Monitoring report form for CDM project activity
(Version 07.0)

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

MONITORING REPORT		
Title of the project activity	Cucuana Hydroelectric Power Plant	
UNFCCC reference number of the project activity	9830	
Version number of the PDD applicable to this monitoring report	05	
Version number of this monitoring report	01	
Completion date of this monitoring report	22/09/2019	
Monitoring period number	2nd	
Duration of this monitoring period	01/01/2018 – 30/06/2019 (first and last days included)	
Monitoring report number for this monitoring report	01	
Project participants	Empresa de Energía del Pacífico S.A. E.S.P.	
Host Party	Colombia	
Applied methodologies and standardized baselines	ACM0002 ver.13.0.0 - Consolidated baseline methodology for grid-connected electricity generation from renewable sources	
Sectoral scopes	1: Energy industries (renewable - / non-renewable sources)	
Amount of GHG emission reductions or net anthropogenic GHG removals achieved by the project activity in this monitoring period	Amount achieved before 1 January 2013	Amount achieved from 1 January 2013
	0 t CO_2e	149,741 t CO_2e
Amount of GHG emission reductions or net anthropogenic GHG removals estimated ex ante for this monitoring period in the PDD	132,375 t CO_2e[1]	

[1] The amount of GHG emission reductions estimated ex ante for this monitoring period was calculated by multiplying the expected emission reduction by year and the semester, for the equivalent of 01/01/2018 - 30/06/2019 period.

SECTION A. Description of project activity

A.1. General description of project activity

The project consists of a hydroelectric power plant, with a nominal water capacity of 55 MW (total installed capacity of 58.16 MW[2]), with the aim of making use of the capacity of the Cucuana and San Marcos rivers (San Marcos is a tributary of the Cucuana River). The project contributes to the improvement in the efficiency of the electricity system in general; increasing the electricity service in the department of Tolima, while contributing to the sustainable development of the region with the reduction of CO_2 emissions.

The Cucuana Hydroelectric Power Plant (hereafter, the project activity or project) started operation on 14 June, 2015[3]. The project is owned and operated by Empresa de Energía del Pacífico S.A. E.S.P. (hereafter, the project proponent). The project activity is a hydroelectric power plant that utilizes water from the Cucuana river and San Marcos river, located in the department of the Tolima, Colombia (hereafter, the Host Country).

The energy that is generated by the project is dispatched to the National Interconnected System (SIN[4]). Thus, it contributes to sustainable development by increasing the share of renewable energy and reducing GHG emissions.

During the current reporting period from 01/01/2018 to 30/06/2019, the project has generated 385,417 MWh and reduced 149,741 tons of CO_2e.

A.2. Location of project activity

The project of the Hydroelectric Power Plant of Cucuana is an exploitation of the capacity of the Cucuana and San Marcos Rivers (San Marcos is a tributary of the Cucuana River) and is located on the middle section of the basin of the Cucuana River, which include the sub-basin of the San Marcos River. The water flows through the river points 2,200 and 1,500 metres above sea level, in the department of Tolima, municipality of Roncesvalles. The municipality's head is located in the southwest of Ibagué, department's capital, and the access is possible through Ibagué-Rovira-Roncesvalles path within a length of 110 km. A different and longer access is through Espinal-Guamol-Ortega-Chaparral-San Antonio-Roncesvalles path. The engine house is located in the elevation 1,500, before the mouth of the San Marcos tributary into the Cucuana River, in the municipality of Roncesvalles.

In particular, the powerhouse point is located on the following coordinates in both decimal degrees format and Degrees, Minutes and Seconds.

Point	Latitude	Longitude
Powerhouse	4.016247º	-75.526683º
	4° 00' 58.4892"	75° 31' 36.0588"

[2] Given by the nameplate of the turbine

[3] See public XM generation records. Public source link: http://informacioninteligente10.xm.com.co/oferta/Paginas/HistoricoOferta.aspx?RootFolder=%2Foferta%2FHistorico%20Oferta%2FGeneraci%C3%B3n&FolderCTID=0x01200075F2CCF9F779EE4B93D2D54764CDB78A&View={9F21C71E-AD8F-4E3F-B2EA-0B38F49A9BA8}

[4] In Spanish: *Sistema Interconectado Nacional*

Figure 1. Location of the Cucuana hydroelectric power plant

A.3. Parties and project participants

Parties involved	Project participants	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
Colombia (Host)	Empresa de Energía del Pacífico S.A. E.S.P.	NO

A.4. Reference to applied methodologies and standardized baselines

The methodology applied to the registered CDM project activity is ACM0002 Version 13.0.0 *"Consolidated methodology: Grid-connected electricity generation from renewable sources"*[5]. This methodology draws upon the following tools:

- *Tool for the demonstration and assessment of additionality* (version 0.7.0.0)[6]
- *Tool to calculate the emission factor for an electricity system* (version 07.0)[7]

A.5. Crediting period type and duration

01/11/2014 – 31/10/2021 (Renewable)

SECTION B. Implementation of project activity

B.1. Description of implemented project activity

The operation starting date of the Cucuana hydroelectric power plant was on 14 June, 2015. This project has two water catchments, one in the Cucuana River and one in San Marcos River. In the Cucuana River, water is collected in the point 2,170 metres above sea level and is driven to an intake

[5] http://cdm.unfccc.int/filestorage/D/Y/P/DYPFI935XBG274NWH6O8CM1KEZR0VU/EB67_repan13_ACM0002_ver13.0.0.pdf?t=SzV8cHAzZXAxfDAmcrL0EyS7yHGTA1B4drvj
[6] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v7.0.0.pdf
[7] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v7.0.pdf

chamber, a gravel removal system and from here it is driven through an adduction channel until a calming chamber which also collects the water collected in the San Marcos River at the elevation 2,179.5 meters above sea level and which after passing through a gravel removal system is driven until the calming chamber through the San Marcos tunnel. From this calming chamber, both water flows pass through a sedimentation basin and afterwards are driven through a pressure tunnel (Cucuana tunnel), a pressure pipe (La Ensillada siphon) and a conduction tunnel (La Ensillada tunnel) to finally arrive to the load pipe which split into two flows to distribute to four Pelton turbines in tandem configuration. The turbines are hosted in a surface machine house with their respective generators, valves and control panels. The engine house also hosts the connections yard.

