of data	Calculation of baseline emissions
Additional comment	Applicable to section 5.4.1. of the methodology (baseline emissions of methane from the SWDS, $BE_{CH4,y}$).

Data / Parameter	GWP_{CH4}
Unit	tCO_2e/tCH_4
Description	Global warming potential of CH_4
Source of data	IPCC
Value(s) applied	25 for the second commitment period. Shall be updated according to any future COP/MOP decisions.
Choice of data or Measurement methods and procedures	As per the ACM0001.
Purpose of data	Calculation of baseline and project emissions
Additional comment	-

Data / Parameter	NCV_{CH4}
Unit	TJ/t CH_4
Description	Net calorific value of methane at reference conditions
Source of data	Technical literature
Value(s) applied	0.0504
Choice of data or Measurement methods and procedures	As per ACM0001
Purpose of data	Calculation of baseline emissions
Additional comment	-

Data / Parameter	η_{PJ}
Unit	Dimensionless
Description	Efficiency of the LFG capture system that will be installed in the project activity
Source of data	Technical specifications of the LFG capture system to be installed according to SCS Assessment Report # 06212012.00 dated August 2012
Value(s) applied	60%
Choice of data or Measurement methods and procedures	The most conservative value of efficiency for the landfill cells at the beginning year of the crediting period (2015) considering a mid-range projection: Cell 1: 60% from 2014 onwards Cell 2: 75% from 2015 to 2018, 80% in 2019, 85% in 2020 Cell 3: 65% from 2020 to 2026, 85% in 2017
Purpose of data	Calculation of baseline emissions
Additional comment	Applicable to section 5.4.1.2 of the methodology (ex-ante estimation of methane in the LFG which is flared and/or used in the project activity, $F_{CH4,PJ,y}$).

Methodological tool "Emissions from solid waste disposal sites"

Data / Parameter	$\varphi_{default}$
Unit	-
Description	Default value for the model correction factor to account for model uncertainties
Source of data	-
Value(s) applied	0.75
Choice of data or Measurement methods and procedures	As per the applicable methodological tool *"Emissions from solid waste disposal sites"*. This parameter is used to determine the baseline emissions following the procedures related to *Application A*. Further, the project is located nearby Rio de Janeiro municipality (Southeastern region of Brazil) which possesses humid/wet weather conditions[49]: MAT = 23.7ºC MAP = 1.171mm. Therefore, the value correspondent to this condition as presented in Table 3 of the tool is chosen.
Purpose of data	Calculation of baseline emissions
Additional comment	As per Table 3 since the project participants have chosen to apply Option 1 to determine this parameter.

[49] The climatic conditions are based on long-term averages from 1973 to 1990 and were taken from EMBRAPA - Brazilian Agricultural Research Corporation, available at <http://www.bdclima.cnpm.embrapa.br/resultados/balanco.php?UF=&COD=207>.

Data / Parameter	***OX***
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	As per the applicable methodological tool *"Emissions from solid waste disposal sites"*
Purpose of data	Calculation of baseline emissions
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***
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	As per the applicable methodological tool *"Emissions from solid waste disposal sites"*
Purpose of data	Calculation of baseline emissions
Additional comment	Upon biodegradation, organic material is converted to a mixture of methane and carbon dioxide.

Data / Parameter	$DOC_{f,default}$
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 proposed project activity corresponds to *Application A* described in the applicable methodological tool *"Emissions from solid waste disposal sites"*. Therefore, in accordance with the requirements set out by tool, the default value was chosen.
Purpose of data	Calculation of baseline emissions
Additional comment	This factor reflects the fact that some of the degradable organic carbon does not degrade, or degrades very slowly, in the SWDS.

Data / Parameter	$MCF_{default}$
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 proposed project activity matches *Application A* described in the tool *"Emissions from solid waste disposal sites"*. The Dois Arcos Lanfill meets the criteria of managed SWDS. Hence, the value corresponding to anaerobic **managed solid waste disposal sites** is chosen.
Purpose of data	Calculation of baseline emissions
Additional comment	-

<table>
<tr><td>Data / Parameter</td><td>DOC_j</td></tr>
<tr><td>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>DOC_j
(% wet waste)</th><th>Waste type j</th></tr>
<tr><td>43%</td><td>Wood and wood products</td></tr>
<tr><td>40%</td><td>Pulp, paper and cardboard</td></tr>
<tr><td>15%</td><td>Food, food waste, beverages and tobacco</td></tr>
<tr><td>24%</td><td>Textiles</td></tr>
<tr><td>20%</td><td>Garden, yard and park waste</td></tr>
<tr><td>0%</td><td>Glass, plastic, metal, other inert waste</td></tr>
</table>
</td></tr>
<tr><td>Choice of data
or
Measurement methods and procedures</td><td>Values for MSW, as per Table 6 of the methodological tool “Emissions from solid waste disposal sites”.</td></tr>
<tr><td>Purpose of data</td><td>Calculation of baseline emissions</td></tr>
<tr><td>Additional comment</td><td>-</td></tr>
</table>

<table>
<tr><td>Data / Parameter</td><td>k_j</td></tr>
<tr><td>Unit</td><td>1/yr</td></tr>
<tr><td>Description</td><td>Decay rate for the waste type j</td></tr>
<tr><td>Source of data</td><td>IPCC 2006 Guidelines for National Greenhouse Gas Inventories (adapted from Volume 5, Table 3.3)</td></tr>
<tr><td>Value(s) applied</td><td>
<table>
<tr><th colspan="2">Waste type j</th><th>k_j</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>As per Table 7 of the methodological tool “Emissions from solid waste disposal sites”.</td></tr>
<tr><td>Purpose of data</td><td>Calculation of baseline emissions</td></tr>
<tr><td>Additional comment</td><td>The project is located in São Pedro da Aldeia municipality, Rio de Janeiro state (Southeastern region of Brazil) which possesses humid/wet weather conditions[49]:
MAT = 23.7ºC
MAP = 1.171 mm</td></tr>
</table>

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

Data / Parameter	***Ru***
Unit	$Pa.m^3/kmol.K$
Description	Universal ideal gases constant
Source of data	As per the tool
Value(s) applied	8,314
Choice of data or Measurement methods and procedures	-
Purpose of data	Calculation of baseline emissions
Additional comment	Used for $F_{CH4,sent\_flare,y}$ and $F_{CH4,NG,y}$ following Options C and A, respectively.

Data / Parameter	MM_i
Unit	kg/kmol
Description	Molecular mass of greenhouse gas *i* ($i = CH_4$)
Source of data	As per the tool
Value(s) applied	16.04
Choice of data or Measurement methods and procedures	-
Purpose of data	Calculation of baseline emissions
Additional comment	Used for $F_{CH4,sent\_flare,y}$ and $F_{CH4,NG,y}$ following Options C and A, respectively.

Data / Parameter	MM_k
Unit	kg/kmol
Description	Molecular mass of gas *k* ($k = N_2$)
Source of data	As per the tool
Value(s) applied	28.01
Choice of data or Measurement methods and procedures	According to ACM0001, the simplification offered in the tool for calculating the molecular mass of the gaseous stream ($MM_{t,db}$) is valid. Thus, the volumetric fraction of the greenhouse gas (CH_4) is considered and the difference to 100% is considered as pure nitrogen.
Purpose of data	Calculation of baseline emissions
Additional comment	Not used in the case of the proposed project activity.

