PICHACAY LANDFILL GAS RENEWABLE ENERGY PROJECT

Document Prepared by Martijn Vis, BTG Biomass Technology Group B.V.

Contact Information

Project Title	**Pichacay Landfill Gas Renewable Energy Project**
Version	**3.2**
Date of Issue	**7 July 2019**
Monitoring Period	**27 July 2017 to 31 December 2018**
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1 PROJECT DETAILS

1.1 Summary Description of the Project and its Implementation Status

At the Pichacay landfill the municipal wastes from the city of Cuenca are disposed. In the landfill, methane is produced, which before project implementation, was released into the atmosphere. The project involves the implementation of a landfill gas (LFG) extraction network with horizontal and vertical pipes, a biogas pumping station, 4 engine-gensets of 0.85 MWe each, a flare and a transformer to 22 kV. The project recovers landfill methane and delivers electricity to the grid.

The landfill - without landfill gas recovery - is in operation since 2001; the environmental impact assessment and other needed permissions for landfill gas extraction and renewable electricity generation were obtained in 2014. The project was constructed and commissioned between 2014 - 2017 and started commercial operation with one engine-genset on 27 July 2017. The second engine-genset is expected to start operation around July 2019. For the first 2 engines the project has all licences to be operational until 2029. The company wishes to extend operation after this date. The 3rd and 4th engine are planned to become operational around 1 January 2022. Since engine 3 & 4 are still in an early stage of development no permits have been obtained yet.

Prior to the implementation of the project organic waste at the landfill was left to decay, and methane was emitted to the atmosphere. The project collects methane that would otherwise be emitted to the atmosphere. By generation of renewable electricity, grid connected electricity generation capacity is replaced, reducing emissions of fossil-based electricity generation.

The project is located in Santa Ana, city of Cuenca, province of Azuay, in Ecuador.

In the first crediting period, the project is expected to reduce 332369 tCO_2e, which is 33237 tCO_2e per year. In the first monitoring period of 27 July 2017 – 31 Dec 2018 a total emission reduction of 38259 tCO_2e is achieved.

1.2 Sectoral Scope and Project Type

Sectoral scope: 13 & 1, Waste handling and disposal & Energy (renewable/non-renewable)

Project Type -III Other project and Type-I Renewable Energy Project

The project activity is not a grouped project.

1.3 Project Proponent

Organization name	EMAC-BGP ENERGY COMPAÑÍA DE ECONOMÍA MIXTA CEM
Contact person	Mr. Ing. Ernesto Andrade Mr. David González Hidalgo (since 13 May 2019)
Title	General manager
Address	Edif. San Vicente de Paúl, 6to Piso Av. Solano y 12 de Abril, Cuenca Ecuador
Telephone	+593 7-284-1806
Email	ernesto.andrade@ebe.com.ec davidgh0218@gmail.com (since 13 May 2019)

1.4 Other Entities Involved in the Project

Organization name	EMAC EP
Role in the project	Main Partner of project proponent
Contact person	César Arévalo
Title	Technical Director
Address	Avda. Solano y Avda. 12 de Abril Edif. San Vicente de Paul
Telephone	+5937 284 0045
Email	carevalo@emac.gob.ec

Organization name	BGP Engineers B.V.
Role in the project	Main partner of project proponent, project developer
Contact person	Jilles Nijboer
Title	General Director
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Telephone	+31 162 820 399
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Organization name	BTG Biomass Technology Group B.V.
Role in the project	Consultant
Contact person	Martijn Vis
Title	Senior consultant
Address	Josink Esweg 34, 7545 PN, Enschede, The Netherlands
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1.5 Project Start Date

The start date of the project is 27 July 2017, this is the official date of entry into commercial operation of the plant, as confirmed in the letter Nr. CENACE-CENACE-2017-0179-O of 25 July 2017 signed by CENACE, Ecuador's National Centre of Energy Control.

1.6 Project Crediting Period

The project proponent has chosen a renewable crediting period of 10 years. The crediting period starts from 27 July 2017 (the project start date) to 26 July 2027 (including both days). The crediting period can be renewed 2 x 10 years.

1.7 Project Scale and Estimated GHG Emission Reductions or Removals

Project Scale	
Project	Yes
Large project	No

Year	Estimated GHG emission reductions or removals (tCO_2e)
2017 (27 July – 31 Dec)	10777
2018	22548
2019	26539
2020	28832
2021	30072
2022	35517
2023	36755

2024	37992
2025	39227
2026	40463
2027 (1 Jan – 26 July)	23647
Total estimated ERs	**332369**
Total number of crediting years	**10**
Average annual ERs	**33237**

1.8 Description of the Project Activity

At the Pichacay landfill the municipal wastes from the city of Cuenca are disposed. In the landfill, methane is developing and was, before project implementation, released into the atmosphere. The landfill operator EMAC, in view of its ambition to contribute to Cuenca as "green city", intends to collect and destruct the biogas and so reduce the GHG emissions.

Looking to exploit the landfill gas potential available at the Pichacay landfill through the generation of electricity, EMAC EP chose as strategic partner the Dutch company BGP Engineers B.V. and established the mixed (public-private) joint venture company EMAC-BGP ENERGY COMPAÑÍA DE ECONOMIA MIXTA CEM (EBE in short), which is responsible for the construction, execution and operation of the project.

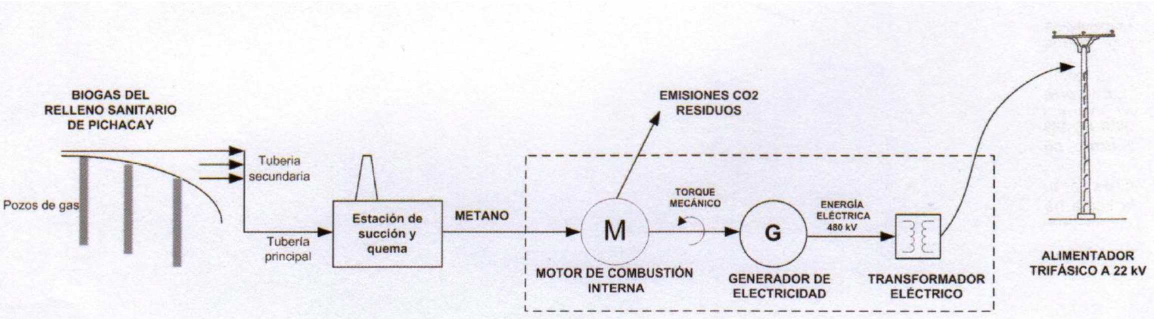


Figure 1: Main equipment parts of the landfill gas extraction project. Source: Environmental Impact Assessment (Barragán et al 2014)

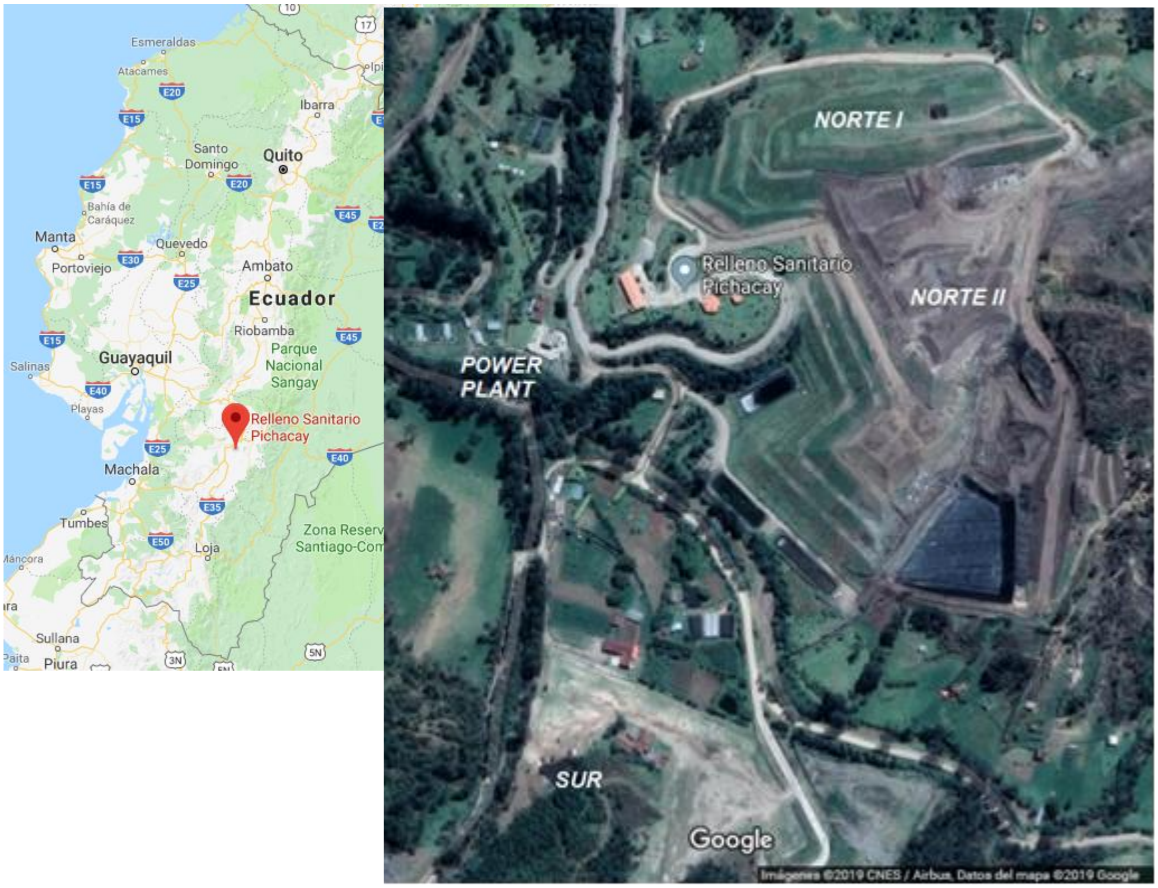
The three main landfill spaces are called Norte (N1) Norte II (N2) and Sur. N1 is operational since 2001, N2 since 2009, and Sur is expected to become operational in 2022. Figure 1 shows the main equipment parts of the installation. A biogas well network is implemented with 23 wells in N1 and 22 wells in N2. The biogas network will be extended in the future to connect with Sur. A horizontal pipe network connects the wells with each other. A biogas pumping station extracts the biogas from the pipeline and transports it to the engine(s). The project is developed in 3 stages. The first 1 MW engine plus genset started producing up to 0.85 MWe electricity for the public grid since 27 July 2017; a second 1 MWe engine plus generator is planned to be installed around 1 July 2019; the third and fourth (1 + 1 MWe) engines plus generator are planned to be installed around 1 Jan 2022. All four 1.1 MWe engines have been derated to 0.85 MW as the height of the installation is 2500 meter above sea level. The first engines plus genset has an electric efficiency of 36.0%. The 480 kV electricity is transformed to 22 kV and supplied to the grid. In addition, a flare is installed to combust the biogas in the event that the engines are not available. The engines will run for around 7600 hours/year, the flare will burn the landfill gas in case the engines are not operational.

The pipeline networks, wells and gas fixtures and accessories have a lifetime projection of 40 years. The engines need an overhaul every 30.000 operating hours. With a maximum of 2 overhauls the engines can run 90.000 hours. Given that the engines are estimated to run for 7600 hours/year, in normal operation the engine will have a lifetime of 11 – 12 years. The generator has the same lifetime as the engine, i.e. 11 – 12 years. The project has all licences to be operational until 2029. The company wishes to extend operation after this date.

1.9 Project Location

The project is located at Santa Ana, Cuenca, Azuay, Ecuador.

Coordinates: Lat = -2.9660411, Long = -78.9314400



1.10 Conditions Prior to Project Initiation

The conditions prior to project initiation are described in the baseline scenario. See section 2.4.

1.11 Compliance with Laws, Statutes and Other Regulatory Frameworks

The project has received all legal required permissions for the extraction of landfill gas, the installation of the engine and genset and the delivery of electricity to the national grid.

The project owner, EMAC-BGP ENERGY COMPAÑÍA DE ECONOMÍA MIXTA CEM (EBE in short), has a contract and all permits to construct and operate the landfill gas extraction and electricity generation at Pichacay. This is documented in the “Título Habilitante”, the overall contract of construction, installation and operation of the Pichacay landfill gas extraction and electricity generation project, between EBE and CONELEC. CONELEC means Consejo Nacional de Electricidad, the National Electricity Council, representing the Ecuadorian authorities. Nowadays CONELEC is called ARCONEL.

The project has received an environmental licence for the construction, operation and retirement of the project to generate electricity from landfill gas, which can be proven by the “Certificado de inscription de Licencia Ambietal No.600” (Reslución No. DE-2014-044 de 12 de marzo de 2014).

In order to obtain the environmental permit an environmental impact assessment was performed, including the possibility for public comments. The environmental impact assessment was approved.

1.12 Ownership and Other Programs

1.12.1 Project Ownership

EMAC-BGP ENERGY COMPAÑÍA DE ECONOMÍA MIXTA CEM (EBE in short) is the project owner, which is a joint venture between the Municipal waste processing company of Cuenca EMAC-EMPRESA MUNICIPAL DE ASEO DE CUENCA (in short: EMAC) and BGP Engineers B.V, with the aim to generate electric energy from the biogas obtained from the landfill of Pichacay, Santa Ana, Cuenca, Azuay, Ecuador, and other landfills at a later stage. This can be found in the Public Deed of Constitution of EBE.

In the contract between the National Electricity Council (CONELEC) and EBE (“Título Habilitante”), the company EBE is called the “Company” or “owner”.

Miguel Serrano Corral was the legal representative of EBE at the time of establishment of the contract between CONELEC and EBE.

At the time of submission of this project description, EBE is legally represented by Mr. Ing. Ernesto Andrade. Proof of his position can be found in the declaration of appointment (nombramiento).

1.12.2 Emissions Trading Programs and Other Binding Limits

The project does not reduce GHG from activities that are included in an emissions trading program or any other mechanism that includes GHG allowance trading.

1.12.3 Other Forms of Environmental Credit

The project has not sought or received another form of GHG-related environmental credit, including renewable energy certificates, during this monitoring project.

1.12.4 Participation under Other GHG Programs

The project activity has not been registered, or currently seeking registration under any other GHG programs.

In 2012 the “Biogas project at the Municipal landfill of Pichacay, Cuenca” was submitted for comments between 01 May 12 – 30 May 12[1]. However, the project never passed the validation stage and has not been registered as CDM project.

1.12.5 Projects Rejected by Other GHG Programs

The project has not been rejected by any other GHG programs. The PDD of the CDM project “Biogas project at the Municipal landfill of Pichacay, Cuenca” was submitted for public comments, but the project was not validated and registered. The project was not rejected.

1.13 Additional Information Relevant to the Project

Eligibility Criteria

The project activity is not a grouped project.

Leakage Management

As per the applied methodology, there are no leakage emissions envisaged. Hence, leakage emissions management is not applicable.

Commercially Sensitive Information

No commercially sensitive information has been excluded from the public version of the project description.

Sustainable Development

Numeral 66. Article 27 of the Constitution of the Republic of Ecuador, recognizes and guarantees individuals the right to live in a healthy, ecologically balanced, free from contamination and in

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[1] See https://cdm.unfccc.int/Projects/Validation/DB/B91W1L5HMMP6UYA7K1QT9HE7TWITB6/view.html.

harmony with nature. The project strongly contributes to a sustainable development both within the local area and at national level.