The electrical energy distribution line is rated at 115 KV using a simple circuit with metallic small towers, and it is connected to the sub-station of Mirolindo, located in Ibagué, capital of the department of Tolima. The distribution line is 64.3 km in length, starts in the engine house and pass through rural areas in the municipalities of Roncesvalles, San Antonio, Rovira and Ibagué.

A small explanation of each stage and unit mentioned in the previous paragraph is included below:

Collection in Cucuana River:

- **Dam**: it is located in the point 2,172 metres above sea level and its function is to generate a small damming that allow the water collection from the river above (its function is not to store water but to make easier the collection of water). It is designed to evacuate a maximum rising tide of the last 1,000 years by the Cucuana River.
- **Desilting canal**: it is located in the left margin of the Cucuana River and allows the handling of the river during the construction of the dam as well as to establish a fast flow in front of the lateral collection point that allow sweeping all the sediments aggraded in front of it.
- **Water collection**: the water intake point or bypass point is a lateral collection point at 2,170 metres above sea level and is formed by two units with gratings leaning 15 º with respect the vertical line.
- **Intake chamber and Gravel removal system**: they act as transition between both the water intake point and the adduction channel and the sedimentation basin. The last one has a structure that allows to discharge the required ecological flow downstream the water collection, especially in the low-water season due to in the high-water season water run over the dam. The discharge of the ecologic flow happen downstream the dam in the Cucuana River through the desilting canal.
- **Adduction channel**: it has a slope of 0.11% and drives water collected in the Cucuana River until the sedimentation basin.
- **Calming tank**: it also receives the water collected in the San Marcos River. From this point both water flows from the Cucuana and San Marcos rivers are delivered into the sedimentation basin.

Collection in San Marcos River:

- **Dam**: it is located in the point 2,181.5 metres above sea level and its function is to generate a small damming that allow the water collection from the river above (its function is not to store water but to make easier the collection of water).It is designed to evacuate a maximum rising tide of the last 1,000 years.
- **Desilting canal**: it is located in the right margin of the San Marcos River and allows the handling of the river during the construction of the dam as well as to establish a fast flow in front of the lateral collection point that allow sweeping all the sediments aggraded in front of it.
- **Water collection**: the water intake point or bypass point is a lateral collection point at 2,179.5 metres above sea level and is formed by one unit with gratings leaning 15 º with respect the vertical line.
- **Gravel removal system**: it acts as transition between both the water intake point and the adduction channel to the San Marcos tunnel. The last one has a structure that allows to discharge the required ecological flow downstream the dam through the desilting canal.
- **Connexion channel**: it links the gravel removal system with the San Marcos tunnel and has a slope of 0.64% and 14.1 metres in length.
- **San Marcos tunnel**: it is a free-flow diversion tunnel with 1,076 metres in length, a slope of 0.67% and a horseshoe section. This tunnel delivers the water collected in the San Marcos river into the calming chamber located upstream of the sedimentation basin.
- **Sedimentation basin**: it is a double sand trap that eliminates thin sediments collected in the

Cucuana River and the ones diverted from San Marcos River.

- **Cucuana tunnel**: horseshoe section and partially lined tunnel with 1,698 metres in length and a diameter of 3 metres. Its slope is 2% and it delivers to La Ensillada siphon at the point 2,130.43 metres above sea level.
- **La Ensillada pipe**: it is a metallic pressure pipe with 137.7 metres in length and a diameter of 1.75 metres. Its function is to overcome the small plateau that is in the alignment of the conduction tunnel that links the Cucuana River with the load pipe in the engine house. The pipe is superficial, and it delivers to La Ensillada tunnel.
- **La Ensillada tunnel**: horseshoe section and partially lined tunnel with 1,700.9 metres in length, a diameter of 3 metres and a slope of 0.4%. At the end of the tunnel there is a holder with a vertical well.
- **Load pipe**: it is 1,596 metres long and is divided in four parts with different diameter. This pipe splits into two flows to distribute to two generation units at the point 1,453 metres above sea level.
- **Engine house**: house of the superficial type that integrates the spaces required to host the two sets of generators with four Pelton turbines of 58.14 MW of installed capacity in tandem configuration and the connection's yard. The installed capacityof each generator is the same and is thus equivalent to 50% of the total capacity of 58.16 MW with a water capacity of 55 MW.
- **Discharge structure**: it allows to return the water flow diverted upstream to the Cucuana River. It is formed by a box-culvert, a dissipation chamber and a delivery trapezoidal channel. The discharge takes place at the point 1,443.00 metres above sea level.
- **Electrical distribution line**: line that enables the connection of the energy generated between the engine house and the sub-station of Mirolindo. The distribution line pass through rural areas in the municipalities of Roncesvalles, San Antonio, Rovira and Ibagué
- **Complementary civil works**: access path to the collection, holder, engine house, adaptation of landfills, rehabilitation of current routes, expansion of energy networks for the construction, workshops, offices, concrete and crusher plant and personnel facilities for workers.

First verification process that aims at verifying real emission reductions that result from the implementation of the project activity was performed during the monitoring period from 01/11/2014 to 31/12/2017.

Second verification considered in this Monitoring report, goes from 01/01/2018 to 30/06/2019.

During this monitoring period, 385,417 MWh were delivered to the Colombian power grid. Table **1** presents the most significant events related whit shutdowns/maintenance, minor events that are not cited can be verified in the spreadsheet "ER Generation Cucuana.xls".