Data / Parameter	P_n
Unit	Pa
Description	Total pressure at normal conditions
Source of data	As per the tool
Value(s) applied	101,325
Choice of data or Measurement methods and procedures	-
Purpose of data	Calculation of baseline and project emissions
Additional comment	Used for $F_{CH4,sent\_flare,y}$ following Option C.

Data / Parameter	T_n
Unit	K
Description	Temperature at normal conditions
Source of data	As per the tool
Value(s) applied	273.15
Choice of data or Measurement methods and procedures	-
Purpose of data	Calculation of baseline and project emissions
Additional comment	Used for $F_{CH4,sent\_flare,y}$ following Option C.

"Tool to calculate the emission factor for an electricity system"

Data / Parameter	$FC_{i,m,y}$, $FC_{i,y}$, $FC_{i,k,y}$, $FC_{i,n,y}$ and $FC_{i,n,h}$
Unit	mass or volume unit
Description	Amount of fuel type i consumed by power plant/unit m, k or n (or in the project electricity system in case of FCi,y) in year y or hour h
Source of data	Official publications (data from ONS), IPCC default values and default values provided by the *"Tool to calculate the emission factor for an electricity system"*
Value(s) applied	Large amount of data. Please refer to the emission factor calculation spreadsheet which is attached to the PDD.
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 the project emissions due to electricity consumption
Additional comment	For methodological choices details, please refer to section E.6.1.

Data / Parameter	$EF_{CO2,i,y}$ and $EF_{CO2,m,i,y}$
Unit	tCO_2/GJ
Description	CO_2 emission factor of fossil fuel type *i* used in power unit *m* in year *y*
Source of data	IPCC default values at the lower limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories
Value(s) applied	Large amount of data. Please refer to the emission factor calculation spreadsheet which is attached to the PDD.
Choice of data or Measurement methods and procedures	As per the recommendation of the "Tool to calculate the emission factor for an electricity system". IPCC default values are being used since this information is neither provided by fuel suppliers nor regional and/or local default values are publicly available.
Purpose of data	Calculation of the project emissions due to electricity consumption
Additional comment	-

Data / Parameter	$EG_{m,y}$ and $EG_{k,y}$
Unit	MWh
Description	Net electricity generated by power plant/unit *m* or *k* in year *y*
Source of data	Official publications. Data from the Electric System National Operator was used.
Value(s) applied	Large amount of data. Please refer to the emission factor calculation spreadsheet which is attached to the PDD.
Choice of data or Measurement methods and procedures	Once for each crediting period using the most recent three historical years for which data is available at the time of submission of the PDD to the DOE for validation (*ex-ante* option).
Purpose of data	Calculation of the project emissions due to electricity consumption
Additional comment	For methodological choices details, please refer to section E.6.1.

Data / Parameter	$\eta_{m,y}$
Unit	-
Description	Average net energy conversion efficiency of power unit *m* in year *y*
Source of data	Default values provided in Annex 1 of the *"Tool to calculate the emission factor for an electricity system"*
Value(s) applied	Large amount of data. Please refer to the emission factor calculation spreadsheet which is attached to the PDD.
Choice of data or Measurement methods and procedures	As per the recommendation of the *"Tool to calculate the emission factor for an electricity system"*.
Purpose of data	Calculation of the project emissions due to electricity consumption
Additional comment	For methodological choices details, please refer to section E.6.1.

Data / Parameter	$EF_{grid,OM-adj,y}$
Unit	tCO_2/MWh
Description	Simple adjusted operating margin CO_2 emission factor in year *y*
Source of data	Official publications (data from ONS), IPCC default values and default values provided by the *"Tool to calculate the emission factor for an electricity system"*
Value(s) applied	0.3612
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 the project emissions due to electricity consumption
Additional comment	For methodological choices details, please refer to section E.6.1.

Data / Parameter	$EF_{BM,2013}$
Unit	tCO_2/MWh
Description	Build Margin CO_2 emission factor in year *y*
Source of data	Official publications (data from ONS), IPCC default values and default values provided by the *"Tool to calculate the emission factor for an electricity system"*
Value(s) applied	0.2850
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 the project emissions due to electricity consumption
Additional comment	For methodological choices details, please refer to section E.6.1.

The methodological tool "Project and leakage emissions from transportation of freight"

Data / Parameter	$EF_{CO2,f}$
Unit	g CO_2/t km
Description	Default CO_2 emission factor for freight transportation activity *f*
Source of data	Default data from the tool.
Value(s) applied	**Vehicle class** / **Emission factor (gCO_2/ t km)**: Light vehicles – 245; Heavy vehicles – 129
Choice of data or Measurement methods and procedures	Parameter applicable to Option B of the tool.
Purpose of data	Calculation of the project emissions due to transportation of freight
Additional comment	-

No additional parameters are required to be fixed *ex-ante* in the case of the proposed project activity. All parameters required for the project emissions calculation regarding transportation of freight will be monitored. Please refer to the section B.7.1.

The methodological tool "Project emissions from flaring"

No additional parameters are required to be fixed *ex-ante* in the case of the proposed project activity, since the project applies an open flare (50% default efficiency).

"Tool to calculate baseline, project and/or leakage emissions from electricity consumption"

No additional parameters are required to be fixed *ex-ante* in the case of the proposed project activity, since electricity to be used in the project is from the grid. *Ex-ante* parameters for the CO_2 emission factor of the grid is presented in section "Tool to calculate the emission factor for an electricity system" above.

Possibly, electricity may be generated from a captive plant installed at the project site considering the high variation of electricity supply which the project has been facing at the time of commissioning.

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

No additional parameters are required to be fixed *ex-ante* in the case of the proposed project activity. All parameters required for the project emissions calculation regarding fossil fuel combustion will be monitored. Please refer to the section B.7.1.

B.6.3. Ex ante calculation of emission reductions

Baseline emissions

Ex-ante calculation of baseline emissions is presented in the table below:

Table 9 – *Ex-ante* calculation of baseline emissions

Year	$BE_{CH4,y}$ (tCO_2/yr)	$BE_{NG,y}$ (tCO_2/yr)	$BE_{,y}$ (tCO_2/yr)
2016	46,379	7,398	53,776
2017	49,539	7,902	57,441
2018	52,474	8,370	60,844
2019	55,263	8,815	64,078
2020	57,963	9,246	67,208
2021	60,612	9,668	70,280
2022	63,238	10,087	73,325

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

Table 10 – Baseline emissions of methane from the SWDS

Year	$BE_{CH4,y}$ (tCO_2/yr)	$F_{CH4,PJ,y}$ (tCH_4/yr)	$F_{CH4,BL,y}$ (tCH_4/yr)	$BE_{CH4,y}$ (tCO_2/yr)
2016	110,425	2,650	530	46,379
2017	117,951	2,831	566	49,539
2018	124,937	2,998	600	52,474

2019	131,578	3,158	632	55,263
2020	138,007	3,312	662	57,963
2021	144,314	3,464	693	60,612
2022	150,567	3,614	723	63,238