Locally the project will have its strongest impacts in social and environmental benefits. The release of landfill gas could directly influence the health of the affected inhabitants negatively and additionally leads to the risk of explosions in the surroundings. Furthermore, emissions of other harmful gases, such as H_2S and odorous compounds are going to be reduced. This will improve the living conditions of the direct affected neighbourhoods. Furthermore, the project will have a small but positive impact on employment in the local area as staff will be needed to maintain the operation of the project.

Focusing on national level, the project contributes to the generation of renewable energy from non-conventional resources, which is welcomed by CONELEC, as stated in the “Titulo habiliante”. Moreover, the project contributes to the reduction the emission of greenhouse gases. Finally, the project promotes the sustainable development of Ecuador by increasing the employment opportunities in the area due to direct or indirect effects of the project realisation.

Further Information

Not applicable.

2 APPLICATION OF METHODOLOGY

2.1 Title and Reference of Methodology

The following approved baseline & monitoring methodology is applied:

Title: AMS-III.G Small-scale Methodology: Landfill methane recovery. Version 10.0, Sectoral Scope: 01 and 13, valid from 14 June 2019 onwards.

Tools and methodologies referenced in this methodology, used in this project:

- Tool04 Methodological tool: Emissions from solid waste disposal sites, Version 08.0.
- Tool05 Methodological tool: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation, version 03.0
- AMS-III.H: Methane recovery in wastewater treatment, version 19.0
- Tool06: Methodological tool: project emissions from flaring, version 02.0.0

Title: AMS-I.D Small-scale Methodology: Grid connected renewable electricity generation. Version 18.0, sectoral Scope: 01, valid from 18 Nov 2014 onwards.

Tools and methodologies referred to in this methodology, used in this project:

- Tool07 Methodological tool: Tool to calculate the emission factor for an electricity system, version 05.0.

Other tools referred to:

- Tool 32, Methodological tool: Positive of technologies, version 01.0. (CDM-EB101).

2.2 Applicability of Methodology

AMS-III.G (version 10.0) §3-6 and AMS-ID (version 18.0) §4-11 provide the following project applicability conditions. Also the applicability of the different tools is investigated and confirmed.

Small-scale methodology	Applicability conditions	Project applicability
AMS-III.G	Different options to utilise the recovered landfill gas as detailed in paragraph 4 of “AMS-III.H.: Methane recovery in wastewater treatment” (version 19.0) are eligible for use under this methodology. The relevant procedures in AMS-III.H. shall be followed in this regard. AMS-III.H (version 19.0): paragraph 4 states that *the recovered biogas from the above measures may also be utilised for the following applications instead of combustion/flaring: (a) Thermal or mechanical, electrical energy generation directly.* AMS-III. H: paragraph 5 states that *If the recovered biogas is used for project activities covered under paragraph 4(a), that component of the project activity can use a corresponding methodology under Type I.*	The recovered biogas will be directly combusted in a gas engine for electricity generation. Type I methodology AMS-I.D will be used next to AMS III.G.
	Measures are limited to those that result in aggregate emission reductions of less than or equal to 60 kt CO2 equivalent annually from all Type III components of the project activity	The emissions of all Type III components will result in aggregate emission reductions of less than or equal to 60 kt CO_2 equivalent annually, namely 33246 kt CO_2e.
	The proposed project activity does not reduce the amount of organic waste that would have been recycled in the absence of the project activity.	There are no recycling facilities available to which the municipal waste would have been directed in absence of the project.

	This methodology is not applicable if the management of the solid waste disposal site (SWDS) in the project activity is deliberately changed in order to increase methane generation compared to the situation prior to the implementation of the project activity (e.g. other than to meet a technical or regulatory requirement). Such changes may include, for example, the addition of liquids to a SWDS, pre-treating waste to seed it with bacteria for the purpose of increasing the rate of anaerobic degradation of the SWDS or changing the shape of the SWDS to increase methane production.	The management of the solid waste disposal site (SWDS) in the project activity is not deliberately changed in order to increase methane generation compared to the situation prior to the implementation of the project activity.
AMS-I.D	This methodology is applicable to project activities that: (a) Install a Greenfield plant; (b) Involve a capacity addition in (an) existing plant(s); (c) Involve a retrofit of (an) existing plant(s); (d) Involve a rehabilitation of (an) existing plant(s)/unit(s); or (e) Involve a replacement of (an) existing plant(s).	For the project new biogas engines and generators were purchased. Therefore (a) installation of a Greenfield plant is applicable.
	Hydro power plants with reservoirs that satisfy at least one of the following conditions are eligible to apply this methodology: (a) The project activity is implemented in an existing reservoir with no change in the volume of reservoir; (b) The project activity is implemented in an existing reservoir, where the volume of reservoir is increased and the power density of the project activity, as per definitions given in the project emissions section, is greater than 4 W/m^2; (c) The project activity results in new reservoirs and the power density of the power plant, as	This paragraph is about hydro power plants and not applicable to the project.

	per definitions given in the project emissions section, is greater than 4 W/m^2.	
	If the new unit has both renewable and non-renewable components (e.g. a wind/diesel unit), the eligibility limit of 15 MW for a small-scale CDM project activity applies only to the renewable component. If the new unit co-fires fossil fuel, the capacity of the entire unit shall not exceed the limit of 15 MW.	The new unit has only renewable components.
	Combined heat and power (co-generation) systems are not eligible under this category.	The biogas electricity generation plant only produces electricity.
	In the case of project activities that involve the capacity addition of renewable energy generation units at an existing renewable power generation facility, the added capacity of the units added by the project should be lower than 15 MW and should be physically distinct from the existing units.	The project does not involve capacity addition at an existing renewable power generation facility. The first engine-genset is commercially in operation since 27 July 2017; the second engine-genset is expected to be installed in July 2019. The third and fourth engine-gensets are expected in January 2022. All four engine-gensets are part of the project.
	In the case of retrofit, rehabilitation or replacement, to qualify as a small-scale project, the total output of the retrofitted, rehabilitated or replacement power plant/unit shall not exceed the limit of 15 MW.	The project is not a retrofit project.
	In the case of landfill gas, waste gas, wastewater treatment and agro-industries projects, recovered methane emissions are eligible under a relevant Type III category. If the recovered methane is used for electricity generation for supply to a grid then the baseline for the electricity component shall be in	As the biogas is used for electricity generation for supply to grid; the recovered heat is not used for heat generation or cogeneration. Therefore AMS-I.D is applicable.

	accordance with procedure prescribed under this methodology. If the recovered methane is used for heat generation or cogeneration other applicable Type-I methodologies such as "AMS-I.C.: Thermal energy production with or without electricity" shall be explored.	
	In case biomass is sourced from dedicated plantations, the applicability criteria in the tool "Project emissions from cultivation of biomass" shall apply.	There is no biomass sourced from dedicated plantations
Tool07 "tool to calculate the emission factor for an electricity system"	This tool may be applied to estimate the OM, BM and/or CM when calculating baseline emissions for a project activity that substitutes grid electricity that is where a project activity supplies electricity to a grid or a project activity that results in savings of electricity that would have been provided by the grid (e.g. demand-side energy efficiency projects).	The project activity substitutes grid electricity by supplying electricity to a grid.
	Under this tool, the emission factor for the project electricity system can be calculated either for grid power plants only or, as an option, can include off-grid power plants. In the latter case, two sub-options under the step 2 of the tool are available to the project participants, i.e. option IIa and option IIb. If option IIa is chosen, the conditions specified in "Appendix 1: Procedures related to off-grid power generation" should be met. Namely, the total capacity of off-grid power plants (in MW) should be at least 10 per cent of the total capacity of grid power plants in the electricity system; or the total electricity generation by off-grid power plants (in MWh) should be at least 10 per cent of the total electricity generation by grid power plants in the electricity system; and that factors which negatively affect the reliability and stability of the grid are primarily due to constraints in generation and not to other aspects such as transmission capacity.	The emission factor for the project electricity system is calculated for grid power plants only.
	In case of CDM projects the tool is not applicable if the project electricity system is located partially or totally in an Annex I country.	The project electricity system is not located partially or totally in an Annex I country.

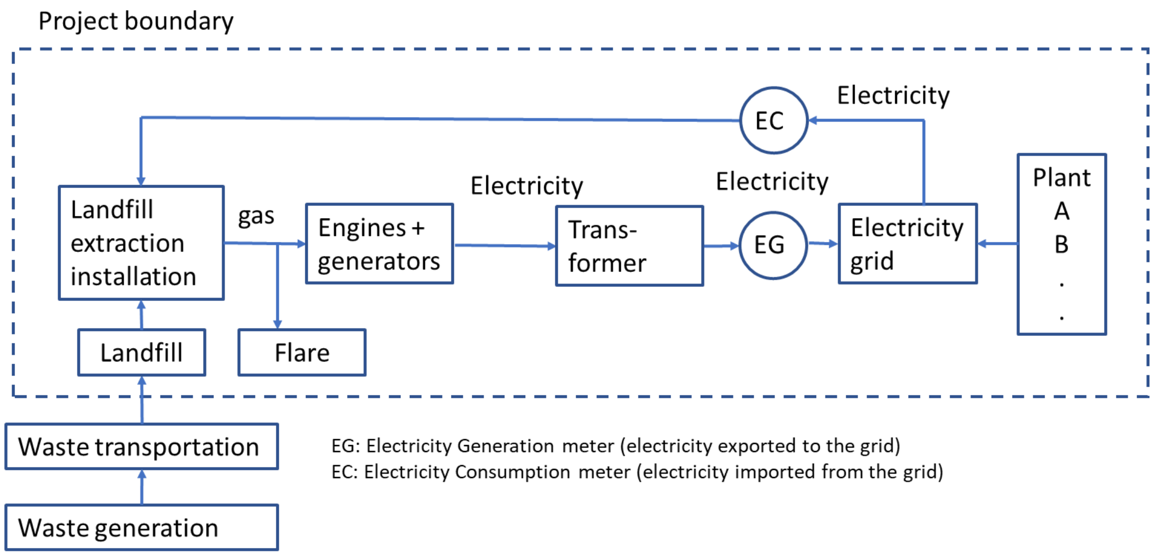
	Under this tool, the value applied to the CO_2 emission factor of biofuels is zero	A CO_2 emission factor of biofuels of zero will be applied.
Tool04 “Emissions from solid waste disposal sites”	The tool can be used to determine emissions for the following types of applications: (a) Application A: The CDM project activity mitigates methane emissions from a specific existing SWDS. Methane emissions are mitigated by capturing and flaring or combusting the methane (e.g. “ACM0001: Flaring or use of landfill gas”). 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 project design document (CDM-PDD). The emissions will then be monitored during the crediting period using the applicable approaches in the relevant methodologies (e.g. measuring the amount of methane captured from the SWDS); (b) Application B: The CDM project activity avoids or involves the disposal of waste at a SWDS. An example of this application of the tool is ACM0022, in which municipal solid waste (MSW) is treated with an alternative option, such as composting or anaerobic digestion, and is then prevented from being disposed of in a SWDS. The methane is generated from waste disposed or avoided from disposal during the crediting period. In these cases, the tool can be applied for both ex ante and ex post estimation of emissions. These project activities may apply the simplified approach detailed in 0 when calculating baseline emissions.	This project mitigates methane emissions from a specific existing SWDS. (a) Application A is applicable to the project activity, as methane emissions are mitigated by capturing for energy. The tool is only applied for an ex ante estimation of emissions on this project PDD.
Tool “Tool 06: project emissions from flaring”	Methane is the component with the highest concentration in the flammable residual gas;	This is the case.
	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 source of the residual gas is from a biogenic source, namely landfill gas.

Tool “Tool32 Methodology tool, positive list of technologies”	The use of this methodological tool is not mandatory for the project participants of a CDM project activity or CDM PoA for demonstrating their additionality	Although the tool is not mandatory for project participants, it will be applied in this project to confer automatic additionality.
	This methodological tool shall be applied in conjunction with a small-scale or large-scale methodology which refers to this tool.	The methodological tool will be applied in conjunction with AMS.III-G, version 10.0. which refers to this tool.
	The positive list as contained in section 5 of this tool is valid up to XX November 2021. Notwithstanding the provisions on the validity of new, revised and previous versions of methodologies and methodological tools in the “Procedure: Development, revision and clarification of baseline and monitoring methodologies and methodological tools”, there will be no grace period for the application of this tool and the validity of the positive list after this date, including in cases where further technologies are added to the positive list through revisions of this tool before this date.	The project documentation is submitted between 29 November 2018 and 29 November 2021.

It is concluded that the project is eligible under AMS-III.G and AMS-I.D, that TOOL04: Emissions from solid waste disposal sites, TOOL07: Tool to calculate the emission factor for an electricity system, and that TOOL32: positive list of technologies can be applied.

2.3 Project Boundary

According to AMS-III.G and AMS-I.D, the project boundary should encompass the physical/geographical site of the landfill where the gas should be captured to use the renewable generation source. And the spatial extent of this project boundary includes the project power plant and all power plants connected physically to the electricity system that the CDM project power plant is connected to. Thus, this project boundary is the site of the project activity, Pichacay landfill in where LFG is captured and used it to generate electricity, and the grid-connected system is included in the project boundary as well. The project boundary is delineated in Figure 2 below.



EG: Electricity Generation meter (electricity exported to the grid)
EC: Electricity Consumption meter (electricity imported from the grid)

Figure 2: Project boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Emissions from the decomposition of waste at the SWDS site	CO_2	No	CO_2 emissions from the decomposition of organic waste are not accounted since the CO_2 is also released under the project activity.
		CH_4	Yes	CH_4 is the major source of emissions in the baseline.
		N_2O	No	NO_2 emissions are small compared to CH4 emissions from SWDS. Exclusion of this gas is conservative.
		Other	No	Excluded for simplification. This is conservative.
	Emissions from grid connected electricity production	CO_2	Yes	Main source of emission, since power generation is included in the project activity.
		CH_4	No	Excluded for simplification. This is conservative.
		N_2O	No	Excluded for simplification. This is conservative.
		Other	No	Excluded for simplification. This is conservative.
Project	Emissions from the flare	CO_2	No	CO_2 emissions from the flare are produced from landfill gas, a renewable energy source.
		CH_4	Yes	Main source of emission
		N_2O	No	Excluded for simplification
		Other	No	Excluded for simplification
	Emissions from electricity consumption due to the project activity	CO_2	Yes	Main source of emission. CO_2 emissions will be accounted for electricity consumed from the grid.
		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
		Other	No	Excluded for simplification. This emission source is assumed to be very small

2.4 Baseline Scenario

Baseline scenario according to AMS-III.G

The project meets the baseline scenario as described in AMS-III.G paragraph 16. In absence of the proposed project activity the Project Proponent would leave biomass and other organic matter to decay within the project boundary, and methane would be emitted to the atmosphere. No national or local safety requirements or legal regulations are in place that require methane from the landfill to be removed. In addition, the effect of methane oxidation that is present in the baseline and absent in the project will be taken into account in the baseline emission calculation (See section 3.1).

Baseline scenario according to AMS-I.D

The baseline scenario for greenfield power plant is applicable (AMS-I.D, paragraph 18). The baseline scenario is that the electricity delivered to the grid by the project activity would have otherwise been generated by the operation of grid-connected power plant and by the addition of new generation sources to the grid.

2.5 Additionality

Following AMS-III.G, version 10.0, paragraph 14, project proponent may apply a simplified procedure for additionality demonstration, using the methodological tool “Positive list of technologies” (TOOL 32, EB meeting EB 101 Annex 6, version 01.0. valid from 29 Nov 2018 on).