Table 1. Shutdowns summary (01/01/2018 – 30/06/2019)

Date	Event
March 8-10, 2018	Unit 1: scheduled maintenance Unit 2: scheduled maintenance exit of the 115 kV line Cucuana - Mirolindo (Maintenance requested by T&D)
March 12-14, 2018	Unit 1: scheduled maintenance Unit 2: scheduled maintenance exit of the 115 kV line Cucuana - Mirolindo (Maintenance requested by T&D)
March 15, 2018	Unit 1: scheduled maintenance Unit 2: scheduled maintenance
March 16, 2018	Unit 1: scheduled maintenance Unit 2: scheduled maintenance exit of the 115 kV line Cucuana - Mirolindo (Maintenance requested by T&D)
May 10, 2018	Stop of the units due to the increase of the Cucuana and San Marcos rivers
September 11-12, 2018	Unit 1: Stop due to low hydrology Unit 2: Trip due to lack of voltage, 115 kV line fault
October 28, 2018	National consignment CO162420 for maintenance of the 115 kV line Cucuana - Mirolindo (Maintenance requested by T&D)
February 17, 2019	Unit 1: scheduled maintenance Unit 2: scheduled maintenance exit of the 115 kV line Cucuana - Mirolindo (Maintenance requested by T&D)
April 23 - 25, 2019	Plant stop for maintenance on the shut-off valve (anti-jet pipe in turbine A of

Date	Event
	unit 1).

B.2. Post-registration changes

B.2.1. Temporary deviations from the registered monitoring plan, applied methodologies or standardized baselines

There have not been any temporary deviations from the registered monitoring plan, applied methodologies or standardized baselines.

B.2.2. Corrections

There have not been any corrections to project information or parameters fixed at the registration or renewal of crediting period of the project activity.

B.2.3. Changes to the start date of the crediting period

There have not been any changes to the start date of the crediting period fixed at the registration of the project activity.

B.2.4. Inclusion of monitoring plan

There has not been any post-registration change to include a monitoring plan into the PDD.

B.2.5. Permanent changes to the registered monitoring plan, or permanent deviation of monitoring from the applied methodologies, standardized baselines, or other methodological regulatory documents

Changes were submitted with the first monitoring report as part of the request for issuance (post-registration change - issuance track) were made in the revised PDD (completion date 02/04/2019, version 05).

Section B.6.1 in step 4 of the revised PDD, option A1 of the “tool to calculate the emission factor of an electrical system” was added as an approach to calculate the emission factor of each plant m based on fuel consumption and electricity generation, as this information is available to the public in the database of the national interconnected system: http://informacioninteligente10.xm.com.co/oferta/Paginas/HistoricoOferta.aspx.

In this monitoring report, option A2 was used.

B.2.6. Changes to project design

There have not been any changes to the project design of the project activity.

SECTION C. Description of monitoring system

The project uses the approved ACM0002 monitoring methodology “Consolidated baseline methodology for grid-connected electricity generation from renewable sources”, version ACM0002,

Version 13.0.0. In the case of the Power Plant of Cucuana[8], this document establishes that the following data must be monitored:

1. Electricity generated by the project's activity

2. Data required to recalculate the operating margin emission factor

All data required for the verification and issue of CERs was stored in electronic format during at least two years after the end of the crediting period or the last issue of CERs for the project.

EPSA has a Quality Improvement System that has been certified by the ISO 9001 standard and is applied to the Energy Generation, Transmission, Distribution and Retail Marketing processes, as well as Diverting Processes and Support Processes that could have an impact on the quality of the products or services supplied by EPSA. To ensure employee training the procedure PR.GRH.07.002, "Procedure for the Develop of Competencies" is available.

The general operation of the plant of Cucuana and the Monitoring Plan for the reduction of GHG emissions was integrated within the System, being subject to an audit by a third part that guarantee its correct implementation.

The monitoring plan was designed with the purpose of guaranteeing that the project activity is correctly organised from the start, in terms of data gathering and maintenance, as required to obtain realistic GHG emission data.

Therefore, the Supervisor of the project activity maintenance tasks was defined prior to the start of the crediting period, who shall assume the development and execution of the monitoring plan.

The project activity was supervised throughout the crediting period with the measurement systems that provided the official flow, energy and power measures.

The Hydroelectric Power Plant of Cucuana delivered its energy to the interconnected system in the sub-station of Mirolindo, which is where the commercial frontier registered with the Administrator of the electrical interconnected system - XM- established. The information was recorded each day by two measurement units with a precision of 0.2 and the active energy dispatched the previous day must be reported at 8:00 in the morning.

The energy control department is responsible for the maintenance and supervision of the measurement equipment, which monitored the deviations presented with its verification and energy balancing systems.

The complete revision of the measurement equipment is carried out every two years and the industrial measurement area is in charge of coordinating these processes with the production management area.

To guarantee the ecologic flow in the section of the Cucuana and San Marcos rivers, two measurements are taken respectively: one measures the total flow before its collection and the other one is taken in the bypass channel. The difference between these values gives the natural river flow volume. To guarantee that the ecologic flow is 22% of the total before its collection, the measurements taken on these two points are recorded on a system that is in charge of processing the information and adjusting the gate automatically to guarantee the flows required.

The plant has all equipment required for the instantaneous measurement of the active and apparent power, power levels, current per phase, power factor and energy delivered per turbine generator group. These measurements are local and remote from the EPSA control centre.

[8] This plant does not have a reservoir or water reserve to operate during at least 10 days.

The following sheme shows the power plant, the substation and the metering points:

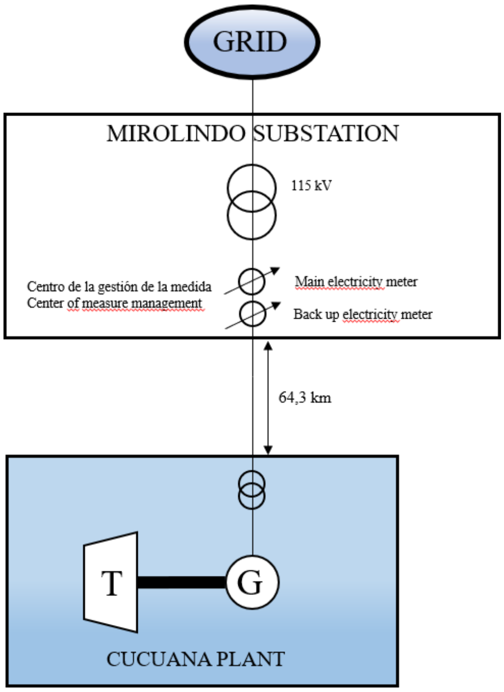

Figure 2. Metering scheme of the Cucuana hydroelectric power plant

Likewise, the Plant's Operation Reports are used as a reference and are available for any inspections carried out during the crediting period, including the following aspects:

- Annual electricity production, broken down by month, is part of the Plant Operation Log, with all real and reactive power production data.
- Annual and monthly plant factor.
- Maximum annual and monthly demand.
- Annual and monthly load factor.
- Annual and monthly consumption of turbines.
- Relevant events during the year.