As explained in section B.6.1, $F_{CH4,BL,y}$ is calculated according equation 3 and $F_{CH4,PJ,y}$ was calculated according to equation 11 based on 60% efficiency of the LFG capture system as presented in SCS Assessment Report 06212012.00 dated August 2012 and data used to calculate $BE_{CH4,y}$ is presented below following the methodological tool "Emissions from solid waste disposal sites":

- Model correction factor (φ) to account for model uncertainties: 0.75 (default value for Option 1 as per the Tool);
- The fraction of methane captured at the SWDS and flared (*f*), combusted or used in another manner is zero according to ACM0001;
- The global warming potential of methane (GWP_{CH4}) is 25 tCO_2/tCH_4 for the 2nd commitment period of Kyoto Protocol;
- Oxidation factor, reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste: 0.1 (default value as per ACM0001)
- The fraction of methane in the SWDS gas (F) is 50% according to the default value of the tool;
- Fraction of degradable organic carbon (DOC_f) that can decompose is 0.5 according to the default value of the tool;
- The values of fraction of degradable organic carbon (DOC_j) and the decay rate of waste (k_j) were used according to default values available in the tool of each type of waste j;
- *MFC (Methane Conversion Factor):* MCF value is adopted according with the type of SWDS. The Dois Arcos Landfill is a managed SWDS; thus, the MCF adopted is equal to 1.0;
- W_x (Total amount of organic waste prevented disposed in year x, in tons):

The amount of the solid waste entering in the Dois Arcos Landfill has been monitored by DAGR (the owner and operator of the landfill). For future years, estimative of residues was based on the SCS Assessment Report.

Table 11 – Historical and forecasted deposited solid waste at the site.

Year	*Annual disposal in tonnes ($W_{j,x}$)*
2008	52,999
2009	101,521
2010	113,751
2011	128,528
2012	155,385
2013	175,200

Year	*Annual disposal in tonnes (Wj,x)*
2017	197,189
2018	203,105
2019	209,198
2020	215,474
2021	221,938
2022	228,596

2014	180,456
2015	185,870
2016	191,446

2023	235,454
2024	242,518
2025	249,793

Source: SCS Assessment Report (2012)

The estimated amount of waste to be received is based on the SCS Assessment Report and the waste collection data based on project operator monitored information. The characterization of the municipal solid waste is based on the study performed by COMLURB in 2007:

Table 12 – Waste types historically disposed at the project site.

Category	% (wet basis)
Wood and wood products	1.38
Pulp, paper and cardboard	14.61
Food, food waste, beverages and tobacco	58.13
Textiles	0.00
Garden, yard and park waste	1.75
Glass, plastic, metal, other inert waste	24.13

Source: SCS Assessment Report (2012)

It is important mentioning that for $F_{CH4,PJ,y}$ calculation, the PPs ensured that the maximum plant upgrading capacity was considered.

b) Baseline emissions associated with natural gas use ($BE_{NG,y}$)

ACM0001 does not provide a guide for the *ex-ante* calculation of these baseline emissions. Therefore, it has been estimated that 95% of the collected gas ($F_{CH4,PJ,y}$) will be derived to the gas purification process. The balance of LFG collected is considered to be burned in flare while the upgrading facility stops (*e.g.* during maintenance or emergencies) or when there is an excess of LFG.

The IPCC emission factor for the natural gas[50] is equal to 58.3tCO_2e/TJ. Applying these figures to Equation 13, we obtain the results presented in the below table.

Table 13 --- Baseline emissions associated with natural gas use

Year	$F_{CH4,NG,y}$ (tCH_4/yr)	$BE_{NG,y}$ (tCO_2/yr)
2016	2,518	7,398
2017	2,689	7,902
2018	2,849	8,370
2019	3,000	8,815
2020	3,147	9,246

50 Value at the upper limit of the uncertainty at a 95% confidence interval as per the "*Tool to calculate project or leakage CO2 emissions from fossil fuel combustion*"..

2021	3,290	9,668
2022	3,433	10,087

Project Emissions (PE_y)

Ex-ante calculation of project emissions is presented in the table below:

Table 14 – *Ex-ante* calculation of project emissions

Year	$PE_{EC,y}$ (tCO_2/yr)	$PE_{FC,i,y}$ (tCO_2/yr)	$PE_{DT,y}$ (tCO_2/yr)	$PE_{flare,y}$ (tCO_2/yr)	PE_y (tCO_2/yr)
2016	1,601	0.04	0	1,656	3,258
2017	1,601	0.04	0	1,769	3,371
2018	1,601	0.04	0	1,874	3,475
2019	1,601	0.04	0	1,974	3,575
2020	1,601	0.04	0	2,070	3,671
2021	1,601	0.04	0	2,165	3,766
2022	1,601	0.04	0	2,259	3,860

a) Emissions from consumption of electricity ($PE_{EC,y}$)

The electricity consumed by the project activity is based on estimative from GNR DOIS ARCOS VALORIZAÇÃO DE BIOGÁS S.A. for the operation of the LFG capture system, upgrading facility and administrative office at the project site. Then, $EC_{PJ,y}$ is 4,130MWh/year.

The $TDL_{j,y}$ considered for the ex-ante calculation of $PE_{EC,y}$ is 20%, the default value provided by the "Tool to estimate the baseline, project and/or leakage emissions from electricity consumption".

Grid Emission Factor Calculation

The calculation of the combined margin CO_2 emission factor for grid connected power generation ($EF_{grid,CM,y}$) follows the steps established in the "Tool to calculate the emission factor for an electricity system".

Following Resolution #8, issued by the Brazilian DNA on 26th May, 2008, the Brazilian Interconnected Grid corresponds to the system to be considered, which includes grid power plants only (Option I of step 2 of the tool).

As described in the section B.6.1, the simple adjusted operating margin (option b of step 3 of the tool) and *ex-ante* data vintage were chosen for the calculation of $EF_{grid,OM,y}$. therefore, data from 2011, 2012 and 2013 were used in the calculation, since it is the most recent data available to the Project Participants.

$$EF_{grid,OM\text{-}adj,2011\text{-}2013} = 0.3612 tCO_2e/MWh$$

The $EF_{grid,BM,y}$ was calculated based on data from 2012 (the most recent data available) following the methodological choices presented in section B.6.1. An ex-ante option was chosen for this parameter.

$EF_{grid,BM,2013} = 0.2850tCO_2e/MWh$

Therefore:

$EF_{grid,CM,y} = 0.3231tCO_2e/MWh$

Considering $EC_{PJ,y}$ and $TDL_{j,\ y}$, and the $EF_{grid,CM,y}$ calculated above, the estimated project emissions are 1,601 tCO_2/year, as presented in the table below.

Table 15 – Estimative of project emissions from electricity consumption

Year	Electricity Consumed (MWh)	Grid Emission Factor (tCO_2e/MWh)	TDL_y (%)	Project emissions (tCO_2e)
2016	4,130	0.3231	20	1,601
2017	4,130			1,601
2018	4,130			1,601
2019	4,130			1,601
2020	4,130			1,601
2021	4,130			1,601
2022	4,130			1,601

If a fossil fuel generator is installed at the project site for electricity generation, fuel consumption will be considered and monitored following the "Tool to calculate project of leakage CO_2 emissions from fossil fuel consumption". However, for the *ex-ante* estimative, electricity consumption is considered to be supplied by the grid and, therefore, emissions due to the operation of a fossil fuel generator are zero.

b) Emissions from consumption of fossil fuels ($PE_{FC,y}$)

The quantity of LPG expected to be used in Dois Arcos project activity is 13kg per year. Considering a value for $NCV_{i,y}$ of 0.0465 GJ/kg from the 2014 Brazilian Energy Balance and $EF_{CO2i,y}$ of 0.0656tCO_2/GJ from the 2006 IPCC Guidelines on National GHG Inventories (at the upper limit of the uncertainty at a 95% confidence interval following the Tool), $COEF_{i,y}$ = 0.00305 tCO_2/kg while using Option B of the "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion".