Section 5 of this tool contains a positive list of technologies, which are deemed automatically additional if project activities exclusively apply the technologies listed and demonstrate that they fulfil the related conditions. Paragraph 11 of the tool specifies landfill gas recovery and its gainful use:

“The project activities and PoAs at new or existing landfills (greenfield or brownfield) are deemed automatically additional, if it is demonstrated that prior to the implementation of the project activities and PoAs the landfill gas (LFG) was only vented and/or flared (in the case of brownfield projects) or would have been only vented and/or flared (in the case of greenfield projects) but not utilized for energy generation, and that under the project activities and PoAs any of the following conditions are met:

(a) The LFG is used to generate electricity in one or several power plants with a total nameplate capacity that equals or is below 10 MW;

(b) The LFG is used to generate heat for internal or external consumption;

(c) The LFG is flared.”

Prior to the implementation of the project, the landfill gas (LFG) was only vented. The landfill is in operation since 2001, and only since the start of the project 27 July 2017, the landfill gas is captured and used to generate electricity.

In the project the LFG is used to generate electricity in two gas engine-generator sets with a total nameplate capacity of 4 MW, which is below 10 MW.

It is concluded that the project meets the requirements of Tool 32 and is additional.

Furthermore, as per AMS-III.G, paragraph 14(b), the LFG is used for electricity generation within the project boundary, a corresponding methodology under Type I project categories can be applied. In our case this is AMS I.D.

2.6 Methodology Deviations

Not applicable

3 ESTIMATED GHG EMISSION REDUCTIONS AND REMOVALS

3.1 Baseline Emissions

Baseline emissions includes two parts, which are calculated as per AMS-III.G and AMS-I.D separately. Based on both AMS-III.G and AMS-I.D, the baseline scenario for the proposed project is:

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

Where:

Parameter	Unit	Description
BE_y	tCO$_e$e	Baseline emission in year y
$BE_{CH4,y}$	tCO$_e$e	Baseline emission from LFG avoidance that otherwise would be emitted to the atmosphere in absence of the Project in year y (tCO2e) which is estimated as per AMS-III.G
$BE_{electricity,y}$	tCO$_e$e	Baseline emission from electricity displacement that otherwise would be provided by grid in year y (tCO2e) which is estimated as per AMS-I.D

Baseline emission from landfill methane recovery ($BE_{CH4,y}$):

Following AMS-III.G equation (1), the baseline emissions from landfill methane recovery are determined ex ante as follows.

$$BE_{CH4,y} = \eta_{PJ} \times BE_{CH4,SWDS,y} - (1 - OX) \times F_{CH4,BL,y} \times GWP_{CH4}$$

Where:

Parameter	Unit	Description
η_{PJ}	%	Efficiency of the LFG capture system that will be installed in the project activity. It is used for ex ante estimation only. A default value of 50 percent may be used
$BE_{CH4,SWDS,y}$	tCO_2e	Methane emission potential of a solid waste disposal site calculated using the methodological tool “Emissions from solid waste disposal sites”. This tool may be used: • With the factor “f=0.0” because the amount of LFG that would have been captured and destroyed is already accounted for in this equation; • With the definition of year x as ‘the year since the landfill started receiving wastes, x runs from the first year of landfill operation (x=1) to the year for which emissions are calculated (x=y)’ The amount of waste type j deposited each year x (Wj,x) shall be determined by sampling (as specified in the above-mentioned tool), in the case that waste is generated during the crediting period. Alternatively, for existing SWDS, if the pre-existing amount and composition of the wastes in the landfill are unknown, they can be estimated by using parameters related to the serviced population or industrial activity, or by comparison with other landfills with similar conditions at regional or national level.
OX	-	Oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste) (dimensionless). A default value of 0.1 may be used.
$F_{CH4,BL,y}$	tCH_4	Methane emissions that would be captured and destroyed to comply with national or local safety requirement or legal regulations in the year y. The relevant procedures in “ACM0001: Flaring or use of landfill gas” may be followed, as well as taking into account the compliance with the

		relevant local laws and regulation if such laws and regulations exist.
GWP_{CH4}	-	Global Warming Potential for methane (value of 25)

The methane emission potential of the solid waste disposal site (in t CO_2e) is calculated using the methodological tool "Emissions from waste disposal sites" (TOOL04), paragraph 17.

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

Where:

Parameter	Unit	Description
$BE_{CH4,SWDS,y}$	tCO_2e/yr	Baseline methane emissions occurring in year y generated from waste disposal at a SWDS during a time period ending in year y
x	-	Years in the time period in which waste is disposed at the SWDS, extending from the first year in the time period (x = 1) to year y (x = y)
y	-	Year of the crediting period for which methane emissions are calculated (y is a consecutive period of 12 months)
φ_y	-	Model correction factor to account for model uncertainties for year y
f_y	-	Fraction of methane captured at the SWDS and flared, combusted or used in another manner that prevents the emissions of methane to the atmosphere in year y. As this is already accounted for in $F_{CH4,BL,y}$, "f" in the tool shall be assigned a value of 0.)
OX	-	Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)
F	Volume fraction	Fraction of methane in the SWDS gas

$DOC_{f,y}$	Weight fraction	Fraction of degradable organic carbon (DOC) that decomposes under the specific conditions occurring in the SWDS for year y
MCF_y	-	Methane correction factor for year y
$W_{j,x}$	t	Amount of solid waste type j disposed or prevented from disposal in the SWDS in the year x
DOC_j	Weight fraction	Fraction of degradable organic carbon in the waste type *j*
k_j	1/yr	Decay rate
j	-	Type of residual waste or types of waste in the MSW

$F_{CH4,BL,y}$ is determined using the methodology ACM0001. In Ecuador there is no law that requires the collection and destruction of landfill gas. Before the project no existing LFG capture and destruction system was in place. Hence $F_{CH4,BL,y}$ as per table 3 of ACM0001 “Flaring or use of landfill gas” Case 1 is applicable. In this situation $F_{CH4,BL,y} = 0$.

Baseline emissions from electricity displacement ($BE_{electricity,y}$)

Baseline emissions include only CO_2 emissions from electricity generation in power plants that are displaced due to the project activity.

$$BE_{electricity,y} = EG_{PJ,y} \times EF_{grid,y}$$

Where:

Parameter	Unit	Description
$BE_{electricity,y}$	tCO_2e	Baseline emissions from grid electricity displacement in year y
$EG_{PJ,y}$	MWh	Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity in year y As per paragraph of AMS-I.D, if the project activity is the installation of a greenfield power plant, then $EG_{PJ,y} = EG_{PJ,facility,y}$ Where:

		$EG_{PJ,facility,y}$ = Quantity of net electricity generation supplied by the project plant/unit to the grid in year y (MWh)
$EF_{grid,y}$	tCO_2e/MWh	Combined margin CO_2 emission factor for grid connected power generation in year y calculated using the latest version of the "Tool to calculate the emission factor for an electricity system"

The calculation of the emission factor of the National Grid, Power Grid ($EF_{grid,y}$) is provided in Annex A, and is based on the official report on the emission factor of the national interconnected electricity system of Ecuador "Informe 2017, Factor de emission de CO2 del Sistema Nacional Interconectado".

3.2 Project Emissions

Project emissions includes two parts, which are calculated as per AMS-III.G and AMS-I.D separately.

$$PE_y = PE_{CH4,y,} + PE_{electricity,y}$$

Where:

Parameter	Unit	Description
PE_y	tCO_ee	Project emissions in year y
$PE_{CH4,y}$	tCO_ee	Project emissions of landfill methane recovery estimated as per AMS-III.G
$PE_{electricity,y}$	tCO_ee	Project emissions from LFG electricity generation estimated as per AMS-I.D

Project emissions landfill methane recovery ($PE_{CH4,y}$)

Following AMS.III-G the project emissions are described as follows:

$$PE_y = PE_{power,y} + PE_{flare,y} + PE_{process,y}$$

Where:

Parameter	Unit	Description
PE_y	$t\ CO_2e$	Project emissions in year y

$PE_{power,y}$	t CO_2e	Emissions from the use of fossil fuel or electricity for the operation of the installed facilities in the year y
$PE_{flare,y}$	t CO_2e	Emissions from flaring or combustion of the landfill gas stream in the year y
$PE_{process,y}$	t CO_2e	Emissions from the landfill gas upgrading process in the year y, determined by following the relevant procedures described in annex 1 of AMS-III.H

No fossil fuels are used for the operation of the installed facilities, only electricity is used. A flare is used in case the engines are out of operation. The landfill gas upgrading process is not applicable to this project, so it is excluded. Therefore, $PE_{process,y}$ =0.

Therefore, $PE_{CH4,y} = PE_{power,y} + PE_{flare,y}$.

Project emissions from the use of electricity ($PE_{power,y}$)

Following AMS-III.G paragraph 18, project emissions from electricity consumption are determined as per procedures described in the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption” and “AMS-I.D.: Grid connected renewable electricity generation”. The project emissions from the use of electricity are calculated as follows:

$$PE_{power,y} = EC_{project,y} \times EF_{grid,y} \times (1 + TDL_{j,y})$$

Where:

Parameter	Unit	Description
$PE_{power,y}$	tCO_2e	Emissions from the use of electricity for the operation of the installed facilities in the year y (t CO_2e)
$EC_{project,y}$	MWh	The quantity of electricity used for the operation of the installed facilities in the year y
$EF_{grid,y}$	tCO_2e/MWh	Combined margin CO_2 emission factor for grid connected power generation in year y calculated using the latest version of the “Tool to calculate the emission factor for an electricity system”
$TDL_{j,y}$	fraction	Average technical transmission and distribution losses for providing electricity to source j in year y

$EF_{grid,y}$ will be determined ex ante as described in section 3.1 under “baseline emissions from electricity displacement”. $EC_{project,y}$ will be measured for 2017&2018 (as monitoring data is available). For the rest of the first crediting period (2019 -2017) $EC_{project,y}$ will be estimated by relating it to the expected amount electricity generation, assuming a fixed ratio between electricity consumption and production, based on the measured electricity generation and consumption in 2017&2018.

The value of $TDL_{j,y}$ will be obtained from CENTROSUR, the electric distribution company that owns and manages the electricity grid.

Project emissions from flaring ($PE_{flare,y}$)

Following AMS.III-G, point 18, If flaring (single or multiple) is used to destroy all or part of the recovered landfill gas, project emissions from flaring in year y ($PE_{flare,y}$ in t CO_2e) shall be determined for each flare following the procedure described in the methodological TOOL06 “Project emissions from flaring”.

At the project site a flare has been installed that is operational in case the engines are not operational. The emission reduction achieved by the flare is not counted in this project, since no measurement equipment is installed that meets the requirements of TOOL06 and TOOL08. Therefore, during *monitoring*, the baseline and project emissions of the use of the flare also will not be taken into account. ($ER_{flare} = BE_{flare} – PE_{flare} = 0$). This is a very conservative approach, as in reality the flare does destroy methane. For the purpose of the *ex ante estimation of emission reductions* achieved in the project, the project emissions of the flare will be estimated, using a simplified approach.

Following TOOL06 methodological tool “project emissions from flaring”, the project emissions are calculated as follows “step 3”:

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

Where:

Parameter	Unit	Description
$PE_{flare,y}$	tCO_2e	Project emissions from flaring of the residual gas in year y
GWP_{CH4}	tCO2e/tCH4	= Global warming potential of methane valid for the commitment period
$F_{CH4,RG,m}$	kg	Mass flow of methane in the residual gas in the minute m
$\eta_{flare,m}$	-	Flare efficiency in minute m

The mass flow of methane in the residual gas is not measured each minute. Therefore, for this ex ante emission reduction calculation a simplified approach is used, estimating the yearly methane flow to the flare.

It is estimated that in 2019 – 2027 the engines will be operational 7600 hours/year, and it is assumed that all collected methane is sent to the flare the remaining 1160 hours/year (as a year has 8760 hours). The total mass flow of methane directed to the flare in year y is estimated as follows:

$$\sum_{m=1}^{525600} F_{CH4,RG,m} = \frac{OT_{flare,y}}{8760} \times \frac{BE_{CH4,y}}{GWP_{CH4}}$$

Where:

Parameter	Unit	Description
$\sum_{m=1}^{525600} F_{CH4,RG,m}$	tCH_4	The mass flow of methane directed to the flare in year y
$OT_{flare,h,y}$	hours/year	The number of operational hours of the flare in year y
$BE_{CH4,y}$	tCO_2e	Baseline emission from LFG avoidance that otherwise would be emitted to the atmosphere in absence of the project in year y
GWP_{CH4}	tCO_2e/tCH_4	Global warming potential of methane valid for the commitment period

This means that the project emissions from flaring will be estimated as follows:

$$PE_{flare,y} = BE_{CH4,y} \times \frac{OT_{flare,h,y}}{8760} \times (1 - \eta_{flare})$$

Where:

Parameter	Unit	Description
$PE_{flare,y}$	tCO_2e	The project emissions from flaring in year y
$OT_{flare,h,y}$	hours/year	The number of operational hours of the flare in year y
$BE_{CH4,y}$	tCO_2e	Baseline emission from LFG avoidance that otherwise would be emitted to the atmosphere in absence of the project in year y
$\eta_{flare,y}$	dimensionless	Flare efficiency in the year y

Step 2 of TOOL06 describes the procedure to determine the flare efficiency. An enclosed flare is applied. Since the flame is not detected each minute m, a flare efficiency of zero has to be applied: η_{flare}=0%.

Project emissions renewable electricity production ($PE_{electricity,y}$)

For the project emissions of renewable electricity production AMS-I.D is applicable. AMS-I.D (§39) states that for most renewable energy activities PE_y = 0. Exceptions are geothermal plants and emissions from water reservoirs of hydro power plants. Therefore, the project emissions of power generation from LFG are zero ($PE_{electricity,y}$ = 0).

3.3 Leakage

Following paragraph 20 of AMS-III.G leakage has to be considered if the methane recovery technology is transferred from another activity. As this project doesn't involve transfer of any equipment from another activity therefore the leakage has been considered zero.

Following paragraph 42 of AMS-I.D general guidance on leakage in biomass project activities shall be followed to quantify leakages pertaining to the use of biomass residues. Biomass residues are defined as per CDM glossary of Terms version 09.1 as "*Non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms which is a by-product, residue or waste stream from agriculture, forestry and related industries*". This project doesn't pertain to the use of biomass residues. Therefore, no leakage effects need to be accounted under the AMS-I.D.

3.4 Estimated Net GHG Emission Reductions and Removals

The emission reduction achieved by the project activity is constituted by both the methane destruction and grid displacement components.

$$ER_{y,estimated} = BE_y - PE_y - LE_y$$

Where:

Parameter	Unit	Description
$ER_{y,estimated}$	t CO_2e	Estimated emission reduction from both methane destruction and grid displacement
BE_y	t CO_2e	Baseline emissions from both methane destruction and grid displacement
PE_y	t CO_2e	Project emissions from electricity or fossil fuel use

LE_y	t CO_2e	Leakage emissions from both methane destruction and grid displacement

Baseline emissions

The baseline emissions are calculated as follows:

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

Baseline emissions from landfill methane recovery ($BE_{CH4,y}$)

The ex-ante baseline emissions from landfill methane recovery are calculated as follows:

$$BE_{CH4,y} = \eta_{PJ} \times BE_{CH4,SWDS,y} - (1 - OX) \times F_{CH4,BL,y} \times GWP_{CH4}$$

And:

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

The parameters are selected and described in section 3.1. The justification of the selected the parameters can be found in section 4.1. Below the determination of the used quantities of each waste type j is ($W_{j,x}$) is presented, classified according to the waste types for which default values for DOC_j are available.