The Project Manager is responsible for the implementation and update of all data and parameters monitored, included in the previous section, ensuring that the emission reduction calculations obtained are realistic and based on evidence. Likewise, said Supervisor is in periodical contact with the person responsible for the execution of the Environmental Handling Plant of the Hydroelectric Power Plant of Cucuana, with the purpose of guaranteeing the execution of the project and that it contributes to the social and environmental development of the Cauca Valley.

In addition, the following data which are necessary to calculate the baseline was downloaded annually from the XM system:

- Quantity of electricity generated by the Minor Hydroelectric Power Plant of Cucuana each hour. The measurement data registered by the personnel of EPSA was compared with the data provided by the XM system to detect possible error.
- Annual electricity generated by each plant of the National Interconnected System of Colombia.
- Electricity generated by the National Interconnected System of Colombian hourly.
- New plants built and those commissioned in the National Interconnected System of Colombia, in order to update the list of the plants that can be included in the calculation of the build margin emission factor. This data was downloaded from the XM system if the

Electricity Market Regulator does not provide such information.

Annually, it was also updated the calculation of:

- Annual electricity generated by low-cost/must-run power plants and the rest of the power plants.
- Fuel consumption of each power unit.
- Emission factor of each plant.
- Operating margin emission factor.
- Build margin emission factor.
- Baseline emission factor.

All data and parameters were recorded in accordance with the quality systems of the companies participating in the project, with their corresponding quality control and assurance procedures, Likewise, there is a record of the Power Plant Operation reports, in accordance with these procedures.

Calibration of monitoring equipment

For this monitoring period a calibration was performed for both installed meters on 20/08/2016, after this date no calibration was done until 26/10/2018. Considering these facts, the project generation was penalized from 20/08/2018 to 26/10/2018 with the maximum permissible error of the meter 0.2 S.

Table 2. Calibration frequency and penalization from 01/01/2018 to 30/06/2019

Meter ID	Serial and Type	Class	Calibration frequency	Meters: commissioning – dismantling and calibration dates
MAIN METER	MJ-1308A302-03	0.2s	Every 2y	Calibration dates 20/11/2014 20/08//2016 26/10/2018 For this monitoring period from 01/01/2018 to 30/06/2019 a calibration for this meter was required for 20/08/2018 but did not happened, therefore the hourly data of the days between 20/08/2018 and 26/10/2018 received the maximum permissible error of the meter 0.2 S.
BACKUP METER	MJ-1308A302-03	0.2s	Every 2y	Calibration dates 20/11/2014 20/08//2016 26/10/2018 For this monitoring period from 01/01/2018 to 30/06/2019 a calibration for this meter was required for 20/08/2018 but did not happened, therefore the hourly data of the days between 20/08/2018 and 26/10/2018 received the maximum permissible error of the meter 0.2 S.

SECTION D. Data and parameters

D.1. Data and parameters fixed ex ante

Data/Parameter	$EF_{grid,BM,y}$
Unit	t CO_2/MWh

Description	Building margin CO2 emission factor of the grid in year y using the "Tool to calculate the emission factor for an electricity system"
Source of data	As per the "Tool to calculate de emission factor for an electricity system"
Value(s) applied	0.2345
Choice of data or measurement methods and procedures	As per the "Tool to calculate de emission factor for an electricity system"
Purpose of data/parameter	Calculation of baseline emissions
Additional comments	-

Data/Parameter	EF_{Res}
Unit	Kg CO_2e/MWh
Description	Default emission factor for the emissions of reservoirs of hydro power plants
Source of data	Decision by EB23 (See PDD)
Value(s) applied	90 Kg CO_2e/MWh.
Choice of data or measurement methods and procedures	-
Purpose of data/parameter	Calculation of project emissions
Additional comments	This value will be revised when a new value is determined and indicated.

Data/Parameter	Cap_{BL}
Unit	W
Description	Installed capacity of the hydro power plant before the implementation of the project activity. For new hydro power plants, this value is zero
Source of data	Project site
Value(s) applied	0
Choice of data or measurement methods and procedures	Determine the installed capacity based on recognized standards

Purpose of data/parameter	Calculation of project emissions
Additional comments	-

Data/Parameter	A_{BL}
Unit	m^2
Description	Area of the single reservoir measured in the surface of the water, before the implementation of the project, when the reservoir is full. For new reservoirs, this value is zero
Source of data	Project site
Value(s) applied	0
Choice of data or measurement methods and procedures	Measured from topographical surveys, maps, satellite pictures, etc.
Purpose of data/parameter	Calculation of project emissions
Additional comments	-

D.2. Data and parameters monitored

Data/Parameter	$EF_{CO2,i,y}$ and $EF_{CO2,m,i,y}$
Unit	kg CO_2/TJ
Description	CO_2 emission factor of fossil fuel type i used in power unit *m* in year y
Measured/calculated/ default	Default
Source of data	Fuel Emissions Factor database of Colombia published by UPME (FECOCupme.xls)
Value(s) of monitored parameter	See Fuel EF Summary tap of the EF calculation sheet “EF Colombia 2018_Cucuana”
Monitoring equipment	-
Measuring/reading/recording frequency	-
Calculation method (if applicable)	Values are reliable and documented in national energy balances provided by the Mining and Energy Planning Unit (UPME) of the Colombian Ministry of Mines and Energy.
QA/QC procedures	-
Purpose of data/parameter	Calculation of baseline emissions
Additional comments	Originally the “2006 IPPC Guidelines for National Greenhouse Gas Inventories” were used in the PDD. As indicated in the PDD, these values shall be revised when relevant bibliography is available. They have been updated with the source above that provides specific values for fuels in Colombia and was published after the registration of the PDD.