Table 16 – Estimative of project emissions from fossil fuel consumption

Year	LPG Consumption (kg)	$COEF_{i,y}$ (tCO_2/kg)	Project emissions (tCO_2e)
2016	13	0.00305	0.04
2017	13		0.04

2018	13		0.04
2019	13		0.04
2020	13		0.04
2021	13		0.04
2022	13		0.04

c) Emissions from the distribution of compressed/liquefied LFG using trucks ($PE_{DT,y}$)

Emissions from the transportation of compressed/liquefied LFG using trucks

In the first year of the project operation, the upgraded gas will be transported by trucks up to the implementation of NG pipelines at the project site, which is expected to occur in December 2015. Therefore, the NG pipelines will be implemented before the starting date of the crediting period (January 2016), thus $PE_{DT,y}$ = 0 tCO_2e/yr.

Emissions from CH_4 leaks during the transportation of compressed/liquefied LFG

As mentioned above, upgraded gas transportation by trucks is not expected to occur in January onwards. $PE_{leaks,y}$ = 0 tCO_2e/yr.

d) Project emissions from flaring

The calculation of the *ex-ante* methane emissions from flaring of vent gas has been estimated using the balance of methane in the LFG collected by the proposed project activity system and the methane in the LFG sent to the upgrading process. It is assumed that all the methane not injected to the natural gas distribution grid due to inefficiencies of the process will be flared.

As per the tool, for open flares a default value of 50% shall be used when the flame is detected in minute *m* (please refer to Section B.6.1 above). It was assumed that 95% LFG collected will be sent to the upgrading facility. Then, the project emissions due to flaring gases have been estimated as:

Table 17 – Estimative of project emissions from flaring

Year	***LFG (Nm^3)***	***$PE_{flare,y}$ (tCO_2e/year)***
2016	370,141	1,656
2017	395,365	1,769
2018	418,784	1,874
2019	441,045	1,974
2020	462,592	2,070
2021	483,735	2,165
2022	504,695	2,259

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)
2016	53,776	3,258	0	50,519
2017	57,441	3,371	0	54,071
2018	60,844	3,475	0	57,368
2019	64,078	3,575	0	60,503
2020	67,208	3,671	0	63,537
2021	70,280	3,766	0	66,514
2022	73,325	3,860	0	69,466
Total	446,953	24,975	0	421,978
Total number of crediting years	7			
Annual average over the crediting period	63,850	3,568	0	60,283

B.7. Monitoring plan

B.7.1. Data and parameters to be monitored

ACM0001 – Flaring or use of landfill gas

Data / Parameter	Management of SWDS
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	Calculation of baseline emissions
Additional comment	-

Data / Parameter	$Op_{j,h}$
Unit	-
Description	Operation of the equipment that consumes the LFG
Source of data	Project participants
Value(s) applied	Not used for *ex-ante* calculation.
Measurement methods and procedures	In the context of the proposed project activity, equipment unit *j* using *the LFG* consists of the LFG upgrading facility and flares. Hence, the following parameters are to be used to ensure that the plant is operating in hour *h*: <u>*For the LFG upgrading facility*</u> • Products generated. Monitor the generation of upgraded gas which is sold to the consumer. This information can be cross-checked with invoices; <u>*For the flaring system*</u> • Flame. Flame detection system is used to ensure that the equipment is in operation; $Op_{j,h}$=0 when: • No products are generated in the hour *h;* • Flame is not detected continuously in hour *h* (instantaneous measurements are made at least every minute); Otherwise, $Op_{j,h}$=1
Monitoring frequency	Hourly
QA/QC procedures	Flow meters and flame detectors will be subject to a regular maintenance and testing regime to ensure accuracy. Calibration shall be according to manufacturers' specifications.
Purpose of data	Calculation of baseline emissions
Additional comment	Monitoring of working hours of equipment is required in order to ensure that no emission reductions are claimed for methane destruction during non-working hours.

Data / Parameter	$EG_{EC,y}$
Unit	MWh
Description	Amount of electricity consumed by the project activity in year *y*
Source of data	Electricity meter
Value(s) applied	4,130
Measurement methods and procedures	Sources of consumption include electricity consumed for the operation of the plant (process and administrative office).
Monitoring frequency	Continuous, aggregated at least annually.
QA/QC procedures	Electricity meter will be subject to regular maintenance and testing to ensure accuracy following the recommendations of the meter manufacturer. Readings will be double checked by the electricity distribution company.
Purpose of data	Calculation of project emissions due to electricity consumption
Additional comment	In accordance with ACM0001, this parameter is equivalent to $EC_{PJ,k,y}$ in the tool.

Data / Parameter	$F_{CH4,NG-cons,y}$
Unit	tCH_4/yr
Description	Amount of methane in the LFG which is delivered to consumers using trucks in year y
Source of data	Onsite measurements
Value(s) applied	Not used for *ex-ante* calculation.
Measurement methods and procedures	Flow meters
Monitoring frequency	Per batch and aggregated annually
QA/QC procedures	Maintenance shall be according to manufacturers' specifications.
Purpose of data	Calculation of project emissions due to upgraded gas transportation using trucks.
Additional comment	Transportation by trucks is not expected to occur during the crediting period of the project. However, if delays for the NG pipeline construction occur $F_{CH4,NG-cons,y}$ monitoring will be conducted following the methodology and applicable tools.

Data / Parameter	$F_{CH4,NG\ TR,y}$
Unit	tCH_4/yr
Description	Amount of methane in the LFG which is sent to trucks in year y
Source of data	Onsite measurements
Value(s) applied	Not used for *ex-ante* calculation.
Measurement methods and procedures	Flow meters
Monitoring frequency	Per batch and aggregated annually
QA/QC procedures	Maintenance shall be according to manufacturers' specifications.
Purpose of data	Calculation of project emissions due to upgraded gas transportation using trucks
Additional comment	Transportation by trucks is not expected to occur during the crediting period of the project. However, if delays for the NG pipeline construction occur, $F_{CH4,NG\ TR,y}$ monitoring will be conducted following the methodology and applicable tools.

Methodological tool "Emissions from solid waste disposal sites"

Data / Parameter	f_y
Unit	-
Description	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.*
Source of data	Select the maximum value from the following: (a) contract or regulation requirements specifying the amount of methane that must be destroyed/used (if available) and (b) historic data on the amount captured.
Value(s) applied	0
Measurement methods and procedures	In accordance with the ACM0001 methodology, this value is to be assigned since the amount of LFG that would have been captured and destroyed is already accounted for in Equation 2.
Monitoring frequency	As per the applicable methodological tool *"Emissions from solid waste disposal sites"*, for application A, this parameter is determined once for the crediting period ($f_y = f$).
QA/QC procedures	-
Purpose of data	Calculation of baseline emissions
Additional comment	

Note: The depth and height of the water table in the SWDS is not monitored as the MCF has been selected as a default value as per Application A of the methodological tool "Emissions from solid waste disposal sites".