Determination of $W_{j,x}$

The Pichacay landfill became operational in 2001. Between 2001 and 2006 the waste quantities were not measured, as not weighting equipment was available. Waste intake in this period is estimated based on 2007 numbers and related to population growth. Data on the intake of different waste types between 2007 and 2018 were made available by Ing. Paúl Crespo, head of the final disposal department, EMAC-EP. Waste types include domestic waste, market waste, industrial waste and activated sludge. Ing Paul Crespo has also provided projections on total future waste disposal quantities in 2019 – 2027 (column "Total" in Table 1). Since quantities of activated sludge vary a lot between years (2013 – 2018), the average value was taken for future projection of activated sludge. Domestic waste, market waste and industrial waste were assumed to grow at the same rate as projected total waste intake minus activated sludge (column "Total excl. activated sludge" in Table 1). The resulting quantities of waste are presented in Table 1.

Table 1: Yearly intake of different waste types at Pichacay landfill (tonnes)

Year	Domestic waste	Market waste	Industrial waste	Activated sludge	Total	Total excl. activated sludge
2001	79343	11878	5768	0	96990	96990
2002	81046	12133	5892	0	99071	99071
2003	82785	12394	6019	0	101197	101197
2004	84562	12660	6148	0	103369	103369
2005	86377	12931	6280	0	105588	105588
2006	88231	13209	6415	0	107854	107854
2007	90124	13492	6552	0	110169	110169
2008	98294	12754	7323	0	118371	118371
2009	95879	12646	6510	0	115034	115034
2010	100889	13061	8650	0	122599	122599
2011	107444	14268	8807	0	130519	130519
2012	103008	14383	8943	0	126334	126334
2013	103935	14829	8956	2093	129813	127720
2014	114358	14638	8608	7030	144635	137605
2015	119916	16290	7226	10757	154189	143432
2016	115562	15099	7592	4060	142314	138254
2017	126224	15673	7565	894	150355	149461
2018	124718	16555	8779	8610	158661	150051
2019	129367	17172	9106	5574	161219	155645
2020	132901	17641	9355	5574	165471	159897
2021	136435	18110	9604	5574	169723	164149
2022	139969	18579	9852	5574	173975	168401
2023	143503	19049	10101	5574	178227	172652
2024	147037	19518	10350	5574	182478	176904
2025	150571	19987	10599	5574	186730	181156
2026	154105	20456	10847	5574	190982	185408
2027	157639	20925	11096	5574	195234	189660

Historic waste composition data of domestic waste in Cuenca is available from EMAC-EP (2016) *“Caracterización de los residues sólidos generatos en el Cantón Cuenca, año 2015, informe preparado para la empresa pública municipal de aseo de Cuenca, enero de 2016”*. The data on these waste types was classified into waste types j as found in TOOL04. See Table 2.

Table 2: Classification of domestic waste classes as available from EMAC-EP (2016) into waste type j as found in TOOL04 (data/parameter table 6).

Waste type j	**Domestic waste classification available from EMAC-EP (2016)**
Wood, wood products and straw	Wood

Pulp, paper and cardboard (other than sludge)	Paper and paperboard
Food, food waste, beverages and tobacco (other than sludge)	Organic material
Textiles	Textiles
Garden, yard and park waste	-
Glass, plastic, metal and other inert waste	Metals, soft plastic, rigid plastics, rubber, inert matter, glass, toilet paper and diapers, tetrapack and others.

The historic waste composition of market waste and its translation into waste type j is presented in Table 3. The composition of market waste is not measured, but will contain on average 80% food waste, as indicated by Hendrik Velthuis of BGP Engineers B.V. The composition of industrial waste is not measured and not known. It is conservatively regarded as inert waste and not taken into account in further calculations. The composition of activated sludge is not measured but contains mainly (nearly) inert material according to Hendrik Velthuis of BGP Engineers B.V. and is therefore not been taken into account.

Table 3: Historic waste composition of domestic waste in Cuenca and classification into waste types j

Year	**2001**	**2007**	**2012**	**2015**
Classification as in EMAC-EP 2016				
Organic material	53.80%	54.49%	60.70%	64.39%
Paper and paperboard	7.55%	8.88%	5.62%	6.30%
Metals	1.12%	1.59%	1.07%	0.94%
Soft plastic	14.96%	6.67%	10.18%	7.07%
Rigid plastic		4.67%	3.15%	3.39%
Rubber	0.48%	0.47%	0.52%	0.16%
Inert matter	9.03%	0.08%	1.44%	0.26%
Glass	2.22%	3.10%	2.53%	2.23%
Wood	0.27%	0.50%	0.26%	0.34%
Textiles	1.54%	2.79%	1.80%	1.92%
Toilet paper and diapers	6.97%	14.46%	11.30%	9.61%
Tetrapack	-	0.60%	0.58%	1.94%
Others	2.06%	1.70%	0.85%	1.46%
Total	**100%**	**100%**	**100%**	**100%**
Classification into waste types j.				
Wood and wood products	0.27%	0.50%	0.26%	0.34%
Pulp, paper and cardboard (other than sludge)	7.55%	8.88%	5.62%	6.30%

Food, food waste, beverages and tobacco (other than sludge)	53.80%	54.49%	60.70%	64.39%
Textiles	1.54%	2.79%	1.80%	1.92%
Garden, yard and park waste	0%	0%	0%	0%
Glass, plastic, metal and other inert waste	36.84%	33.34%	31.62%	27.06%
Total	**100%**	**100%**	**100%**	**100%**

Table 4 shows the yearly waste composition of all relevant waste types. The domestic waste composition of the latest available data is used. i.e. the composition of 2001 is used for 2001 – 2006, the composition of 2007 used for 2007 – 2011, etc.

Table 4: Yearly waste composition of relevant waste types (waste type j)

	Domestic waste				**Market waste**
Year	**Pulp, paper cardboard (other than sludge)**	**Wood, wood products and straw**	**Food, food waste, sewage sludge, beverages and tobacco**	**Textiles**	**Food, food waste, sewage sludge, beverages and tobacco**
2001	7.55%	0.27%	53.80%	1.54%	80%
2002	7.55%	0.27%	53.80%	1.54%	80%
2003	7.55%	0.27%	53.80%	1.54%	80%
2004	7.55%	0.27%	53.80%	1.54%	80%
2005	7.55%	0.27%	53.80%	1.54%	80%
2006	7.55%	0.27%	53.80%	1.54%	80%
2007	8.88%	0.50%	54.49%	2.79%	80%
2008	8.88%	0.50%	54.49%	2.79%	80%
2009	8.88%	0.50%	54.49%	2.79%	80%
2010	8.88%	0.50%	54.49%	2.79%	80%
2011	8.88%	0.50%	54.49%	2.79%	80%
2012	5.62%	0.26%	60.70%	1.80%	80%
2013	5.62%	0.26%	60.70%	1.80%	80%
2014	5.62%	0.26%	60.70%	1.80%	80%
2015	6.30%	0.34%	64.39%	1.92%	80%
2016	6.30%	0.34%	64.39%	1.92%	80%
2017	6.30%	0.34%	64.39%	1.92%	80%
2018	6.30%	0.34%	64.39%	1.92%	80%
2019	6.30%	0.34%	64.39%	1.92%	80%
2020	6.30%	0.34%	64.39%	1.92%	80%
2021	6.30%	0.34%	64.39%	1.92%	80%
2022	6.30%	0.34%	64.39%	1.92%	80%
2023	6.30%	0.34%	64.39%	1.92%	80%
2024	6.30%	0.34%	64.39%	1.92%	80%

2025	6.30%	0.34%	64.39%	1.92%	80%
2026	6.30%	0.34%	64.39%	1.92%	80%
2027	6.30%	0.34%	64.39%	1.92%	80%

The yearly amounts of waste type j (W_{jx}) used for the ex ante calculation of baseline emissions is presented in Table 5.

Table 5: Yearly amount of waste type j (W_{xj}) (tonnes)

Year	Total amount of waste (excl. inert waste) (Wx)	Pulp, paper cardboard (other than sludge)	Wood, wood products and straw	Food, food waste, sewage sludge, beverages and tobacco	Textiles
2001	59616	5990	214	52189	1222
2002	60895	6119	219	53309	1248
2003	62202	6250	224	54453	1275
2004	63537	6384	228	55622	1302
2005	64901	6521	233	56816	1330
2006	66294	6661	238	58035	1359
2007	70871	8003	451	59903	2514
2008	75726	8729	491	63764	2742
2009	74029	8514	479	62361	2675
2010	77701	8959	504	65423	2815
2011	83037	9541	537	69961	2998
2012	81943	5789	268	74032	1854
2013	82934	5841	270	74952	1871
2014	89909	6427	297	81126	2058
2015	100511	7555	408	90246	2302
2016	96382	7280	393	86490	2219
2017	104618	7952	429	93814	2423
2018	104225	7857	424	93550	2395
2019	108111	8150	440	97037	2484
2020	111064	8373	452	99688	2552
2021	114018	8595	464	102339	2620
2022	116971	8818	476	104990	2687
2023	119924	9041	488	107640	2755
2024	122877	9263	500	110291	2823
2025	125831	9486	512	112942	2891
2026	128784	9709	524	115593	2959
2027	131737	9931	536	118243	3027

The resulting baseline emissions of methane avoidance are presented in the Table 6. Since the crediting period starts and ends during a calendar year, the data of 2017 and 2027 are corrected based by the share of the year covered. I.e. 27 July – 31 Dec 2017 contains 158 days, so the yearly $BE_{CH4,SWDS,y}$ was multiplied by 158/365; 1 Jan – 26 July 2027 contains 207 days, so the yearly $BE_{CH4,SWDS,y}$ was multiplied by 207/365.

Table 6: Ex-ante determination of the baseline emissions from landfill methane recovery ($BE_{CH4,y}$)

Year	η_{PJ}	$BE_{CH4,SWDS,y}$	$BE_{CH4,y}$
27 Jul - 31 Dec 2017	50%	20876	10438
2018	50%	51043	25522
2019	50%	53909	26954
2020	50%	56771	28385
2021	50%	59629	29815
2022	50%	62485	31243
2023	50%	65339	32669
2024	50%	68190	34095
2025	50%	71039	35520
2026	50%	73886	36943
1 Jan - 26 Jul 2027	50%	43516	21758
Total first crediting period			**313342**

Baseline emissions from electricity displacement ($BE_{electricity,y}$)

The ex-ante baseline emissions from electricity displacement are calculated as follows:

$$BE_{electricity,y} = EG_{PJ,y} \times EF_{grid,y}$$

Where:

Parameter	Unit	Description
$BE_{electricity,y}$	t CO_2e	Baseline emissions from grid electricity displacement in year y
$EG_{PJ,y}$	MWh	Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity in year y Where:
$EF_{grid,y}$	tCO_2e/MWh	Combined margin CO_2 emission factor for grid connected power generation in year y was calculated using the latest version of the “Tool to calculate the emission factor for an electricity system”.

As per paragraph of AMS-I.D, if the project activity is the installation of a greenfield power plant, therefore:

$$EG_{PJ,y} = EG_{PJ,facility,y}$$

Where:

$EG_{PJ,facility,y}$ = Quantity of net electricity generation supplied by the project plant/unit to the grid in year y (MWh)

Since this concerns the ex ante determination of emissions of a retroactive project, for the years 2017-2018 measured data is used, and for 2019 – 2027 an estimation. Therefore,

$$EG_{PJ,facility,y} = EG_{PJ,facility,2017-2018} + EG_{PJ,facility,2019-2027,estimated}$$

See section 4.1 for further details.

The determination of $EF_{grid,y}$ is further detailed in section 3.1.

The ex ante baseline emissions from electricity displacement from the grid are presented in Table 7.

Table 7: Ex-ante determination of the baseline emissions from electricity displacement ($BE_{electricity,y}$)

Year	**$EG_{PJ,y}$**	**$EF_{grid,y}$**	**$BE_{electricity,y}$**
27 Jul - 31 Dec 2017	2776	0.3349	930
2018	5165	0.3349	1730
2019	9690	0.3349	3245
2020	12920	0.3349	4327
2021	12920	0.3349	4327
2022	25840	0.3349	8654
2023	25840	0.3349	8654
2024	25840	0.3349	8654
2025	25840	0.3349	8654
2026	25840	0.3349	8654
1 Jan - 26 Jul 2027	14654	0.3349	4908
Total first crediting period	**187325**		**62735**

Project emissions

As explained in section 3.2 the project emissions from grid connected renewable electricity generation are set at zero. The project emissions from landfill methane recovery consist of (1) Emissions from the use of fossil fuel or electricity for the operation of the installed facilities in the year y ($PE_{power,y}$) and (2) emissions from flaring or combustion of the landfill gas stream in the year y ($PE_{flare,y}$). Therefore, $PE_{CH4,y} = PE_{power,y} + PE_{flare,y}$.

Project emissions from the use of electricity ($PE_{power,y}$)

The project emissions from the use of electricity are estimated as follows:

$$PE_{power,y} = EC_{project,y} \times EF_{grid,y} \times (1 + TDL_{j,y})$$

Where:

Parameter	Unit	Description
$PE_{power,y}$	tCO_2e	Emissions from the use of electricity for the operation of the installed facilities in the year y ($t\ CO_2e$)
$EC_{project,y}$	MWh	The quantity of electricity used for the operation of the installed facilities in the year y
$EF_{grid,y}$	tCO_2e/MWh	Combined margin CO_2 emission factor for grid connected power generation in year y calculated using the latest version of the “Tool to calculate the emission factor for an electricity system”
$TDL_{j,y}$	fraction	Average technical transmission and distribution losses for providing electricity to source j in year y

$EC_{project,y}$ is measured for 2017&2018 (as monitoring data is available). For the rest of the first crediting period (2019 - 2027) $EC_{project,y}$ has been estimated by relating it to the expected amount electricity generation, assuming a fixed ratio between electricity consumption and production, based on the measured electricity generation and consumption in 2017&2018.

Table 8 shows that the above-mentioned ratio is 2.65%. Given that the engines are expected to produce electricity during 7600 hours/year producing at 0.85 MWe, the yearly electricity generation for each engine is 6400 MWh, and related electricity consumption used for the operation of the installed facilities 2.65% of 6400 MWh, which equals 171 MWh/engine/year.

Table 8: Monitored electricity production and consumption in 2017 & 2018

Item	**Electricity production & delivered to the grid**	**Electricity consumption**	**Ratio Electricity Consumption / production**
Symbol	$EG_{PJ,\ facility,y}$	EC_y	$EC_y/EG_{PJ,\ facility,y}$
27 Jul – 31 Dec 2017	2776	67	2.41%

2018	5165	143	2.78%
Total	**7941**	**210**	**2.65%**

Table 9 shows the expected electricity consumption for the operation of the installed facilities, taking into account that the second engine will start operation on 1 July 2019, and using the ex ante determined $EF_{grid,y}$ of 0.3349 tCO_2e/MWh. The technical distribution losses ($TDL_{j,y}$) are taken from CENTROSUR and were 5,76% in 2018.