Data/Parameter	$EG_{facility, y}$
Unit	MWh/yr
Description	Quantity of net electricity generation supplied by the project plant to the grid in the year y.
Measured/calculated/ default	-
Source of data	Project activity site. It was measured by EPSA,
Value(s) of monitored parameter	**Year** / **Dispatch (MWh)**: 2018 – 271,393; To 30/06/2019 – 114,024
Monitoring equipment	**Meters:**

Year	**Dispatch (MWh)**
2018	271,393
To 30/06/2019	114,024

	Serial	Type	Brand	Calibration date	Accuracy	Expiry time
Main	MJ-1308A302-03	ION7650	Schneider	20/11/2014 20/08//2016 26/10/2018	0.2%	2 years
Backup	MJ-1308A303-03	ION7650	Schneider	20/11/2014 20/08//2016 26/10/2018	0.2%	2 years

Measuring/reading/recording frequency	The quantity of energy generated was monitored by EPSA each hour. The data obtained was recorded once a month on a spreadsheet. In addition, the data was also be provided by the XM system, which was downloaded annually and recorded on a different spreadsheet
Calculation method (if applicable)	-
QA/QC procedures	Cross check measurement results with records for sold electricity: the measurement units (main and backup) of the energy transferred from the plant to the network was calibrated every 2 years. The measurement data registered by the personnel of EPSA was compared with the data provided by the XM system to detect possible error. There is the procedure PR.PRO.03.0001, “Procedure for control of the production equipment”, to carry out the calibration and verification (internal and external) of measuring equipment.
Purpose of data/parameter	Baseline emissions
Additional comments	-

Data/Parameter	$EG_{m,y}$, EG_h and $EG_{k,y}$
Unit	MWh
Description	Net electricity generated by power plant/unit m or k (or in the project electricity system in case of EGh) in year y or hour h
Measured/calculated/ default	Measured
Source of data	XM system (previously called NEON system)
Value(s) of monitored parameter	See Plants Generation of the XM data organized document
Monitoring equipment	-
Measuring/reading/recording frequency	Annually during the crediting period.
Calculation method (if applicable)	The quantity of energy generated by the power plants during the year is registered in the XM System as "Real Generation". This system was accessed once a year to download data, which was stored in an electronic spreadsheet. It should take into account each year adding new power plants and their typology.
QA/QC procedures	The hourly data of the total generation of the system and the hourly data corresponding to each plant was downloaded. The sum of all individual data was checked, in order to ensure that it is similar to the total system generation data. In case there are differences between the two types of data, the reasons and sources were analysed and errors were corrected
Purpose of data/parameter	Calculation of baseline emissions
Additional comments	-

Data/Parameter	$\eta_{m,y}$ and $\eta_{k,y}$
Unit	-
Description	Average net energy conversion efficiency of power unit m or k in year y
Measured/calculated/ default	-

Source of data	Associated Services Management, XM Compañía de Expertos en Mercados S.A. E.S.P. Heat Rate in MBTU/MWh of the different plants connected to the National Interconnected System of Colombia is provided by the "Dirección Servicios Asociados, XM Compañía de Expertos en Mercados S.A. E.S.P.", but this information is not provided for cogeneration. So, for cogeneration using bagassefuel, fuel oil and coal + bagasse have been selected the heat rates "Promedios horarios de emisión para el cálculo de la metodología consolidada de línea base ACM0002 para proyectos de generación de escala completa" published by the Energy Mining Planning Unit of the Ministry of Mines and Energy of the Republic of Colombia. For cogeneration using coal as fuel and gas has been taken respectively the average value of all Colombian centrals that use such fuels.
Value(s) of monitored parameter	See Spreadsheet "EF Colombia 2018_Cucuana.xls" worksheet Fuel+HR
Monitoring equipment	
Measuring/reading/recording frequency	Annually during the crediting period for the relevant year.
Calculation method (if applicable)	The unit of the data provided by the "Dirección Servicios Asociados, XM Compañía de Expertos en Mercados S.A. E.S.P." concerning the heat rate of each power plants is MBTU / MWh. Through a change of units, according to the conversions indicated in the spreadsheet for calculating the operating margin emission factor (first sheet, Fuel+HR).
QA/QC procedures	If the data obtained from the utility or the dispatch center of official records is significantly lower than the default value provided in appendix 1 of "Tool to calculate the emission factor for an electricity system, version 03.0.0" for the applicable technology, Epsa will assess the reliability of the values, and will provide appropriate justification if deemed reliable. Otherwise, the default values provided in appendix 1 will be used.
Purpose of data/parameter	Calculation of baseline emissions
Additional comments	The data will be updated in accordance with the latest information facilitated by the Colombian electricity authorities.

Data/Parameter	EFgrid,CM,y
Unit	t CO_2/MWh
Description	Combined margin CO_2 emission factor of the grid in year y using the "Tool to calculate the emission factor for an electricity system"
Measured/calculated/ default	Calculated
Source of data	-
Value(s) of monitored parameter	Year: 2018; $EF_{grid,CM,y}$: 0.3886 See Spreadsheet "EF Colombia 2018_Cucuana.xls" worksheet OM
Monitoring equipment	
Measuring/reading/recording frequency	Annually during the crediting period for the relevant year
Calculation method (if applicable)	As per the "Tool to calculate de emission factor for an electricity system
QA/QC procedures	This variable is calculated, not measured, and therefore does not need specific quality control procedures
Purpose of data/parameter	Calculation of baseline emissions
Additional comments	-

Data/Parameter	Cap_{PJ}
Unit	MW
Description	Installed capacity of the hydro power plant after the implementation of the project activity

Measured/calculated/ default	-
Source of data	Project Site
Value(s) of monitored parameter	55
Monitoring equipment	-
Measuring/reading/recording frequency	Yearly
Calculation method (if applicable)	Determine the installed capacity based on recognized standards
QA/QC procedures	-
Purpose of data/parameter	Calculation of project emissions
Additional comments	-

Data/Parameter	A_{PJ}
Unit	m^2
Description	Area of the single reservoir measured in the surface of the water, after the implementation of the project, when the reservoir is full
Measured/calculated/ default	Measured
Source of data	EPSA E.S.P.
Value(s) of monitored parameter	Cucuana: 3,138
Monitoring equipment	Drone Dji Phantom 4, Image 60 meters high, error margin per image 2 cm. Area Estimate: Software ArcGIS Pro
Measuring/reading/recording frequency	Yearly
Calculation method (if applicable)	-
QA/QC procedures	-
Purpose of data/parameter	Calculation of project emissions
Additional comments	The maximum value remains the same as it depends on the dam height or “bocatoma” and the dam was not changed.