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

Data / Parameter	$V_{t,wb}$
Unit	m^3 wet gas/h
Description	Volumetric flow of the gaseous stream in time interval *t* on a wet basis
Source of data	Onsite measurements
Value(s) applied	Not used for *ex-ante* calculations.
Measurement methods and procedures	Volumetric flow measurement should always refer to the actual pressure and temperature. Instruments with recordable electronic signal (analogical or digital) are required.
Monitoring frequency	Continuous, aggregated at least hourly.
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 specification.
Purpose of data	Calculation of baseline and project emissions
Additional comment	This parameter will be monitored in Option C, in order to calculate $F_{CH4,sent\_flare,y}$ (LFG flared)

Data / Parameter	$V_{t,db}$
Unit	m^3 dry gas/h
Description	Volumetric flow of the gaseous stream in time interval *t* on a dry basis
Source of data	Onsite measurements
Value(s) applied	Not used for *ex-ante* calculations.
Measurement methods and procedures	Volumetric flow measurement should always refer to the actual pressure and temperature. Calculated based on the wet basis flow measurement plus water concentration measurement.
Monitoring frequency	Continuous, aggregated at least hourly.
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 specification.
Purpose of data	Calculation of baseline and project emissions
Additional comment	This parameter will be monitored in Option A, in order to calculate $F_{CH4,NG}$ and $F_{CH4,sent\_flare,y}$ (upgraded gas that does not reach specifications to be sent to the NG pipeline).

Data / Parameter	$V_{i,t,db}$
Unit	m^3 gas *i*/m^3 dry gas
Description	Volumetric fraction of greenhouse gas *i* in time interval *t* on a dry basis
Source of data	Onsite measurements
Value(s) applied	Not used for *ex-ante* calculations.
Measurement methods and procedures	Continuous gas analyzer operating in dry basis. Volumetric flow measurement should always refer to the actual pressure and temperature.
Monitoring frequency	Continuous, aggregated at least hourly.
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	Calculation of baseline and project emissions
Additional comment	This parameter will be monitored in Option A, in order to calculate $F_{CH4,NG}$ and $F_{CH4,sent\_flare,y}$ (upgraded gas that does not reach specifications to be sent to the NG pipeline).

Data / Parameter	$v_{i,t,wb}$
Unit	m^3 gas *i*/m^3 wet gas
Description	Volumetric fraction of greenhouse gas *i* in a time interval *t* on a wet basis
Source of data	Onsite measurements
Value(s) applied	Not used for *ex-ante* calculations.
Measurement methods and procedures	Calculated based on the dry basis analysis plus water concentration measurement or continuous in-situ analyzers if not specified in the underlying methodology
Monitoring frequency	Continuous, aggregated at least hourly.
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	Calculation of baseline emissions
Additional comment	This parameter will be monitored in Option C in order to calculate $F_{CH4,sent\_flare,y}$

Data / Parameter	T_t
Unit	K
Description	Temperature of the gaseous stream in time interval *t*
Source of data	Onsite measurements
Value(s) applied	Not used for *ex-ante* calculations.
Measurement methods and procedures	Instruments with recordable electronic signal (analogical or digital) are required. The temperature will be measured by the flow meters turbines which possesses temperature sensors.
Monitoring frequency	Continuous, aggregated at least hourly.
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	Calculation of baseline and project emissions
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. Applicable to Options A and C in order to determine $F_{CH4,NG}$ and $F_{CH4,sent\_flare,y}$ parameters, respectively.

Data / Parameter	P_t
Unit	Pa
Description	Pressure of the gaseous stream in time interval *t*
Source of data	Onsite measurements
Value(s) applied	Not used for *ex-ante* calculation.
Measurement methods and procedures	Instruments with recordable electronic signal (analogical or digital) are required. Examples include pressure transducers, etc.
Monitoring frequency	Continuous, aggregated at least hourly.
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.
Purpose of data	Calculation of baseline and project emissions
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). Applicable to Option A and C in order to determine the $F_{CH4,NG}$ and $F_{CH4,sent\_flare,y}$ parameters, respectively.

The methodological tool "Project and leakage emissions from transportation of freight"

Data / Parameter	$D_{f,m}$
Unit	kilometre
Description	Return trip distance between the origin and destination of freight transportation activity *f* in monitoring period *m*
Source of data	Records of vehicle operator or records by project participants
Value(s) applied	Not used for *ex-ante* calculation.
Measurement methods and procedures	Determined once for each freight transportation activity *f* for a reference trip using the vehicle odometer or any other appropriate sources (e.g. on-line sources). In the case of the project, a tachometer register will be used.
Monitoring frequency	To be updated whenever the distance changes.
QA/QC procedures	Parameter applicable to Option B.
Purpose of data	Calculation of project emissions due to transportation of freight
Additional comment	Transportation by trucks is not expected to occur during the crediting period of the project. However, if delays for the NG pipeline construction occur, $D_{f,m}$ monitoring will be conducted as required by the methodology.

Data / Parameter	$FR_{f,m}$
Unit	Tonnes
Description	Total mass of freight transported in freight transportation activity *f* in monitoring period *m*
Source of data	Records by project participants or records by truck operators
Value(s) applied	Not used for *ex-ante* calculation.
Measurement methods and procedures	Measurements are undertaken in line with national or international fuel standards.
Monitoring frequency	Continuously
QA/QC procedures	-
Purpose of data	Calculation of project emissions due to transportation of freight
Additional comment	Parameter applicable to Option B.

The methodological tool "Project emissions from flaring"

Data / Parameter	$Flame_m$
Unit	Flame on or Flame off
Description	Flame detection of flare in the minute *m*
Source of data	Project participants
Value(s) applied	Not used for *ex-ante* calculations.
Measurement methods and procedures	Measure using a fixed installation optical flame detector: Thermopar, type "K".
Monitoring frequency	Once per minute. Detection of flame recorder 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 project emissions from flaring
Additional comment	Applicable to all flares.

"Tool to calculate baseline, project and/or leakage emissions from electricity consumption"

Data / Parameter	$TDL_{project, y}$
Unit	%
Description	Average technical transmission and distribution losses for providing electricity to source *j* in year *y*
Source of data	The Brazilian Power Regulatory Agency (ANEEL)
Value(s) applied	If ANEEL data is not available at the time of the verification, then the default data provided by tool of 20% shall be considered. 20% (default data provided by the tool was considered for the ex-ante estimative)
Measurement methods and procedures	Use recent, accurate and reliable data available within the host country.
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	Official source of data.
Purpose of data	Calculation of project emissions due to electricity consumption.
Additional comment	TDL from the local power utility shall be used.