For 2017 and 2018 monitored electricity consumption is taken. Since the crediting period ends during a calendar year the data of 2027 is corrected based by the share of the year covered: 1 Jan – 26 July 2027 contains 207 days, so the yearly electricity consumption was multiplied by 207/365.

Table 9: Ex ante calculation of project emissions from the electricity consumption for the operation of the installed facilities ($PE_{power,y}$)

Year	**$EC_{project,y}$**	**$EF_{grid,y}$**	**$PE_{power,y}$**
27 Jul - 31 Dec 2017	67	0.3349	24
2018	143	0.3349	51
2019	257	0.3349	91
2020	342	0.3349	121
2021	342	0.3349	121
2022	684	0.3349	242
2023	684	0.3349	242
2024	684	0.3349	242
2025	684	0.3349	242
2026	684	0.3349	242
1 Jan - 26 Jul 2027	388	0.3349	137
Total first crediting period	**4962**		**1757**

Project emissions from flaring ($PE_{flare,y}$)

At the project site a flare has been installed that is operational in case the engines are not operational. In section 3.2 it was derived that ex ante project emissions from flaring will be estimated as follows:

$$PE_{flare,y} = BE_{CH4,y} \times \frac{OT_{flare,h,y}}{8760} \times (1 - \eta_{flare})$$

Where:

Parameter	Unit	Description
$PE_{flare,y}$	tCO_2e	The project emissions from flaring in year y
$OT_{flare,h,y}$	hours/year	The number of operational hours of the flare in year y
$BE_{CH4,y}$	tCO_2e	Baseline emission from LFG avoidance that otherwise would be emitted to the atmosphere in absence of the project in year y
$\eta_{flare,y}$	dimensionless	Flare efficiency in the year y

Since the engines are expected to be operational 7600 hours/year, the operating time of the flare is estimated at 8760 – 7600 = 1160 hours/year, which is 13.2% of the year. For 2017 & 2018 all hours that the engine was not running were monitored and used for the estimation of the operating time of the flare. Since the flame is not detected each minute m, a flare efficiency of zero has to be applied (as prescribed in step 2 of TOOL06). Therefore, the project emissions from flaring equal 13.2% of the baseline emissions of landfill methane recovery ($BE_{CH4,y}$). See Table 10 for the resulting ex ante calculation of the project emissions from flaring.

Table 10: Ex ante calculation of the project emissions from flaring ($PE_{flare,y}$)

Year	$BE_{CH4,y}$	$OT_{flare,y}$ (corrected to full years)	$PE_{flare,y}$
27 Jul - 31 Dec 2017	10438	476	567
2018	25522	1597	4653
2019	26954	1160	3569
2020	28385	1160	3759
2021	29815	1160	3948
2022	31243	1160	4137
2023	32669	1160	4326
2024	34095	1160	4515
2025	35520	1160	4704
2026	36943	1160	4892
1 Jan - 26 Jul 2027	21758	1160	2881
Total first crediting period			**41951**

Leakage emissions

There is no equipment transferred in this project, no leakage effects need to be accounted under AMS-III.G and AMS-I.D. Therefore, Leakage emissions are zero.

Emission reductions

The resulting emission reductions are presented in Table 11.

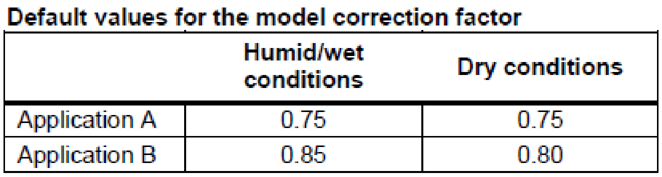
Table 11: Ex ante emission reduction calculation of the first crediting period

Year	Estimated baseline emissions or removals (tCO_2e)	Estimated project emissions or removals (tCO_2e)	Estimated leakage emissions (tCO_2e)	Estimated net GHG emission reductions or removals (tCO_2e)
27 Jul - 31 Dec 2017	11368	591	0	10777
2018	27251	4704	0	22548
2019	30200	3660	0	26539
2020	32712	3880	0	28832
2021	34142	4069	0	30072
2022	39897	4380	0	35517
2023	41323	4569	0	36755
2024	42749	4757	0	37992
2025	44173	4946	0	39227
2026	45597	5134	0	40463
1 Jan - 26 Jul 2027	26666	3019	0	23647
Total	**376077**	**43708**	**0**	**332369**

4 MONITORING

4.1 Data and Parameters Available at Validation

Data / Parameter	η_{PJ}
Data unit	%
Description	Efficiency of the LFG capture system that will be installed in the project activity. It is used for ex ante estimation only. A default value of 50 percent is used.
Source of data	-
Value applied:	50%
Justification of choice of data or description of measurement methods and procedures applied	A default value may be used.
Purpose of Data	Ex ante calculation of baseline emissions
Comments	

<table>
<tr><td>Data / Parameter</td><td>$\varphi_{default}$</td></tr>
<tr><td>Data unit</td><td>-</td></tr>
<tr><td>Description</td><td>Default value for the model correction factor to account for model uncertainties</td></tr>
<tr><td>Source of data</td><td>-</td></tr>
<tr><td>Value applied:</td><td>0.75</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td>Option 1 of Tool04 is chosen, therefore a default value for $\varphi_{default}$ is used. For baseline emissions: refer to the table below to identify the appropriate factor based on the application of the tool (A or B) and the climate where the SWDS is located.

Default values for the model correction factor
<table>
<tr><th></th><th>Humid/wet conditions</th><th>Dry conditions</th></tr>
<tr><td>Application A</td><td>0.75</td><td>0.75</td></tr>
<tr><td>Application B</td><td>0.85</td><td>0.80</td></tr>
</table>
As application A is applicable, 0.75 is the value to be applied.</td></tr>
<tr><td>Purpose of Data</td><td>Ex ante calculation of baseline emissions</td></tr>
<tr><td>Comments</td><td></td></tr>
</table>

Data / Parameter	f_y
Data 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	-
Value applied:	0
Justification of choice of data or description of measurement methods and procedures applied	As this is already accounted for in $F_{CH4,BL,y}$, "f" in the tool is assigned a value of 0
Purpose of Data	Ex ante calculation of baseline emissions
Comments	

Data / Parameter	GWP_{CH4}
Data unit	t CO_2e/t CH_4
Description	Global Warming Potential of methane
Source of data	IPCC
Value applied:	25
Justification of choice of data or description of measurement methods and procedures applied	Global warming potential of methane valid for the relevant commitment period.
Purpose of Data	Calculation of baseline emissions
Comments	

Data / Parameter	OX
Data unit	-
Description	Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)
Source of data	Based on an extensive review of published literature on this subject, including the IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value applied:	0.1

Justification of choice of data or description of measurement methods and procedures applied	Default value
Purpose of Data	Ex ante calculation of baseline emissions
Comments	When methane passes through the top-layer, part of it is oxidized by methanotrophic bacteria to produce CO_2. The oxidation factor represents the proportion of methane that is oxidized to CO_2 This should be distinguished from the methane correction factor (MCF) which is to account for the situation that ambient air might intrude into the SWDS and prevent methane from being formed in the upper layer of SWDS

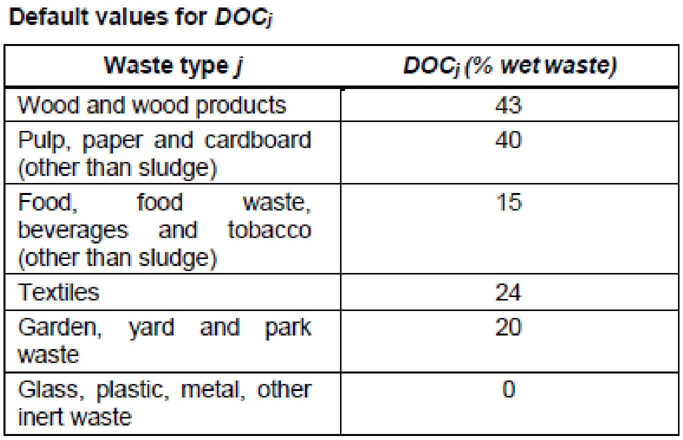
Data / Parameter	F
Data unit	-
Description	Fraction of methane in the SWDS gas (volume fraction)
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value applied:	0.5
Justification of choice of data or description of measurement methods and procedures applied	Default value
Purpose of Data	Ex ante calculation of baseline emissions
Comments	Upon biodegradation, organic material is converted to a mixture of methane and carbon dioxide.

Data / Parameter	$DOC_{f,default}$
Data unit	Weight fraction
Description	Fraction of degradable organic carbon (DOC) that decomposes under the specific conditions occurring in the SWDS for year y
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value applied:	0.5
Justification of choice of data or description of measurement methods and procedures applied	In case of ex ante estimation of emissions (Application A) following Tool 04 paragraph 4) a default value of DOC_f can be used. $DOC_{f,y} = DOC_{f, default} = 0.5$
Purpose of Data	Ex ante calculation of baseline emissions

Comments	This factor reflects the fact that some degradable organic carbon does not degrade, or degrades very slowly, in the SWDS. This default value can only be used for Application A or Application B if the tool is applied to MSW.

Data / Parameter	$MCF_{default}$
Data unit	-
Description	Methane correction factor
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value applied:	1.0
Justification of choice of data or description of measurement methods and procedures applied	In case that the SWDS does not have a water table above the bottom of the SWDS and in case of application A, then select the applicable value from the following: (a) 1.0 for anaerobic managed solid waste disposal sites. These must have controlled placement of waste (i.e.waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling of the waste; (b) 0.5 for semi-aerobic managed solid waste disposal sites. These must have controlled placement of waste and will include all of the following structures for introducing air to the waste layers: (i) permeable cover material; (ii) leachate drainage system; (iii) regulating pondage; and (iv) gas ventilation system; (c) 0.8 for unmanaged solid waste disposal sites – deep. This comprises all SWDS not meeting the criteria of managed SWDS and which have depths of greater than or equal to 5 meters; (d) 0.4 for unmanaged-shallow solid waste disposal sites or stockpiles that are considered SWDS. This comprises all SWDS not meeting the criteria of managed SWDS and which have depths of less than five meters. This includes stockpiles of solid waste that are considered SWDS (according to the definition given for a SWDS) Application A is applicable. The landfill of Pichacay is an anaerobic managed solid waste disposal site, as described under (a).
Purpose of Data	Ex ante calculation of baseline emissions
Comments	

Data / Parameter	$W_{j,x}$
Data unit	T
Description	Amount of solid waste type j disposed or prevented from disposal in the SWDS in the year x
Source of data	Several sources: EMAC-EP (2016) Caracterización de los residues sólidos generatos en el Cantón Cuenca, año 2015, informe preparado para la empresa pública municipal de aseo de Cuenca, enero de 2016; estimations from Ing Paul Crespo, head of the final disposal department of EMAC-EP, Hendrik Velthuis BGP Engineering B.V. See section 3.4 under *Determination of Wj,x* including Table 1 to Table 4.
Value applied:	See Table 5 (p 33)
Justification of choice of data or description of measurement methods and procedures applied	The characterisation of solid waste in Cuenca has been done for three decades. EMAC-EP (2016) is the most recent update and includes historical data on waste composition. More info is provided in section 3.4.
Purpose of Data	Ex ante calculation of baseline emissions
Comments	The time period in which waste is disposed at the SWDS is from 2001 on. Therefore, x=1 corresponds with the year 2001.

<table>
<tr><td>Data / Parameter</td><td>DOC_j</td></tr>
<tr><td>Data unit</td><td>Weight fraction</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 applied:</td><td>For MSW, the following values for the different waste types j should be applied:

Default values for DOC_j
<table>
<tr><th>Waste type j</th><th>DOC_j (% wet waste)</th></tr>
<tr><td>Wood and wood products</td><td>43</td></tr>
<tr><td>Pulp, paper and cardboard (other than sludge)</td><td>40</td></tr>
<tr><td>Food, food waste, beverages and tobacco (other than sludge)</td><td>15</td></tr>
<tr><td>Textiles</td><td>24</td></tr>
<tr><td>Garden, yard and park waste</td><td>20</td></tr>
<tr><td>Glass, plastic, metal, other inert waste</td><td>0</td></tr>
</table>
</td></tr>
</table>

Justification of choice of data or description of measurement methods and procedures applied	The default values are applied.
Purpose of Data	Ex ante calculation of baseline emissions
Comments	The procedure for the ignition loss test is described in BS EN 15169:2007 Characterization of waste. Determination of loss on ignition in waste, sludge and sediments. The percentages listed in table above are based on wet waste basis which are concentrations in the waste as it is delivered to the SWDS. The IPCC Guidelines also specify DOC values on a dry waste basis, which are the concentrations after complete removal of all moist from the waste, which is not believed practical for this situation.

<table>
<tr><td>Data / Parameter</td><td>k_j</td></tr>
<tr><td>Data 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 applied:</td><td>
<table>
<tr><td></td><td>Waste type j</td><td>Value for boreal and temperature (MAT≤20°C). Dry (MAP/PET<1)</td></tr>
<tr><td rowspan="2">Slowly degrading</td><td>Pulp, paper, cardboard (other than sludge), textiles</td><td>0.04</td></tr>
<tr><td>Wood, wood products and straw</td><td>0.02</td></tr>
<tr><td>Moderately degrading</td><td>Other (non-food) organic putrescible garden and park waste</td><td>0.05</td></tr>
<tr><td>Rapidly degrading</td><td>Food, food waste, sewage sludge, beverages and tobacco</td><td>0.06</td></tr>
</table>
</td></tr>
</table>

Justification of choice of data or description of measurement methods and procedures applied	MAT = 14.7° C. Therefore, the values belonging to a boreal and temperature (MAT≤20°C) should be applied Source: Sistema de Clasificación Bioclimática Mundial (temperatures) and: Cuenca Climate Guide, meaning that Cuenca has a boreal and temperate climate. MAP = 878 mm/year (source: https://www.weather-atlas.com/en/ecuador/cuenca-climate#rainfall) PET = 1189 mm/year (source: data from weather station Cuenca-Ricauerte obtained from FAO Climwat, processed in FAO Eto calculator. ETo represents the evapotranspiration rate from a reference surface, not short of water. The ETo calculator assesses ETo from meteorological data by means of the FAO Penman-Monteith equation. See http://www.fao.org/land-water/databases-and-software/eto-calculator/en/ and MAP/PET < 1, so values for dry climate are taken
Purpose of Data	Ex ante calculation of baseline emissions
Comments	MAT = Mean Annual Temperature MAP = Mean Annual Precipitation PET = Potential evapotranspiration.

Data / Parameter	$F_{CH4,BL,y}$
Data unit	t CH_4
Description	Methane emissions that would be captured and destroyed to comply with national or local safety requirement or legal regulations in the year y (t CH4).
Source of data	-
Value applied:	0
Justification of choice of data or description of measurement methods and procedures applied	In Ecuador there is no law that requires to destroy methane. Before the project no existing LFG capture and destruction system was in place. Hence $F_{CH4,BL,y}$ as per table 3 of ACM0001 "Flaring or use of landfill gas" Case 1 is applicable. In this situation $F_{CH4,BL,y}$=0.
Purpose of Data	Ex ante calculation of baseline emissions
Comments	The relevant procedures in "ACM0001: Flaring or use of landfill gas" may be followed, as well as taking into account the compliance with the relevant local laws and regulation if such laws and regulations exist

Data / Parameter	$EF_{grid,y}$
Data unit	t CO_2e/MWh
Description	CO_2 emission factor of the grid electricity in year y
Source of data	CENACE (2017), 2017 report, CO_2 emission factor of the National Interconnected System, determined by the Technical Commission for Determination of Greenhouse Gas Emission Factors. See Appendix A.
Value applied:	0.3349
Justification of choice of data or description of measurement methods and procedures applied	Combined margin CO_2 emission factor for grid connected power generation in year y was calculated using the latest version of the "Tool to calculate the emission factor for an electricity system". For the determination of OM and BM it was chosen to determine these factors ex ante for the whole duration of the first crediting period.
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments	The calculation of $EF_{grid,y}$ using the "Tool to calculate the emission factor for an electricity system" is described in further detail in Appendix A.