D.3. Implementation of sampling plan

N/A

SECTION E. Calculation of emission reductions or net anthropogenic removals

E.1. Calculation of baseline emissions or baseline net removals

The baseline scenario represents the electricity delivery to the grid by the project activity would have otherwise been generated by the operation of grid-connected power plants and by the addition of new generation sources. So, the baseline emissions include only CO_2 emissions from electricity generation in fossil fuel power plants that are displaced due to the project activity. The baseline emissions are calculated as follows:

$$BE_y = EG_{PJ,y}\ x\ EF_{grid,CM,y}$$ **Equation (1)**

Example: $BE_{2018-2019} = 385{,}335\ MWh\ x\ \frac{0.3886\ tCO_2}{MWh} = 149{,}741\ tCO_2$

Where:

- BE_y= Baseline emissions in year y (tCO_2)
- $EG_{PJ,y}$= Quantity of net electricity generation that is produced and fed into the grid as result of the implementation of the CDM project activity in year y (MWh)
- $EF_{grid,CM,y}$ = Combined margin CO_2 emission factor for grid connected power generation in year y (tCO_2/MWh)

The method selected to calculate the operating margin (OM) emission factor is the Simple Adjusted Method, i.e., “option b”, for the calculation of the emission factor of the operating margin of the “Tool to calculate the emission factor for an electricity system”.

The operating margin emission factor can be calculated:

For the project activity, the simple adjusted OM is applied, using the ex post option:

Ex post option: if the ex post option is chosen, the emission factor is determined for the year in which the project activity displaces grid electricity, requiring the emissions factor to be updated annually during monitoring. If the data required to calculate the emission factor for year y is usually only available later than six months after the end of year y, alternatively the emission factor of the previous year y-1 may be used. If the data is usually only available 18 months after the end of year y, the emission factor of the year proceeding the previous year y-2 may be used. The same data vintage (y, y-1 or y-2) should be used throughout all crediting periods.

All power plants connected to the SIN are included. Power plants registered as CDM project activities are also included as suggested by the tool. The data of the most recent year is available from XM (grid operator and administrator9).

In this case, the calculation ex-post has been selected for calculating the operation margin emission factor, so it is recalculated annually. And it is calculated as follows:

$$EF_{grid,OM-adj,y} = \left(1-\lambda_y\right) x \; \frac{\sum_m EG_{m,y} x EF_{EL,m,y}}{\sum_m EG_{m,y}} + \lambda_y \; x \; \frac{\sum_k EG_{k,y} x EF_{EL,k,y}}{\sum_k EG_{k,y}}$$ **Equation (2)**

Where:

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

The parameter λ_y is defined as follows:

$$\lambda_y(\%) = \frac{\text{Nº hours low } - \frac{\text{cost}}{\text{must}} - \text{ run sources are on the margin during the year y}}{\text{8760 hours per year}}$$ **Equation (3)**

[9] www.xm.com.co

Example: $\lambda_{2018}(\%) = 17{,}69\%$

According to the methodology, the number of hours low-cost/must-run sources are on the margin is obtained through the following procedure (see Figure 3 below):

Step i) Plot a Load Duration Curve

Collect chronological load data (typically in MW) for each hour of the year y, and sort the load data from the highest to the lowest MW level. Plot MW against 8760 hours in the year in descending order.

Step ii) Organize Data by Generating Sources

Collect electricity generation data from each power plant/unit. Calculate the total annual generation (in MWh) from low-cost/must-run power plants/units.

Step iii) Fill Load Duration Curve

Fill the load duration curve. Plot a horizontal line across the load duration curve such that the area under horizontal line and the curve right from the intersection point (MW times hours) equals the total generation (in MWh) from low-cost/must-run power plants/units

Step iv) Determine the "Number of hours per year low-cost/must-run sources are on the margin"

Determine the "Number of hours for which low-cost/must-run sources are on the margin in year y. First, locate the intersection of the horizontal line plotted in Step (iii) and the load duration curve plotted in Step (i). The number of hours (out of the total of 8760 hours) to the right of the intersection is the number of hours for which low-cost/must-run sources are on the margin. If the lines do not intersect, then one may conclude that low-cost/must-run sources do not appear on the margin and lambda is equal to zero.

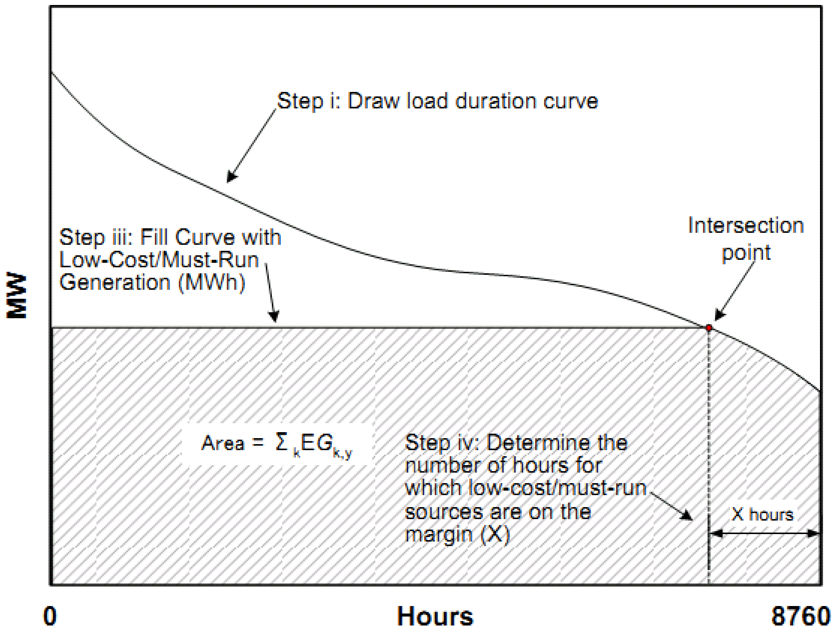

Figure 3. Illustration of Lambda calculation for simple adjusted OM method.