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

Data / Parameter	$EF_{CO2,i,y}$
Unit	tCO_2/GJ
Description	Weighted average CO_2 emission factor of fuel type *i* in year *y* (*i* = natural gas)
Source of data	2006 IPCC Guidelines on National GHG Inventories
Value(s) applied	0.0583
Measurement methods and procedures	IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories following the tool.
Monitoring frequency	Any future revision of the IPCC Guidelines shall be taken into account.
QA/QC procedures	Official source of data.
Purpose of data	Calculation of baseline emissions due to natural gas use
Additional comment	Option (c) of the "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion"

Data / Parameter	$FC_{i,j,y}$
Unit	kg/yr
Description	Quantity of fuel type *i* combusted in process *j* during the year y (*i* = LPG)
Source of data	Sales of receipt
Value(s) applied	13
Measurement methods and procedures	Conservatively, it shall be considered that all LPG purchase will be used.
Monitoring frequency	At every purchase of LPG
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 due to fossil fuel consumption for the flare ignition.
Additional comment	-

Data / Parameter	$NCV_{i,y}$
Unit	GJ/m^3
Description	Weighted average net calorific value of fuel type *i* in year *y* (*i* = LPG)
Source of data	The Brazilian Energetic Balance ("BEN")
Value(s) applied	0.0465
Measurement methods and procedures	Measurements should be undertaken in line with national or international fuel standards
Monitoring frequency	Review appropriateness of the 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 ISO17025 accreditation or justify that they can comply with similar quality standards.
Purpose of data	Calculation of project emissions due to fossil fuel consumption for the flare ignition.
Additional comment	Applicable where Option B is used.

Data / Parameter	$EF_{CO2,i,y}$
Unit	tCO_2/GJ
Description	Weighted average CO_2 emission factor of fuel type *i* in year *y* (*i* = LPG)
Source of data	2006 IPCC Guidelines on National GHG Inventories
Value(s) applied	0.0656
Measurement methods and procedures	IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories following the tool.
Monitoring frequency	Any future revision of the IPCC Guidelines shall be taken into account.
QA/QC procedures	Official source of data.
Purpose of data	Calculation of project emissions from fossil fuel consumption for the flare ignition.
Additional comment	Option (c) of the "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion"

Data / Parameter	$FC_{i,j,y}$
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	Not used for *ex-ante* calculation
Measurement methods and procedures	Conservatively, it shall be considered that all fossil fuel purchase will be used.
Monitoring frequency	At every purchase of fossil fuel.
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 due to fossil fuel consumption for electricity generation
Additional comment	The installation of a fossil fuel generator is possible considering intermittences of electricity supply at the project site. If this type of generator is installed at the project site, fossil fuel shall be monitored in order to calculation project emissions.

Data / Parameter	$NCV_{i,y}$
Unit	GJ/m^3
Description	Weighted average net calorific value of fuel type *i* in year *y*
Source of data	The Brazilian Energetic Balance ("BEN")
Value(s) applied	Not used for *ex-ante* calculation
Measurement methods and procedures	Measurements should be undertaken in line with national or international fuel standards
Monitoring frequency	Review appropriateness of the 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 ISO17025 accreditation or justify that they can comply with similar quality standards.
Purpose of data	Calculation of project emissions due to fossil fuel consumption for electricity generation
Additional comment	Applicable where Option B is used.

Data / Parameter	$EF_{CO2,i,y}$
Unit	tCO_2/GJ
Description	Weighted average CO_2 emission factor of fuel type *i* in year *y*
Source of data	2006 IPCC Guidelines on National GHG Inventories
Value(s) applied	Not used for *ex-ante* calculation
Measurement methods and procedures	IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories following the tool.
Monitoring frequency	Any future revision of the IPCC Guidelines shall be taken into account.
QA/QC procedures	Official source of data.
Purpose of data	Calculation of project emissions due to fossil fuel consumption for electricity generation
Additional comment	Option (c) of the "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion"

Data / Parameter	$FC_{i,j,y}$
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	Not used for *ex-ante* calculation
Measurement methods and procedures	Conservatively, it shall be considered that all fossil fuel purchase will be used.
Monitoring frequency	At every purchase of fossil fuel.
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 due to fossil fuel consumption for transportation of upgraded gas
Additional comment	Applicable to Option A of the methodological tool “Project and leakage emissions from transportation of freight”.

Data / Parameter	$NCV_{i,y}$
Unit	GJ/m^3
Description	Weighted average net calorific value of fuel type *i* in year *y*
Source of data	The Brazilian Energetic Balance ("BEN")
Value(s) applied	Not used for *ex-ante* calculation
Measurement methods and procedures	Measurements should be undertaken in line with national or international fuel standards
Monitoring frequency	Review appropriateness of the 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 ISO17025 accreditation or justify that they can comply with similar quality standards.
Purpose of data	Calculation of project emissions due to fossil fuel consumption for transportation of upgraded gas
Additional comment	Applicable to Option A of the methodological tool "Project and leakage emissions from transportation of freight".

Data / Parameter	$EF_{CO2,i,y}$
Unit	tCO_2/GJ
Description	Weighted average CO_2 emission factor of fuel type *i* in year *y*
Source of data	2006 IPCC Guidelines on National GHG Inventories
Value(s) applied	Not used for *ex-ante* calculation
Measurement methods and procedures	IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories following the tool.
Monitoring frequency	Any future revision of the IPCC Guidelines shall be taken into account.
QA/QC procedures	Official source of data.
Purpose of data	Calculation of project emissions due to fossil fuel consumption for transportation of upgraded gas
Additional comment	Applicable to Option A of the methodological tool "Project and leakage emissions from transportation of freight".

B.7.2. Sampling plan

Not applicable.

B.7.3. Other elements of monitoring plan

The monitoring of project activity will follow the requirements established in ACM0001 and referred tools. All data monitored will be available at the time of the verification and will be archived electronically for two years after the end of the crediting period or the last issuance of CERs, whichever occurs later.

Monitoring equipment/system

The plant is expected to have 5 (five) meters, which measures: (i) the landfill gas (LFG) sent to flare (FT1), (ii) the LFG sent to the upgrading system (FT2), (iii) the biomethane resulted from upgrading (FT3), (iv) the biomethane sent to the NG distribution system (FT5), (iv) the biomethane which does not reach the required parameters to be delivered to the NG distribution system and, for this reason, is flared (FT6). The project sponsor ensures that if delays during the NG pipelines occur, the required monitoring will be proceeded to determine the biomethane loaded in trucks and delivered to off-site consumers in order to calculate baseline and project emissions, otherwise, emission reductions will be considered as zero during this period.

During the validation visit, there were 8 (eight) gas analysers installed at the plant for the monitoring of O_2, H_2S, CH_4 and CO_2 of the LFG and the upgraded gas. Furthermore, there was an

electricity meter from the local power utility, which measures electricity used for the production process and the administrative office. In the future, the project sponsor may install another electricity meter in order to separate the electricity measurement used in the process and at the office.

Maintenance and calibration of the monitoring equipment and system will be made in accordance with manufacturer's recommendations and following national/international standards. Calibrations of measuring equipment will be carried out by an accredited person or institution.