Data / Parameter	$TDL_{j,y}$
Data unit	Fraction
Description	Average technical transmission and distribution losses for providing electricity to source j in year y.
Source of data	CENTROSUR, the electricity distribution company that owns and manages the electric grid
Value applied:	5.76%
Justification of choice of data or description of measurement methods and procedures applied	Scenario A of TOOL 05 "Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation" applies. The annual average value based on the most recent data available within the host country was chosen. (See TOOL05, version 03.0, Data / Parameter table 3)
Purpose of Data	Calculation of project emissions
Comments	-

Data / Parameter	$EG_{PJ,facility,2017-2018}$
Data unit	MWh
Description	Quantity of net electricity generation supplied by the project plant/unit to the grid in 2017-2018
Source of data	Electricity meters (ION 7650)
Value applied:	2017: 2776 2018: 5165
Justification of choice of data or description of measurement methods and procedures applied	Since this is a retroactive project it is possible to apply measured data for the ex ante determination of the emission reduction from grid displacement electricity.
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	$EG_{PJ,facility,2019 – 2027,estimated}$
Data unit	MWh
Description	Quantity of net electricity generation supplied by the project plant/unit to the grid in year y
Source of data	Estimation from project owner
Value applied:	2019: 9690 2020: 12920 2021: 12920 2022: 25840 2023: 25840 2024: 25840 2025: 25840 2026: 25840 1 Jan – 26 July 2027: 14654
Justification of choice of data or description of measurement methods and procedures applied	The project consists of 4 engines that convert landfill gas into electricity. Engine 1 started commercial operation on 27 July 2017; engine 2 is expected to start operation on 1 July 2019. Engine 3 & 4 are expected to start operation on 1 Jan 2022. Each engine has a capacity of 1 MW and is expected to generate 0.85 MWh/h during 7600 hours per year, i.e. 6460 MWh/engine/year, and 25840 MWh/year for all 4 engines together. For 2027, a fraction of 207/365 is applied, based on the number of calendar days from 1 Jan – 26 July.

Purpose of Data	Ex ante calculation of baseline emissions
Comments	

Parameters needed for baseline emission calculations with monitoring data, not monitored

Data / Parameter	NCV_{CH4}
Data unit	MJ/Nm^3
Description	NCV of methane
Source of data	-
Value applied:	35.9
Justification of choice of data or description of measurement methods and procedures applied	Default value
Purpose of Data	Calculation of baseline emissions
Comments	

Data / Parameter	D_{CH4}
Data unit	$t\ CH_4/Nm^3\ CH_4$
Description	Density of methane at the temperature and pressure of the landfill gas in year y
Source of data	ACM0001 version 11
Value applied:	0.0007168
Justification of choice of data or description of measurement methods and procedures applied	Because the NCV of methane is reported at normal conditions, the density of methane is also determined at normal conditions. In ACM0001 (version 18.1) reference conditions are defined as 0°C (273.15 K) and 1 atm (101.325 kN/m2, 101.325 kPa). According to ACM0001 (version 11.0) at standard temperature and pressure (0 degree Celsius and 1,013 bar) the density of methane is 0.0007168 tCH_4/m^3CH_4)
Purpose of Data	Calculation of baseline emissions
Comments	AMS-III.G, TOOL04, nor ACM0001 (version 18) provide info on the density of methane under normal conditions. Therefore, a value found in ACM0001 (version 11) was applied.

4.2 Data and Parameters Monitored

Data / Parameter	$EG_{PJ,facility}$
Data unit	MWh
Description	Quantity of net electricity generation supplied by the project plant/unit to the grid in year y
Source of data	Electricity meters (ION 7650)
Description of measurement methods and procedures applied	The electricity generated and delivered to the grid is measured continuously and recorded hourly by two ION-7650 meters. The meters are connected to an automatic software – SIMEC, provided by CENACE (technical and economical administrator of the Ecuadorian Electrical System). On a daily basis, SIMEC generates a report automatically, called TPL, with the hourly energy (active, reactive) produced and delivered to the grid. The daily report is double-checked by the Technical Manager of the power plant as well as by CENACE technical specialists. Once the file is approved, it is stored on an online platform – SIMEM. The platform allows viewing and downloading of the stored files, named CON_MED_EXE_20YY-MM-DD.xls. At EBE, the Project Manager groups the data of the respective monitoring period into one excel sheet. All daily reports remain available and can be double checked by the project advisor and verification body.
Frequency of monitoring/recording	Continuous monitoring, hourly measurement and at least monthly recording
Value applied:	To be monitored during the project
Monitoring equipment	Electricity meter M2
QA/QC procedures applied	To achieve the permit that allows EBE to deliver energy to the grid, the two ION meters were calibrated. The company that performed the calibration was the National Center for Energy Control – CENACE, institution that controls and regulate the Ecuadorian Electrical Power System. The meters need to be calibrated every 2 years.
Purpose of data	Calculation of baseline emissions
Calculation method	Reading hourly electricity production and aggregate them for the monitoring period.
Comments	

Data / Parameter	EE_y
Data unit	%

Description	Energy Conversion Efficiency of the project equipment, i.e. Guascor Power Genset type SFGM560.
Source of data	Specification provided by the equipment manufacturer. See specifications provided in offer "Budget reference: "OFV004932-170314-CS-SFGM560-Landfill-BGP Engineers"
Description of measurement methods and procedures applied	The specification provided by the equipment manufacturer is used as the equipment is designed specifically to utilise biogas as fuel. This is the case. If the specification provides a range of efficiency values, the highest value of the range shall be used for the calculation. The efficiency of nominal load is taken, which is the highest value.
Frequency of monitoring/recording	Once for each engine.
Value applied:	Engine 1: 36.0% (Engine 2 will be installed in July 2019; Engine 3 & 4 in January 2022; and are not part of the monitoring period 27 July 2017 – 31 Dec 2018)
Monitoring equipment	-
QA/QC procedures applied	-
Purpose of data	Calculation of baseline emissions
Calculation method	-
Comments	-

Data / Parameter	$EC_{project,y}$
Data unit	MWh
Description	The quantity of electricity used for the operation of the installed facilities in the year y
Source of data	Monthly electricity bills of the of the local energy distribution company Empresa Elèctrica Regional Centro Sur C.A.
Description of measurement methods and procedures applied	They send a monthly bill with detailed specification of the electricity consumed, based on three periods (A: 07h00-18h00; B: 18h00-22h00; C: 22h00-07h00). The monthly electricity bills are kept and stored on paper and as a scanned pdf file.
Frequency of monitoring/recording	Continuous monitoring, hourly measurement and at least monthly recording
Value applied:	To be monitored during the project

Monitoring equipment	Electricity meter class CL200, type A3R model ELSTER ZE3300000L0, owned and maintained by the local energy distribution company
QA/QC procedures applied	Calibration once.
Purpose of data	Calculation of project emissions
Calculation method	-
Comments	

Data / Parameter	$TDL_{j,y}$
Data unit	Fraction
Description	Average technical transmission and distribution losses for providing electricity to source j in year y.
Source of data	CENTROSUR
Description of measurement methods and procedures applied	Obtained from CENTROSUR, the electricity distribution company that owns and manages the electric grid
Frequency of monitoring/recording	Annually
Value applied:	5.76%
Monitoring equipment	-
QA/QC procedures applied	-
Purpose of data	Calculation of project emissions
Calculation method	-
Comments	-

4.3 Monitoring Plan

The methods used for generating/measuring, recording, storing, aggregating, collating and reporting data and parameters. Where relevant, include the procedures for calibrating monitoring equipment.

With regards to monitoring AMS-III.G, AMS-I.D provides the following requirements:

1. Flow meters, sampling devices and gas analysers shall be subject to regular maintenance, testing and calibration to ensure accuracy. (AMS-III.G paragraph 27)
2. The quantities and types of biomass and the biomass to fossil fuel ratio (in case of co-fired system) to be used during the crediting period should be explained and documented transparently in the CDM-PDD. For the selection of the baseline scenario, an ex ante estimation of these quantities should be provided (AMS-I.D paragraph 44)
3. The applicable requirements specified in the “General guidelines for SSC CDM methodologies” (e.g. calibration requirements, sampling requirements) are also an integral part of the monitoring guidelines specified below and therefore shall be applied by the project participants (AMS-III.G paragraph 28 & AMS-I.D paragraph 45)

Conform the data and parameters monitored (section 4.2) the monitoring plan foresees in the metering of electricity generated by the engine-gensets ($EG_{PJ,facility}$), the electricity consumed ($EC_{project,y}$) and the efficiency of the engine-genset (EE_y).

Electricity production ($EG_{PJ,facility}$)

The electricity generated and delivered to the grid is measured continuously and recorded hourly by two ION-7650 meters. The meters are connected to an automatic software – SIMEC, provided by CENACE (technical and economical administrator of the Ecuadorian Electrical System). On a daily basis, SIMEC generates a report automatically, called TPL, with the hourly energy (active, reactive) produced and delivered to the grid.

The daily report is double-checked by the Technical Manager of the power plant as well as by CENACE technical specialists. Once the file is approved, it is stored on an online platform – SIMEM. The platform allows viewing and downloading of the stored files, named CON_MED_EXE_20YY-MM-DD.xls. At EBE, the Project Manager groups the data of the respective monitoring period into one excel sheet. All daily reports remain available and can be double checked by the project advisor and verification body.

To achieve the permit that allows EBE to deliver energy to the grid, the two ION meters were calibrated. The company that performed the calibration was the National Center for Energy Control – CENACE, institution that controls and regulate the Ecuadorian Electrical Power System. The meters need to be calibrated every 2 years.

Electricity consumption ($EC_{project,y}$)

The metering device of electricity consumption is property of the local energy distribution company Empresa Elèctrica Regional Centro Sur C.A.. They send a monthly bill with detailed specification of the electricity consumed, based on three periods(A: 07h00-18h00; B: 18h00-22h00; C: 22h00-07h00). The monthly electricity bills are kept and stored on paper and as a scanned pdf file.

Energy efficiency of the project equipment (EE_y)

The energy efficiency of the first engine-genset (operational since 27 July 2017) has already been determined ex-ante, by specifications provided by the equipment manufacturer. The project manager will determine the energy efficiency of the second engine-genset (expected to be operational from July 2019 on) in the same way and keep the relevant documentation.

The organizational structure, responsibilities and competencies of the personnel that carried out monitoring activities.

Project owner EBE operates the LFG plant that is part of the project and will measure the required monitoring data related to the project and is qualified to do so.

- The *general manager* of EBE legally represents the project owner. He/she is involved in high level decision making.
- The *supervising Engineer* of the plant in charge of the electrical, electronical and mechanical of the LFG extraction and energy generation plant will be responsible for on-site monitoring data collection. He will be qualified to work with the monitoring equipment and preferably speaks English
- Three *operators* working under the directly supervision of the supervising engineer, will support the supervising engineer to collect relevant monitoring data.

BGP Engineers B.V. is responsible for interpretation of the monitoring data, and leakage effects, preparation of the monitoring reports and quality assurance. BGP will provide instructions and training to operators of EBE and operates as the *Project Manager* regarding monitoring in the frame of this VCS project.

- The project manager is preferably a staff member who is located in Ecuador, near to the project site. He speaks English, understand the emission reduction calculations be able to interpret the monitoring data, and to report them in a monitoring report.

Optionally, a *project advisor* is hired to support the project manager with monitoring and quality assurance. For the first monitoring period BTG is appointed as project advisor.

The organisational structure, responsibilities and competencies of the personnel are further described in the Monitoring Protocol, which is yearly updated when there are personal changes, changes in the structure of the organisation, or changes because of observations made in the verification report.

The policies used for oversight and accountability of monitoring activities.

A monitoring protocol is established and available for all persons involved in the collection and processing of monitoring data. The monitoring protocol is yearly checked and if needed updated. The project manager keeps the oversight of all monitored data collected by the supervising engineer. The fact that the generated and supplied to the grid needs to be recorded properly in order to receive a feed in tariff is an extra guarantee that collected measurement data is properly handled. The monthly electricity bills for electricity consumption are officially measured and registered by the local energy distribution company.

The procedures used for internal auditing and QA/QC & procedures used for handling any internal auditing performed and any non-conformances identified

The procedures below are related to the activities of the project manager. Detailed instructions on data collection and processing for the project owner are formulated in the Monitoring Protocol.

The project manager stores and keeps the contracts, fills in data sheets and additional documentation in an orderly way.

The project manager keeps all paper and electronic documents at a safe place during the VCS project period, and longer if so required according to VCS-regulations.

The monitoring data collected from the project owners is processed in the following way:

1. Data is checked on completeness. If the data is not complete, the project manager contacts the supervising engineer by visit, phone, email or fax to ask for additional information.
2. Data is checked on calculation errors. If calculation errors occur, the supervising engineer is contacted by visit, phone, email or fax and asked for clarification, and if necessary additional explanation is given. This type of errors is noted and taken into account in the evaluation of the Monitoring Protocol.
3. If uncertainty exists on the monitoring data, a conservative approach will be applied in the interpretation of this data.
4. Data is entered into the central database, an excel sheet that contains all necessary calculation rules and procedures.
5. Consistency checks are carried out. If significant inconsistencies are observed, the project owner is asked for clarification. The technician of the project owner and project manager will jointly formulate a plausible explanation for the inconsistencies. If this approach does not work, the trouble shooting procedures will be followed.
6. The calculated emission reductions and other relevant information are reported in the monitoring report and offered to the verification body.

The project manager carries out corrective actions as stated in validation and/or verification reports, and/or otherwise as requested by the verification body. If appropriate, the project manager takes care that the project owner implements the corrective actions. The results of corrective actions will be described in the monitoring report of the subsequent period, or will be immediately send to the verification body, depending on its urgency.

The project manager prepares the concept monitoring report and internally checks the report on completeness and quality of data. The concept monitoring report is sent to the project advisor. The project advisor checks the concept monitoring report and the calculations and returns open questions to the project manager. After both project manager and project advisor are fully satisfied with the content of the final monitoring report, the verification body is requested to verify the monitoring report.

If problems occur related to the monitoring of the project performance, for instance data collection, measurement equipment, the data registration form, etc., the project manager will execute the following actions if problems are directly related to the monitoring of projects:

1. The project manager will try to explain and indicate solutions for problems by visit, phone, email or fax.
2. In case of problems that cannot be easily solved, the project manager will contact the project advisor. They will jointly formulate an approach to solve the problem.
3. All disputes that might arise from problems related to monitoring of the project performance will be settled as described in contracts that between project owner, project manager and project advisor.

The implementation of sampling approaches, including target precision levels, sample sizes, sample site locations, stratification, frequency of measurement and QA/QC procedures. Where applicable, demonstrate whether the required confidence level or precision has been met.

Not applicable. For the parameters monitored, no sampling approached need to be applied. These parameters can be just measured and recorded.