(Note: Step (ii) is not shown in the figure; it deals with organizing data by source.)

The detailed calculations of lambda are provided in the Excel file "EF Colombia 2018_Cucuana". The following figures show the load duration curves and the area given by low cost/must run units, and the resulting lambda.

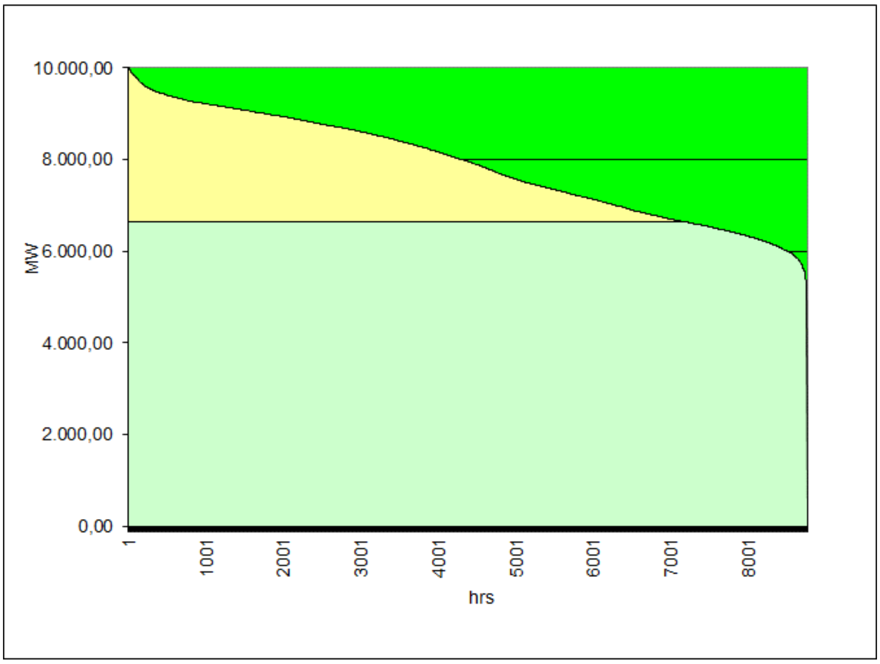

Figure 4. Load duration curve and area given by low-cost/must-run units, and the resulting lambda in year 2018.

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

The emission factor of each power unit m is determined as follows (power units k are not included, since the low-cost/must-run units have zero emissions and thus do not require calculating the emission factor):

For the simple adjusted OM "Option A: Calculation based on average efficiency and electricity generation of each plant" of the tool is chosen as the most appropriate approach. Option A2 is the appropriate method due to the availability of heat rates (efficiencies) of each plant:

$$EF_{EL,m,y} = \frac{EF_{CO2,m,i,y} \times 3.6}{\eta_{m,y}} \quad (4)$$

Where:

$EF_{EL,m,y}$	=	CO_2 emission factor of power unit m in year y (tCO_2/MWh)
$EF_{CO2,m,i,y}$	=	Average CO_2 emission factor of fuel type i used in power unit m in year y ($t CO_2/GJ$)
$\eta_{m,y}$	=	Average net energy conversion efficiency of power unit m in year y (ratio)

By applying formulae (4) to determine the emission factor of each power plant, the results from the lambda calculation and the main equation (3) for the OM emission factor, and the corresponding generation weights of each year, the simple OM emission factor is determined as shown in Table 3.

Table 3. Simple adjusted operating margin emission factor of the year 2018.

Item	2018
EF No LC/MR	0.6595
EF LC/MR	0.000
Lambda	0.1769
Generation [MWh]	**68,948,232**
EF $_{OM\ Simple\ adjusted\ 2018}$($tCO_2/MWh$)	**0.5428**

Build margin (BM) emission factor:

Option 1 of the "Tool to calculate the emission factor for an electricity system", Version 07.0, has been selected for the calculation of the build margin emission factor, which states that, for the first crediting period, the build margin emission factor is calculated (ex-ante) based on the most recent information available on units already built at eh time of CDM-PDD submission to the DOE for validation. So, this option does not require monitoring emission factor during the crediting period.

The baseline emission factor (EF_y) is obtained with the Weighted average CM method through operating and build margin emission factors:

$$EF_{grid,CM,y} = w_{OM}\ x\ EF_{grid,OM,y} + w_{BM}\ x\ EF_{grid,BM,y}$$ **Equation (5)**

Example: $EF_{grid,CM,2017} = 0.5\ x \frac{0.5428\ tCO_2}{MWh} + 0.5\ x \frac{0.2345\ tCO_2}{MWh} = \frac{0.3886\ tCO_2}{MWh}$

Where:

- $EF_{grid,CM,y}$= Combined margin emission factor during year y (tCO_2/MWh).
- w_{OM}= Weighting of the operating margin emission factor (%).
- $EF_{grid,OM,y}$ = Operating margin CO_2 emission factor in year y (tCO_2/MWh).
- w_{BM} = Weighting of the build margin emission factor (%).
- $EF_{grid,BM,y}$ = Build margin CO_2 emission factor in year y (tCO_2/MWh).