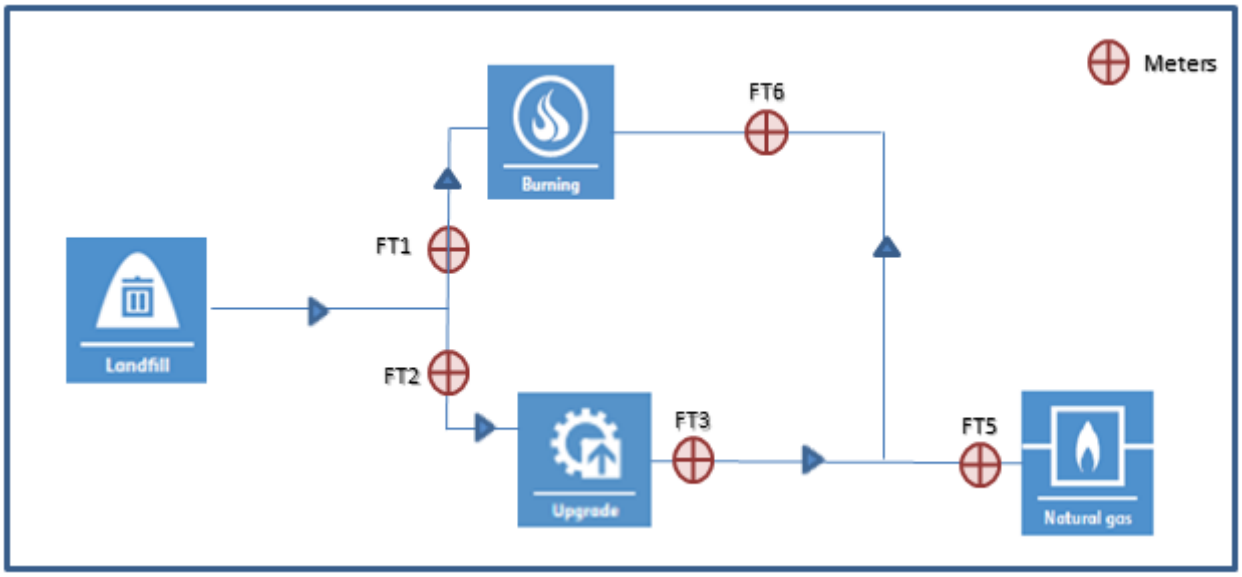

Figure 9 – Diagram of gas meters and expected location

Data transmission, processing and storage

The variables described in item B.7.1 will be automatically registered in a supervisory computer system. There will be a responsible person in charge of data checking in order to keep the process functioning. If the automatic transmission fails, the responsible person will contact an operator to register data manually. If data can be retrieved subsequently, they will be reintegrated on the server. All information will be stored physically on the disk of the server machine and a backup copy is to be done periodically. Copies of the files will be stored up to two years after the end of the crediting period or the last issuance of CERs for this project activity whichever occurs later.

Responsibilities

The CDM aspects of the project are managed by the administrators of the biogas and purification plant, who is in charge of monitoring activities. It is the ultimate responsibility of the Director to ensure the content of the monitoring report is correct at the time of requesting issuance. The CDM Project Managers supervises the calibration and maintenance procedures. Maintenance programs are carried out on site by the Field Technician, who also makes sure the monitoring tools are operating correctly.

Training

Employees involved in the monitoring will be periodically trained internally and/or externally. Training will include: review of equipment, calibration requirements, configuration of monitoring equipment, maintenance requirements.

B.8. Date of completion of application of methodology and standardized baseline and contact information of responsible persons/ entities

Date of completion: 05/08/2015

Contact information of responsible person/entity for completing the PDD form:

Name: A. Ricardo J. Esparta

Company: Ecopart Assessoria em Negócios Empresariais Ltda.

E-mail: ricardo.esparta@egao.com.br

Tel: +55 (11) 3063-9068

SECTION C. Duration and crediting period

C.1. Duration of project activity

C.1.1. Start date of project activity

17/12/2012

In accordance with the "*Glossary of CDM Terms*" (EB66, Annex 63), the start date of the CDM Project Activity corresponds to "*the earliest date at which either the implementation or construction or real action of a CDM project activity or PoA begins*".

Table 18 – Main events related to the implementation of the proposed project activity

Date	Action
04/09/2012	Issuance of the Construction License ("LI" from the Portuguese Licença de Instalação) for the biogas capture and flaring in Dois Arcos landfill
18/09/2012	Creation of the special purpose company GNR Dois Arcos Valorização de Biogás S.A.
17/12/2012	Approval of the capital contribution for the implementation of the proposed project activity
11/01/2013	Transfer of the capital contribution for the SPC GNR Dois Arcos (formerly known as MDCPar)
25/03/2013	Signature of the contract for the purchase and installation of the upgrading system
22/05/2013	Issuance of the Construction License (LI) for the biogas upgrading system by the environmental agency of São Pedro da Aldeia municipality
15/08/2013	Signature of the contract for the plant construction and integration (civil works)
05/11/2013	Issuance of the purchase order of the compressor and other electronic equipment
04/04/2014	Issuance of the Operating License ("LO" from the Portuguese Licença de Operação) for natural gas processing

The identified starting date of the proposed project activity represents the date the capital contribution approval for the project implementation occurred. All other tasks towards the implementation of the proposed CDM Project Activity – issuance of the Construction License and the creation of the SPC company – do not require significant expenditures and, therefore, do not demonstrate that the project would in fact be implemented. The capital contribution represented almost 50% of total investment for the project implementation and, therefore, it shall be considered as the first relevant action for the project implementation.

C.1.2. Expected operational lifetime of project activity

20 year – 0 month.

C.2. Crediting period of project activity

C.2.1. Type of crediting period

Renewable crediting period.

C.2.2. Start date of crediting period

01/01/2016, when the project is expected to be registered under CDM.

C.2.3. Length of crediting period

7 years – 0 month (renewable).

SECTION D. Environmental impacts

D.1. Analysis of environmental impacts

In Brazil, there are no specific environmental policies or regulations regarding LFG capture and destruction. However, the sponsor of any project that involves construction, installation, expansion or operation of any polluting or potentially polluting activity or any other capable to cause environmental degradation is obliged to secure a several permits from the relevant environmental agency (federal and/or local, depending on the project) as determined by Resolution nr. 237/97 from the National Environmental Council ("CONAMA" from the Portuguese Conselho Nacional do Meio Ambiente). Therefore, the following licenses are required:

- The Preliminary License (from the Portuguese *Licença Prévia* or *LP*);
- The Construction License (from the Portuguese *Licença de Instalação* or *LI*);
- The Operating License (from the Portuguese *Licença de Operação* or *LO*).

Furthermore, the CONAMA Resolution nr. 237/97 requires environmental studies in order to issue licenses.

All environmental impacts related to the construction and operation of Dois Arcos landfill were raised at the Environmental Study Assessment prepared to the Landfill Process of Environmental Licensing, and submitted to environmental agency of Rio de Janeiro State ("INEA" from the Portuguese Instituto Estadual do Ambiente). According to this study, no transboundary impacts for the operation of Dois Arcos landfill were identified. For this reason, Dois Arcos Operating License nr. FE013200 for sanitary landfill activities was issued on August 24th, 2007. DAGR is in process to renew the Operating License.