5 SAFEGUARDS

5.1 No Net Harm

Landfill gas can be combusted in the engines with low emissions. Combustion of landfill gas reduces the risk of fire and improve safety at the landfill. The quality of life of the local community increases because of odour reduction and improved air quality. Potential negative impacts are noise and dust emissions.

The Environmental management Plan describes measures to avoid, reduce or mitigate potential negative environmental and socio-economic impacts. It contains programmes on mitigation, safety, prevention, social participation and community relations, environmental training and monitoring. These programmes are developed for the building and operation and maintenance phase of the project. For example, measures are taken for noise and dust control, such as no unnecessary horning, keeping dusty areas wet, etc. Monitoring campaigns on noise, air quality, etc. are foreseen.

The programme on social participation foresees in the appointment of an environmental facilitator to the Ministry of Environment, who will be asked to (1) validate the various stakeholders who may be affected by the operation and (2) check the areas of direct and indirect influence described in the Environmental Impact Study and the Environmental Management Plan.

5.2 Environmental Impact

An environmental impact assessment was carried out with respect to the project: *"Estudio de impacto Ambiental Devinitivo – EIAD, Proyecto de generatción eléctrica de biogas (2 MW) en el* *relleno sanitaria Pichacay y LT Asociada"*, performed by Barragán in 2014. The environmental impact study (EIA) (p13) has the following specific objectives:

- Describe in detail the project with its different components, necessary infrastructure and natural resources that will be used, exploited or affected with the support of secondary information and complementary engineering studies.
- Have an analysis of the legal framework that governs the development of an EIAD, so that once the activities resulting from this study have been completed, all the current environmental legal provisions at national and local levels have been met.
- Determine the areas of direct and indirect influence of the project, supporting this need with criteria supported and based on the project outline and the sensitivity of the ecosystem.
- Carry out studies of the environmental variables that allow describing, characterizing and analysing the physical, biological and social environment, in which the project activities will be developed.
- Qualitatively and quantitatively determine the environmental impacts caused by the construction and operation of the plant, through a systematic and documented verification of the current and future situation of the facilities.
- Design at the executive level the prevention, correction, compensation and mitigation measures, in order to guarantee the optimal socio-environmental management of the project and ensure its implementation in the different stages of its development.
- Design procedures for environmental monitoring and control, to evaluate the behaviour, efficiency and effectiveness of the Environmental Management Plan.
- Prepare the Contingency Plan, based on the identification and evaluation of the natural, technological and social risks related to the construction, operation - maintenance and removal of the project.
- Define all costs, personnel requirements, training and executives, as well as the necessary support services for the implementation of the entire Environmental Management Plan.
- Establish social participation mechanisms according to Decree 1040 and their respective complementary ministerial agreements.

The environmental impact assessment was approved by CONELEC, by Official Letter No. CONELEC-CNRSE-2014-0067-OF of 9 February 2014.

5.3 Local Stakeholder Consultation

Since it concerns a retroactive project, we refer to the local stakeholder consultation conducted during the performance of the Environmental Impact Assessment. This is called the socialisation process, which is documented in a separate report *"Informe de facilitatación, proceso de consulta* *y participación social del borrador del studio de impacto Ambiental definitive y plan de manejo ambiental del proyecto "generation electrica de biogas (2MW) en el relleno sanitaria Pichacay y linea de transmission asociada"* facilitated by Soc. Jaime Arevalo Ayala.

Procedures or methods used for engaging local stakeholders (e.g., dates of announcements or meetings, periods during which input was sought).

The socialisation process to the population living in the area directly and indirectly impacted by the project, was announced in the following ways:

- on the radio "Spendid Radio City Cuenca during 25th, 26th and 27th November 2013 at 06h00, 12h00 and 18h00.
- In the newspaper El Tiempo of the city of Cuenca in the issue of 21 November 2013.
- Posters in the infocentre located in the Tenure Policy Parroquia Santa Ana in El Chorro longhouse in the longhouse Playa de los Angeles and Mosquera.
- Personal invitation to 47 relevant citizens, such as the governor, fire chief, major, community development representatives, parish priest etc.

The following stakeholder consultation activities were performed:

- Establishment of an information centre at the Tenure Policy parish in Santa Ana, from 21 Nov 2013 – 5 Dec 2013. The info centre was open from 08h00 – 12h00, and 14h00 – 17h00.
- Briefings Saturday 23 November at the community houses of Mosquera (22 persons), Playa de los Angeles (26 persons) and El Chorro (34 persons).
- Public presentation of the draft Environmental Impact Assessment and Environmental Management Plan on Nov 28, 2013, at the Longhouse community of El chorro (more than 44 persons).

The procedures or methods used for documenting the outcomes of the local stakeholder consultation.

The outcomes of the local stakeholder consultation is documented in the report *"Informe de facilitatación, proceso de consulta y participación social del borrador del studio de impacto Ambiental definitive y plan de manejo ambiental del proyecto "generation electrica de biogas (2MW) en el relleno sanitaria Pichacay y linea de transmission asociada"*, and is input to the Environmental Management Plan. This report is needed to complete the environmental impact assessment. It systematically registers the questions and comments of the local stakeholders and the responses/explanations given by the project owner or his consultant. One chapter is dedicated to identification and solutions formulation of socio-environmental conflicts.

How due account of all and any input received during the consultation has been taken. Include details on any updates to the project design or justify why updates are not appropriate.

In the above-described stakeholder consultation activities no signs of conflict or opposition to the project were noticed. The plan to let the population benefit from the activities (see next paragraph) and the avoidance of odours was welcomed. One stakeholder recommended to avoid noise and pollution during construction and operation of the project, issues that are addressed in the Environmental Management Plan. By no CNR-2013-0584-0 Office of December 19, 2013, the corresponding process of social participation related to the EIA was approved. The positive responses from the stakeholder process did not raise the need to update the project design.

The mechanism for on-going communication with local stakeholders.

The Environmental Management Plan contains a “Social participation and Community Relations Programme” for the building (PRCC 1) and the operation and maintenance (PRCO1 and PRCO2) phase of the project.

PRCC 1 takes care that the people of the parish of Santa Ana, particularly communities Playa de los Angeles and El Chorro, have been informed about the characteristics of the plant, its construction, and possible impacts incurred.

PRCO 1 on community relations has the objective that the project must operate with less social impact by referring to the security of the people that are in the vicinity of the plant. The inhabitants of the area of directly and indirectly influenced by the project should have access to information concerning the environmental management of facilities.

PRCO 2 takes care that the inhabitants directly or indirectly influenced by the project should be granted benefits by the operation of the plant. This is related to the Social Responsibility Agreement for Co-management of the new Landfill (15 December 2011). In this agreement it is established, among others, that Parish Santana and its communities will be beneficiaries of an Environmental Services Fund, which represents 5% of the amounts collected for the concept of the public cleaning fee and garbage collection. It also means that the communities can manage their development in topics such as economic reactivation, health and sanitation, infrastructure; environmental management, among others. Moreover, it covers prevention of environmental pollution, protection of health and safety.

5.4 Public Comments

No public comments were received in the 30-day public comment period after VCS pipeline listing.

6 ACHIEVED GHG EMISSION REDUCTIONS AND REMOVALS

6.1 Data and Parameters Monitored

Data / Parameter	$EG_{PJ,facility}$
Data unit	MWh
Description	Quantity of net electricity generation supplied by the project plant/unit to the grid in year y
Value applied:	2017: 2776 2018: 5165
Comments	Based on hourly electricity generation data measured by ION7650 electricity meter.

Data / Parameter	EE_y
Data unit	%
Description	Energy Conversion Efficiency of the project equipment
Value applied:	36.0%
Comments	Value for engine 1. Engine 2 was not yet installed. Data found in Budget offer Dresser-Rand/Guascor reference: OFV004932-170314-CSSFGM560-Landfill-BGP Engineers

Data / Parameter	$EC_{project,y}$
Data unit	MWh
Description	The quantity of electricity used for the operation of the installed facilities in the year y
Value applied:	2017: 66.84 2018: 143.50
Comments	Based on monthly electricity bills of Empresa Eléctrica Regional Centro Sur C.A.

Data / Parameter	$TDL_{j,y}$
Data unit	fraction
Description	Average technical transmission and distribution losses for providing electricity to source j in year y.
Value applied:	5.76%
Comments	Obtained from CENTROSUR, the electricity distribution company that owns and manages the electric grid

6.2 Baseline Emissions

The baseline emissions are calculated as follows:

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

Where:

Parameter	Unit	Description
BE_y	tCO_ee	Baseline emission for in year y
$BE_{CH4,y}$	tCO_ee	Baseline emission from LFG avoidance that otherwise would be emitted to the atmosphere in absence of the Project in year y (tCO_2e) which is estimated as per AMS-III.G
$BE_{electricity,y}$	tCO_ee	Baseline emission from electricity displacement that otherwise would be provided by grid in year y (tCO_2e) which is estimated as per AMS-I.D

Baseline emission from landfill methane recovery ($BE_{CH4,y}$):

As per AMS-III.G paragraph 22. the actual emission reduction achieved by the project during the crediting period will be calculated using the amount of methane recovered and destroyed/gainfully used by the project activity calculated as:

$$ER_{y,calculated} = (1 - OX) \times F_{CH4,PJ,y} \times GWP_{CH4} - PE_y - LE_y$$

Thus, the calculated baseline emissions from landfill methane recovery are

$$BE_{CH4,PJ,y} = (1 - OX) \times F_{CH4,PJ,y} \times GWP_{CH4}$$

Where:

Parameter	Unit	Description
$BE_{CH4,PJ,y}$	tCO_2e	Baseline emissions achieved by the project in year y.
OX	-	Oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering

		the waste) (dimensionless). A default value of 0.1 may be used.
$F_{CH4,PJ,y}$	tCH_4	Methane captured and destroyed/gainfully used by the project activity in the year y
GWP_{CH4}	-	Global Warming Potential for methane (value of 25)

At the project site a flare has been installed that is operational in case the engine is not operational. The emission reduction achieved by the flare is not counted in this project, since no measurement equipment is installed that meets the requirements of TOOL06 and TOOL08. Therefore, during *monitoring*, the baseline and project emissions of the use of the flare also will not be taken into account. ($ER_{flare} = BE_{flare} – PE_{flare} = 0$).

As per paragraph 23 of AMS-III.G, for project activities that utilize the recovered methane for power generation, $F_{CH4,PJ,y}$ can be calculated as follows, based on the amount of monitored electricity generation, without monitoring methane flow and concentration:

$$F_{CH4,PJ,y} = \frac{EG_y \times 3600}{NCV_{CH4} \times EE_y} \times D_{CH4}$$

Where:

Parameter	Unit	Description
EG_y	MWh	Electricity generation in year y
3600	-	Conversion factor (1 MWh = 3600 MJ)
EE_y	%	Energy Conversion Efficiency of the project equipment
NCV_{CH4}	MJ/Nm^3	NCV of methane
D_{CH4}	$t\ CH_4/Nm^3\ CH_4$	Density of methane

Remark: In AMS-III.G paragraph 23 the $F_{CH4,PJ,y}$ includes GWP_{CH4}. Since GWP_{CH4} is already included in $BE_{y,calculated}$, it has been left out. The resulting baseline emissions of landfill methane recovery are summarised in Table 12.

Table 12: baseline emissions of landfill methane recovery

Year	**$EG_{PJ,facility}$**	**$F_{CH4,PJ}$**	**$BE_{CH4,y}$**
27 Jul - 31 Dec 2017	2776	554	12471
1 Jan - 31 Dec 2018	5165	1031	23203
Total	**7941**		**35675**

***Baseline emissions from* electricity displacement ($BE_{electricity,y}$)**

The baseline emissions from electricity displacement are calculated as follows:

$$BE_{electricity,y} = EG_{PJ,y} \times EF_{grid,y}$$

Where:

Parameter	Unit	Description
$BE_{electricity,y}$	t CO_2e	Baseline emissions from grid electricity displacement in year y
$EG_{PJ,y}$	MWh	Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity in year y
$EF_{grid,y}$	tCO_2e/MWh	Combined margin CO_2 emission factor for grid connected power generation in year y was calculated using the latest version of the “Tool to calculate the emission factor for an electricity system”.

As per paragraph of AMS-I.D, if the project activity is the installation of a greenfield power plant, therefore:

$$EG_{PJ,y} = EG_{PJ,facility,y}$$

Where:

$EG_{PJ,facility,y}$ = Quantity of net electricity generation supplied by the project plant/unit to the grid in year y (MWh)

$EF_{grid,y}$ has been determined ex ante and is fixed during the first crediting period. See Annex A.

The resulting baseline emissions of landfill methane recovery are summarised in Table 13. The detailed calculations are presented in GHG calculation “VCS project Cuenca.xls” as separate annex to this monitoring report.

Table 13: Monitored baseline emissions from grid connected renewable electricity production

Year	**$EG_{PJ,facility}$**	**$EF_{grid,y}$**	**$BE_{electricity,y}$**
27 Jul - 31 Dec 2017	2776	0.3349	930
2018	5165	0.3349	1730
Total	**7941**		**2659**

6.3 Project Emissions

Project emissions includes two parts, which are calculated as per AMS-III.G and AMS-I.D separately.

$$PE_y = PE_{CH4,y,} + PE_{electricity,y}$$

Where:

Parameter	Unit	Description
PE_y	tCO_ee	Project emissions in year y
$PE_{CH4,y}$	tCO_ee	Project emissions of landfill methane recovery estimated as per AMS-III.G
$PE_{electricity,y}$	tCO_ee	Project emissions from LFG electricity generation estimated as per AMS-I.D

Project emissions landfill methane recovery

As determined in section 3.2 the project emissions from landfill methane recovery in this project can be described as follows:

$$PE_{CH4,y} = PE_{power,y} + PE_{flare,y}$$

Where:

Parameter	Unit	Description
PE_y	t CO_2e	Project emissions in year y
$PE_{power,y}$	t CO_2e	Emissions from the use of fossil fuel or electricity for the operation of the installed facilities in the year y
$PE_{flare,y}$	t CO_2e	Emissions from flaring or combustion of the landfill gas stream in the year y

At the project site a flare has been installed that is operational in case the engine is not operational. The emission reduction achieved by the flare is not counted in this project, since no measurement equipment is installed that meets the requirements of TOOL06 and TOOL08. Therefore, during *monitoring*, the baseline and project emissions of the use of the flare also will not be taken into account. ($ER_{flare} = BE_{flare} – PE_{flare} = 0$). Consequently, the project emissions of the flare have not been taken into account. This is a conservative approach since in reality the flare has destroyed methane part of the year.

Therefore, $PE_{CH4,y} = PE_{power,y}$

Project emissions from electricity consumption for the operation of the installed facilities are determined in the following way:

$$PE_{power,y} = EC_{project,y} \times EF_{grid,y} \times (1 + TDL_{j,y})$$

Where:

Parameter	Unit	Description
$PE_{power,y}$	tCO_2e	Emissions from the use of electricity for the operation of the installed facilities in the year y (t CO_2e)
$EC_{project,y}$	MWh	The quantity of electricity used for the operation of the installed facilities in the year y
$EF_{grid,y}$	tCO_2e/MWh	Combined margin CO_2 emission factor for grid connected power generation in year y calculated using the latest version of the “Tool to calculate the emission factor for an electricity system”
$TDL_{j,y}$	fraction	Average technical transmission and distribution losses for providing electricity to source j in year y

$EF_{grid,y}$ has been determined ex ante and is fixed during the first crediting period. See Annex A. The most recent available (2018) value of TDLj,y is 5.76%.