E.2. Calculation of project emissions or actual net removals

These emissions shall be accounted for by using following equation:

$$PE_y = PE_{FF,y} + PE_{GP,y} + PE_{HP,y}$$ **Equation (6)**

Where:

- PE_y= Project emissions in year y (tCO_2e)
- $PE_{FF,y}$= Project emissions from fossil fuel consumption in year y (tCO_2)
- $PE_{GP,y}$= Project emissions from the operation of geothermal power plants due to the release of non-condensable gases in year y (tCO_2e)
- $PE_{HP,y}$= Project emissions from reservoirs of hydro power plants in year y (tCO_2e)

In this case, only project emissions from reservoirs of hydro power plants are applied $(PE_{HP,y})$. Project proponents shall account for CH4 and CO2 emissions from the reservoirs, estimated as follows:

a) If the power density of the single or multiple reservoirs (PD) is greater than 4 W/m^2 and less than or equal to 10 W/m^2:

$$PE_{HP,y} = \frac{EF_{Res}\ x\ TEG_y}{1000}$$ **Equation (7)**

Where:

- $PE_{HP,y}$= Project emissions from reservoirs of hydro power plants in year y (tCO_2e)
- EF_{Res}= Default emission factor for emissions from reservoirs of hydro power plants ($kgCO_2e$/MWh)
- TEG_y= Total electricity produced by the project activity, including the electricity supplied

to the grid and the electricity supplied to internal loads, in year y (MWh)

b) If the power density of the project activity (PD) is greater than 10 W/m^2:

$$PE_y = 0 \quad \textbf{Equation (8)}$$

The power density of the project activity (PD) is calculated as follows:

$$PD = \frac{Cap_{PJ} - Cap_{BL}}{A_{PJ} - A_{BL}} \quad \textbf{Equation (9)}$$

Example: $PD = \frac{55{,}000{,}000\, W - 0}{3{,}138\, m^2 - 0} = 17{,}527 \frac{W^2}{m}$

Where:

- PD= Power density of the project activity (W/m^2)
- Cap_{PJ}= Installed capacity of the hydro power plant after the implementation of the project activity (W)
- Cap_{BL}= Installed capacity of the hydro power plant before the implementation of the project activity (W). For new hydro power plants, this value is zero
- A_{PJ}= Area of the single or multiple reservoirs measured in the surface of the water, after the implementation of the project activity, when the reservoir is full (m^2)
- A_{BL}= Area of the single or multiple reservoirs measured in the surface of the water before the implementation of the project

Therefore, if we take into account the power density of the project activity, the second case should take into account, where the power density is greater than 10 W/m^2. In this case, the methodology indicates that the project activity is zero, so:

$$PE_y = 0 \frac{tCO_2}{year}$$

E.3. Calculation of leakage emissions

According to the methodology ACM0002 v.13.0.0 no leakage emissions are considered

E.4. Calculation of emission reductions or net anthropogenic removals

	Baseline GHG emissions or baseline net GHG removals (t CO_2e)	Project GHG emissions or actual net GHG removals (t CO_2e)	Leakage GHG emissions (t CO_2e)	GHG emission reductions or net anthropogenic GHG removals (t CO_2e)		
				Before 01/01/2013	From 01/01/2013	Total amount
Total	149,741	0	0	0	149,741	149,741

E.5. Comparison of emission reductions or net anthropogenic removals achieved with estimates in the registered PDD

Year	Amount achieved during this monitoring period (t CO_2e)	Amount estimated ex ante (t CO_2e)
2018	105,431.4	88,250
To 30/06/2019	44,309.7	44,125

E.5.1. Explanation of calculation of “amount estimated ex ante for this monitoring period in the PDD”

The ex-ante calculation was done based on the expected amount of electricity supplied by the Power Plant to the Colombian Interconnected System – 252,000 MWh annually, multiplied by the emission factor calculated in the registered PDD version 5 which is 0.3502 tCO2 /MWh.

E.6. Remarks on increase in achieved emission reductions

Cucuana Hydro Power Plant reduced 149,741 tCO_2e from the Colombian electric Grid between the years 2018 and 30/06/2019 (half year). Considered that the estimated ex ante emission reduction according to the updated PDD are 132,375 tCO_2e for the period to be verified, there is an increase in achieved emission reductions for this period (see table on section E.5). This growth can be explained considering the increase in precipitations due to the occurrence of La Niña – Southern Oscillation (ENSO), throughout year 2018 and beginning 2019, reporting high river flows and therefore increase in generation.

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Document information

Version	*Date*	*Description*
07.0	31 May 2019	Revision to: • Ensure consistency with version 02.0 of the “CDM project standard for project activities” (CDM-EB93-A04-STAN); • Add a section on remarks on the observance of the scale limit of small-scale project activity during the crediting period; • Add "changes specific to afforestation or reforestation project activity" as a possible post-registration changes; • Clarify the reporting of net anthropogenic GHG removals for A/R project activities between two commitment periods; • Make editorial improvements.
06.0	7 June 2017	Revision to: • Ensure consistency with version 01.0 of the “CDM project standard for project activities” (CDM-EB93-A04-STAN); • Make editorial improvements.
05.1	4 May 2015	Editorial revision to correct version numbering.

05.0	1 April 2015	Revisions to: • Include provisions related to delayed submission of a monitoring plan; • Provisions related to the Host Party; • Remove reference to programme of activities; • Overall editorial improvement.
04.0	25 June 2014	Revisions to: • Include the Attachment: Instructions for filling out the monitoring report form (these instructions supersede the "Guideline: Completing the monitoring report form" (Version 04.0)); • Include provisions related to standardized baselines; • Add contact information on a responsible person(s)/ entity(ies) for completing the CDM-MR-FORM in A.6 and Appendix 1; • Change the reference number from *F-CDM-MR* to *CDM-MR-FORM*; • Editorial improvement.
03.2	5 November 2013	Editorial revision to correct table in page 1.
03.1	2 January 2013	Editorial revision to correct table in section E.5.
03.0	3 December 2012	Revision required to introduce a provision on reporting actual emission reductions or net GHG removals by sinks for the period up to 31 December 2012 and the period from 1 January 2013 onwards (EB 70, Annex 11).
02.0	13 March 2012	Revision required to ensure consistency with the "Guidelines for completing the monitoring report form" (EB 66, Annex 20).
01.0	28 May 2010	EB 54, Annex 34. Initial adoption.
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