Regarding the natural gas processing, the project developer received the Operating License nr. 008/2014 issued by the environmental agency of São Pedro da Aldeia on April 4th, 2014 valid up to October 3rd, 2015. As required during the licensing process, a Risk Analysis Study for the LFG use in Dois Arcos landfill was prepared by Eidos do Brasil. The study is composed by 10 chapters as described below:

1. Introduction;
2. Technical of the project and steps involved;
3. Physical and chemical properties of methane and hydrogen sulphide;
4. Transport of substances;
5. Identification of risks and hypothesis;
6. Mapping and calculation of consequences and vulnerability;
7. Preventing and mitigating measures;
8. Conclusion;
9. Technical team;
10. References.

According to the environmental study, the following risks were identified:

- H_2S emission
  There are two phases involved in the LFG treatment: (i) absorption and stripping and (ii) adsorption system. During these phases, CO_2 and H_2S are removed through water absorption and LFG dehumidification. Therefore, H_2S could be released to atmosphere due to problems with the water regeneration system during the LFG treatment. However, the greatest distance of the gas dispersion is 4 meters, which does not reach the local population.
- LFG and renewable natural gas (LFG after treatment) leak
  The LFG is transported from the blowers to the compression system for compression. Thus, it may occur LFG leak considering problems in the LFG compression system. In this case, there is a possibility of: (i) jet fire (combustion in high velocity) immediately after the LFG release, and/or (ii) flashfire (combustion without pressure) and Confined Vapour Cloud Explosion, with retard effect and/or (iii) toxic product release. Also, leaking of renewable natural gas (LFG after treatment) may occur.

Although risks identified for LFG use are tolerable, the following measures were identified in order to avoid risks mentioned above:

- Prepare periodic inspections and maintenance procedures;
- Prepare operational procedures and ensure their applicability;
- Promote training with operators based on legal regulations;
- Install and monitor the supervision/control system;
- Install and monitor H2S and hydrocarbons detection system;
- Eliminate ignition sources;
- Prepare "Emergency Response Plan" and ensure its applicability.

D.2. Environmental impact assessment

As previously explained in section above, the environmental negative impacts of the project implementation are not considered significant and all impacts raised in the Environmental Study were analysed by the environmental agency.

SECTION E. Local stakeholder consultation

E.1. Solicitation of comments from local stakeholders

According to Resolution nr. 7, issued on March 5th 2008[51], Brazilian Designated National Authority (*Comissão Interministerial de Mudanças Globais do Clima – CIMGC)*, requests, among other documents, comments from local stakeholders in order to provide the Letter of Approval for a project.

The Resolution determines that the project proponent has to send invite for comments, at least, the following agents involved in and affected by project activity:

- Municipal governments and City Councils;
- State and Municipal Environmental Agencies;
- Brazilian Forum of NGOs and Social Movements for Environment and Development;
- Community associations;
- State Attorney for the Public Interest (state and federal).

The same resolution also requires that at the time these letters are sent, a version of the PDD in the local language and a declaration stating how the project contributes to the sustainable development of the country must be made available to these stakeholders at least 15 days previous to the starting of the Global Stakeholder Process (GSP).

The Portuguese version of the PDD was published at the internet website <https://sites.google.com/site/dcpconsulta/> on 03/07/2014 which is also the date when the invitation letters were sent to the following agents:

- Prefeitura Municipal de São Pedro da Aldeia - RJ / City Hall of São Pedro da Aldeia – RJ;
- Secretaria Municipal de Meio Ambiente de São Pedro da Aldeia - RJ / Environment Agency of São Pedro da Aldeia – RJ;
- Câmara dos Vereadores de São Pedro da Aldeia - RJ / Municipal Assembly of São Pedro da Aldeia – RJ;
- INEA – Instituto Estadual do Ambiente – Rio de Janeiro / Rio de Janeiro Enviromental Agency;
- Ministério Público do Estado do Rio de Janeiro / State Attorney for the Public Interest of Rio de Janeiro;
- Fórum Brasileiro de ONG's e Movimentos Sociais para o meio Ambiente e Desenvolvimento (FBOMS) / Brazilian Forum of NGOs and Social Movements for the Development and Environment;

[51] Available at: <http://www.mct.gov.br/>.

- ABES – Rio – Associação Brasileira de Engenharia Sanitária e Ambiental / Brazilian Association of Sanitary and Environment Engineering;
- Ministério Público Federal / Federal State Attorney for the Public Interest.

Copies of the letters and post office confirmation of receipt are available upon request and will be submitted to the DOE during the validation of the Project Activity.

E.2. Summary of comments received

No comments have been received yet.

E.3. Report on consideration of comments received

No comments have been received yet.

SECTION F. Approval and authorization

Not applicable. According to the Brazilian DNA requirements, the Letter of Approval is issued after the conclusion of the CDM validation only.

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Appendix 1. Contact information of project participants and responsible persons/ entities

Project participant and/or responsible person/ entity	☒ Project participant ☐ Responsible person/ entity for application of the selected methodology (ies) and, where applicable, the selected standardized baselines to the project activity
Organization name	GNR Dois Arcos Valorização de Biogás S.A.
Street/P.O. Box	Avenida Rio Branco 134/18
Building	-
City	Rio de Janeiro
State/Region	Rio de Janeiro
Postcode	20040-002
Country	Brazil
Telephone	+55 (21) 3177-5900
Fax	-
E-mail	-
Website	http://www.ecometano.com.br/
Contact person	Mrs. Carol Dick
Title	-
Salutation	Mrs.
Last name	Dick
Middle name	-
First name	Carol
Department	-
Mobile	-
Direct fax	-
Direct tel.	-
Personal e-mail	carol.dick@ecometano.com.br

Project participant and/or responsible person/ entity	☐ Project participant ☒ Responsible person/ entity for application of the selected methodology (ies) and, where applicable, the selected standardized baselines to the project activity
Organization name	Ecopart Assessoria em Negócios Empresariais Ltda.
Street/P.O. Box	Rua Padre João Manoel, 222
Building	-
City	São Paulo
State/Region	São Paulo
Postcode	01411-000
Country	Brazil
Telephone	+55 11 3063-9068
Fax	+55 11 3063-9069
E-mail	-
Website	www.eqao.com.br
Contact person	Mr. A. Ricardo J. Esparta
Title	-
Salutation	Mr.
Last name	Esparta
Middle name	Jacintho
First name	A. Ricardo
Department	-
Mobile	-
Direct fax	+ 55 (11) 3063-9068
Direct tel.	+ 55 (11) 3063-9068
Personal e-mail	focalpoint@eqao.com.br

Appendix 2. Affirmation regarding public funding

There is no public funding from Parties included in Annex I involved in this project activity.

Appendix 3. Applicability of methodology and standardized baseline

This section is intentionally left blank. Please refer to sections B.1 and B.2.

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

This section is intentionally left blank. Please refer to sections B.6.1 and B.6.3.

Appendix 5. Further background information on monitoring plan

This section is intentionally left blank. Please refer to sections B.7.1. and B.7.3.

Appendix 6. Summary of post registration changes

Not applicable. This section is intentionally left blank.

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Document information

Version	*Date*	*Description*
06.0	9 March 2015	Revisions 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; • Editorial improvement.
05.0	25 June 2014	Revisions 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;* • Editorial improvement.
04.1	11 April 2012	Editorial revision to change version 02 line in history box from Annex 06 to Annex 06b

Version	*Date*	*Description*
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.

Decision Class: Regulatory
Document Type: Form
Business Function: Registration
Keywords: project activities, project design document