The resulting baseline emissions of landfill methane recovery are summarised in Table 14. The detailed calculations are presented as separate annex to this monitoring report.

Table 14: Monitored project emissions from the operation of the installed facilities

Year	**$EC_{project,y}$**	**$EF_{grid,y}$**	**$PE_{power,y}$**
27 Jul - 31 Dec 2017	67	0,3349	24
2018	143	0,3349	51
Total	**210**		**75**

Project emissions renewable electricity production

As determined in section 3.2 the project emissions from renewable electricity production are zero.

6.4 Leakage

As determined in paragraph 3.3 leakage emissions from landfill methane recovery and replacement of grid connected electricity can be set at zero.

6.5 Net GHG Emission Reductions and Removals

The net GHG emission reductions and removals are summarised in Table 15. These consist of two vintages:

(1) 27 July – 31 Dec 2017 and

(2) 1 Jan – 31 Dec 2018.

Table 15: Net GHG emissions reductions and removals in the first monitoring period

Year	Baseline emissions or removals (tCO_2e)	Project emissions or removals (tCO_2e)	Leakage emissions (tCO_2e)	Net GHG emission reductions or removals (tCO_2e)
2017	13401	24	0	13377
2018	24933	51	0	24882
Total	**38334**	**75**	**0**	**38259**

APPENDIX A: CALCULATION OF THE EMISSION FACTOR OF THE NATIONAL GRID

The emission factor is calculated by the "Technical Commission for Determination of Greenhouse Gas" (CTFEE)[2]. CTFEE was formed in 2010 under a ministerial agreement between the Ministry of Electricity and Renewable Energy (MEER) and the Ministry of Environment (MAE). This committee is composed of the MEER, MAE, the National Electricity Operator (CENACE) and the Agency for Regulation and Control of Electricity (ARCONEL). CENACE as part of the Technical Commission is responsible for the annual update of the calculation of CO_2, making it easier for proponents of projects in renewable energy and energy efficiency, performing the calculations of CO_2 emission reductions. The latest official emission factor is available in Spanish in *"2017 report, CO2 emission factor of the National Interconnected System"*.[3] The report is in Spanish and provided by the Ecuadorian DNA by email. It is based on the operating data of the years 2014, 2015 and 2016 according to the "Tool to calculate the emission factor for an electricity system version v5.0".

According to the methodology AMS-I.D (Version 18), baseline of this project is the kWh produced by the renewable generating unit multiplied by an emission coefficient (measured in kg CO_2e/kWh) calculated in a transparent and conservative manner as:

(a) A combined margin (CM), consisting of the combination of operating margin (OM) and build margin (BM) according to the procedures prescribed in the "Tool to calculate the emission factor for an electricity system"

OR

(b) The weighted average emissions (in tCO_2 /MWh) of the current generation mix. The data of the year in which project generation occurs must be used.

The baseline methodology procedure (§14) consists of six steps:

Step 1. Identify the relevant electricity systems

The grid considered in this calculation is made for all the elements connected to the national grid "Sistema Nacional Interconectado (SNI)" of Ecuador. Option 1 is chosen in which a delineation of the project electricity system and connected electricity system is used, published by the DNA.

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

Option 1 is chosen so only grid power plants are included in the calculation. Generation units not connected to the SNI, such as the units of the Galapagos iland regions, Puna Island, Eastern region isolated systems and electrical systems of PETROECUADOR are not taken into account.

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

The calculation of the operating margin emission factor (EFgrid,OM,y) is based on one of the following methods, which are described under Step 4:

(a) Simple OM; or

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[2] Comisión Técnica de Determinación de Factores de Emisión de Gases de Efecto Invernadero

[3] CENACE (2017) Informe 2017, Factor de emisión de CO2 del Sistema Nacional Interconectado

(b) Simple adjusted OM; or

(c) Dispatch data analysis OM; or

(d) Average OM

For Ecuadorian case **the Simple Adjusted OM** method was applied. Dispatch data analysis OM is not possible as no hourly data from each power plant on power generation and fuel type and fuel consumption is available. Table 16 shows that the generation of low cost/must run (LCMR) represents 62.7% of the average of the last five years, which is more than 50%. Therefore, Simple OM cannot be applied. Since hourly loads of the grid in MW are available, the Simple adjusted OM van be applied.

Table 16: Power generation in the SNI of the last 5 years in GWh

	2012	2013	2014	2015	2016	Average	%
Low cost/must run	12457.97	11729.52	12533.63	13892.31	16095.79	13341.84	62.7%
No Low cost/must run	6861.69	8337.41	8934.02	8711.14	6844.34	7937.72	37.3%
Total	**19319.66**	**20066.93**	**21467.64**	**22603.45**	**22940.14**	**21279.56**	**100%**

For the calculation of the simple Adjusted OM, the ex-ante option is chosen, using a 3-year generation weighed average based on the most recent data available.

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

The simple adjusted OM emission factor ($EF_{grid,OM\text{-}adj,y}$) 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). As under Option A of the simple OM, it is calculated based on the net electricity generation of each power unit and an emission factor for each power unit, as follows:

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

Where:

$EF_{grid,OM\text{-}adj,y}$ = Simple adjusted operating margin CO_2 emission factor in year *y* (t CO_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* (t CO_2/MWh)

$EF_{EL,k,y}$ = CO_2 emission factor of power unit *k* in year *y* (t CO_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

The calculation of the CO2 emission factor of power units ($EF_{EL,k,y}$) is done considering the following Option A1 and Option A2.

Option A1

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{EG_{m,y}}$$

Where:

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

$FC_{i,m,y}$ = Amount of fuel type *i* consumed by power unit *m* in year *y* (Mass or volume unit)

$NCV_{i,y}$ = Net calorific value (energy content) of fuel type *i* in year *y* (GJ/mass or volume unit)

$EF_{CO2,i,y}$ = CO_2 emission factor of fuel type *i* in year *y* (t CO_2/GJ)

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

m = All power units serving the grid in year *y* except low-cost/must-run power u nits

i = All fuel types combusted in power unit *m* in year *y*

y = The relevant year as per the data vintage chosen in Step 3

Option A2

$$EF_{EL,m,y} = \frac{EF_{co2,m,i,y} \times 3.6}{\eta_{m,y}}$$

Where:

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

$EF_{CO2,m,i,y}$ = Average CO_2 emission factor of fuel type *i* used in power unit *m* in year *y* (t CO_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

The factor λ_y is defined as follows:

$$\lambda_y(\%) = \frac{Number\ of\ hours\ \mathrm{low-cost/must-run}\ are\ on\ the\ margin\ in\ year\ y}{8760\ hours\ per\ year}$$

The sources of information used for the calculation of the Emission Factor of the SNI of Ecuador are:

FCi,m,y the amount of fossil fuel used by generating units connected to the grid is provided by ARCONEL.

$EG_{m,y}$ the net energy generated by each generation unit connected to the power grid is provided by CENACE.

$NCV_{i,y}$ the net calorific value used for different fuels is available from the Table 1.2 Chapter 1 of the Guidelines for National Greenhouse Gas Inventories (IPCC, 2016) and PETROECUADOR as shown in Table 2.

Table 17: Net calorific value of fuels used by the electricity sector

Fuel	Net calorific value (TJ/1000 ton)
Fuel oil	39.2
Diesel	40.8
Natural gas	46.5
Naphtha	41.8
Residue	39.7
Bunker	39.7

Source: IPCC, PETROECUADOR

The emission factor of each fuel type is referenced in Table 1.4 of Chapter 1 of Guidelines for National Greenhouse Gas Inventories, IPCC 2006, using the lower limit of the inventory at 95% confidence.

Table 18: CO_2 emission factor for each fuel used by the electricity sector

Fuel	Emission factor (kg CO_2/TJ)
Fuel oil	75.500
Diesel	72.600
Natural gas	54.300

Naphtha	69.300
Residue	73.300
Bunker	73.300

Source: IPCC

Results for operating margin

Based on the equations and calculation parameters mentioned above, the OM factor of the years 2014, 2015 and 2016 were performed. The results are presented in the table below.

Table 19: Results for the operating margin of 2014, 2015 and 2016

Parameter	Unit	2014	2015	2016
λ_y	-	0.0002	0.0013	0.0106
$\sum_m EG_{M,y} \times EF_{EL,m,y}$	tCO_2	5,922,363.67	5,896,868.43	4,448,703.81
$\sum_m EG_{M,y}$	MWh	8,934,016.68	8,711,141.02	6,844,343.92
$\sum_k EG_{k,y} \times EF_{EL,k,y}$	tCO_2	0.000	0.000	0.000
$\sum_k EG_{k,y}$	MWh	11,693,534.00	13,365,063.72	16,095,793.27
$EF_{grid,OM-adj,y}$	tCO2-eq/MWh	0.6628	0.6760	0.6431

Based on the above results the emission factor for operating margin of the period 2014-2016 can be determined, weighted for power production (See Table 20).

Table 20: Weighting of annual electricity generation 2014 – 2016

		2014	2015	2016
$EF_{grid,OM-adj,y}$	tCO2-eq/MWh	0.6628	0.6760	0.6431
Annual electricity generation	GWh	21,467.64	22,603.45	22,940.14
Weighting	%	32.0%	33.7%	34.2%

The resulting operating margin emission factor: $EF_{grid,OM-adj,ex\ ante\ 2014-2016}$ = 0.6605 t CO_2/MWh

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

In terms of data vintage Option 1 is chosen, meaning that for the first crediting period, the build margin emission factor will be determined ex ante based on the most recent information available on units already built, excluding power units registered as CDM project activities.

The set of five power units that started to supply electricity to the grid most recently ($SET_{5 \text{ units}}$) is presented in

Table 21. This set of five units represents 1.47% of the total generation of electricity in 2016.

Table 21: Set of five power units that started to supply electricity to the grid most recently

Power plant	Start operation	Technology	Type of fuel	Unit	Net electricity generation (MWh)	Per-cen-tage %	Accumulated percentage
C.H. Hidrovictoria	Nov 2016	Hydropower	water	U1	2,559.63	0.0%	0.01%
C.H. Hidrovictoria	Nov 2016	Hydropower	Water	U2	0.05	0.0%	0.01%
C.H. Coca Codo S.	Oct 2016	Hydropower	Water	U5	105,057.88	0.5%	0.47%
C.H. Coca Codo S.	Oct 2016	Hydropower	Water	U6	103,265.45	0.5%	0.92%
C.H. Coca Codo S.	Oct 2016	Hydropower	water	U7	127,090.32	0.6%	1.47%
Total					337,973.34		1.47%

Secondly, a 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 annual electricity generation excl. power generated by CDM projects ($SET_{\geq 20 \text{ per cent}}$) is determined. If 20% falls on part of the generation of a unit, the generation of the unit is fully included in the calculation. See Table 22.

Table 22: Set of power units added most recently representing 20% of annual power production

Power plant	Start operation	Technology	Type of fuel	Unit	Net electricity generation (MWh)	Per-cen-tage %	Accumulated percentage
C.H. Hidrovictoria	Nov 2016	Hydropower	water	U1	2,559.63	0.0%	0.0%
C.H. Hidrovictoria	Nov 2016	Hydropower	Water	U2	0.05	0.0%	0.0%
C.H. Coca Codo S.	Oct 2016	Hydropower	Water	U5	105,057.88	0.5%	0.5%
C.H. Coca Codo S.	Oct 2016	Hydropower	Water	U6	103,265.45	0.5%	0.9%
C.H. Coca Codo S.	Oct 2016	Hydropower	Water	U7	127,090.32	0.6%	1.5%

C.H. Coca Codo S.	Oct 2016	Hydropower	Water	U8	112,947.47	0.5%	2.0%
C.H. Alazán	Sept 2016	Hydropower	Water	U1	6,749.66	0.0%	2.0%
C.H. Alazán	Sept 2016	Hydropower	Water	U2	-	0.0%	2.0%
C.H. Topo	Sept 2016	Hydropower	Water	U1	36,160.37	0.2%	2.2%
C.H. Topo	Sept 2016	Hydropower	Water	U2	-	0.0%	2.2%
C.H. Sopladora	Apr 2016	Hydropower	Water	U1	404,821.26	1.8%	3.9%
C.H. Sopladora	Apr 2016	Hydropower	Water	U3	367,854.34	1.6%	5.5%
C.H. Sopladora	Apr 2016	Hydropower	Water	U2	176,469.43	0.8%	6.3%
C.H. Coca Codo S.	Mar 2016	Hydropower	Water	U1	1,833,756.78	8.0%	14.3%
C.H. Coca Codo S.	Mar 2016	Hydropower	Water	U2	227,387.20	1.0%	15.3%
C.H. Coca Codo S.	Mar 2016	Hydropower	Water	U3	224,715.59	1.0%	16.3%
C.H. Coca Codo S.	Mar 2016	Hydropower	Water	U4	237,407.84	1.0%	17.3%
C.H. Tambo	Jan 2016	Hydropower	Water	U1	36,782.70	0.2%	17.4%
C.H. Tambo	Jan 2016	Hydropower	Water	U2	-	0.0%	17.4%
C.H. Manduriacu	Apr 2015	Hydropower	Water	U1	139,824.02	0.6%	18.1%
C.H. Manduriacu	Apr 2015	Hydropower	Water	U2	152,559.91	0.7%	18.7%
C.H. San Bartolo	Jul 2015	Hydropower	Water	U1	204,602.07	0.9%	19.6%
C.H. San Bartolo	Jul 2015	Hydropower	Water	U2	-	0.0%	19.6%
C.H. San Bartolo	Jul 2015	Hydropower	Water	U3	-	0.0%	19.6%
Guangopolo II	Nov 2014	Thermal power	Fuel oil	U1	28,547.69	0.1%	19.7%
Guangopolo II	Nov 2014	Thermal power	Fuel oil	U2	19,552.52	0.1%	19.8%
Guangopolo II	Nov 2014	Thermal power	Fuel oil	U3	26,589.01	0.1%	19.9%
Guangopolo II	Nov 2014	Thermal power	Fuel oil	U4	29,354.78	0.1%	20.1%
Total					**4,604,055.96**		**20.1%**

From the $SET_{5\text{-units}}$ and $SET_{\geq 20\text{ per cent}}$ the set of power unites that comprises the larger annual electricity generation is selected. In our case this is the $SET_{\geq 20\text{ per cent}}$. None of the set of units in this set started to supply electricity to the grid more than 10 years ago. The build margin is therefore calculated from $SET_{\geq 20\text{ per cent}}$.

The build margin emissions factor is the generation-weighed average emission factor (t CO_2/MWh) of all power units m during the most recent year y for which electricity data is available, calculated as follows:

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

Where:

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

m = Power units included in the build margin

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

The resulting Build margin emission factor: $EF_{grid,BM,2016}$ = 0.0092 t CO_2/MWh

Step 6: calculate the combined margin emissions factor

As data to determine OM and BM are available, the calculation of the combined margin (CM) emissions factor is calculated as weighed average CM, as follows:

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

Where:

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

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

w_{OM} = Weighting of operating margin emissions factor (per cent)

w_{BM} = Weighting of build margin emissions factor (per cent)

With the exception of wind and solar projects, the default value of ω_{OM} = 0.5 and ω_{BM} = 0.5 for the first crediting period.

The resulting $EF_{grid,CM,2016}$ = 0.3349 t CO_2/MWh