



CHOL CHAROEN GROUP WASTEWATER TREATMENT WITH BIOGAS SYSTEM I (KHONKAEN)



Document Prepared by South Pole Carbon Asset Management Ltd.

Project Title	Chol Charoen Group Wastewater Treatment with Biogas System I (Khonkaen)
Version	03.1
Report ID	01
Date of Issue	27-September-2021
Project ID	427
Monitoring Period	03-March-2020 to 31-March-2021
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1 PROJECT DETAILS

1.1 Summary Description of the Implementation Status of the Project

Chol Charoen Group Wastewater Treatment with Biogas System I (Khonkaen), hereafter, 'the project activity', of two anaerobic covered lagoon facilities (converted from two existing open lagoons) at Kean Charoen Co., Ltd., a tapioca starch factory in Khonkaen, Thailand. The system has been in operation since 02-October-2006 (project start date). The starch factory has a mean daily production capacity of 175 tons¹ of dried starch, generating 2,000 m³ of wastewater per operational day.

The project activity involves the installation two anaerobic covered lagoons continues to flow to a series of remaining 9 open lagoons. The implementing system enables recovery of biogas that would have been released into the atmosphere and utilise it for thermal and electricity generation. In the case of thermal energy generation, the captured biogas has been co-fired in existing heat generating devices for the process of drying the wet starch (displacing fuel oil under the previous system). In addition, the power produced by this captured biogas was not only facilitated the electricity requirement of the plant, but also be fed to national grid under the pending power purchase agreement with the Provincial Electricity Authority (PEA).

This monitoring report involves with the monitoring duration under the second crediting period started from 15/07/2019 to 14/07/2029. The monitoring duration covers the monitored data from 03/03/2020 to 31/03/2021. The project has achieved 61,493 tCO₂e.

Table 1: Summary of baseline and project conditions

Baseline/ Project Component	Brief Description
Boiler	There are two dual-fired boilers with thermal capacity with a capacity of 4.07 and 6.16 MW_{th} respectively. The first boiler with a capacity of 4.07 MW_{th} was not part of the project activity, in line with the previous crediting period. The second boiler, which previously capacity of 3.78 MW_{th} was replaced by the new one with capacity 6.16 MW_{th} in year 2020 and still included in the project activity. It was important to mention that there was no change in starch or wastewater treatment system capacity². The old second boiler (3.78 MW_{th}) when using biogas as fuel often delivered unstable performance, thus, the PO decided to replace with the new boiler.
Gas engines	There are two electricity generation sets; the first set (no.'s 1 and 2) has 2 generators and the capacity of 952 kW_{el} each. The second generator set (no.'s 3 and 4) with 2 generators capacity of 450 kW_{el} which are not included in this project boundary. It was noted that generator no.'s 1 was decommissioning on 13/06/2020 and generator no's 2 was stopped operation on 26/12/2020. The replacement was due to the low efficiency of the two old engines. The new gas engine with the installed capacity of 1.5 MW_e

¹ Calculated by historical data

² The evidence was submitted to the VVB during validation process.

	was commissioning on 09/01/2021. The installed capacity of the gas engine which replaced the old set is actually lower than what have been registered in the registered PD and within the operation license limit. Thus, no impact on the applicability of the methodology, additionality or the appropriateness of the baseline scenario. Further justification has been described under section 3.2.2 Project Description Deviation. For the second generator set, it was noted that the similar type of gas engine (installed cap of 1.5 MW_e) has taken place. The engine is used as a back-up and still have not been included in the project boundary.
Flare	An open flare system is available at the plant. This is an automatic flare system that will operate when pressure is higher than 3 mbar. There is also a flame arrester to ensure the safe operation of the flare system.
Capacity of auxiliary drives	Total capacity of the auxiliary drives is 458 kW; the same can be referred in the greenhouse gas (GHG) calculation sheet as well as in the document submitted during validation.

Further background information on this project activity can be found on the Verified Carbon Standard (VCS) website:

<https://registry.verra.org/app/projectDetail/VCS/427>

1.2 Sectoral Scope and Project Type

The project activity involves recovery of biogas from wastewater that is released from a tapioca starch processing plant. The recovered biogas is used in a boiler to generate heat for the starch-drying process and to generate electricity in order to meet the power requirement of the starch processing plant; it may be supplied later to the national grid. After satisfying the above demands, surplus biogas is flared for safety purposes. In this monitoring period, the indication of sectoral scope and project type is provided as follows.

Methane avoidance component:

Type III : Other project activities
Category III.H : Methane Recovery in Wastewater Treatment
Sectoral Scope 13 : Waste handling and disposal
Version : 19

Electricity generation component:

Type I : Renewable energy projects
Category I.D : Grid connected renewable electricity generation
Sectoral Scope 1 : Energy industries (renewable/non-renewable sources)
Version : 18

Fuel replacement component

Type I	: Renewable energy projects
Category I.C	: Thermal energy production with or without electricity
Sectoral Scope 1	: Energy industries (renewable/non-renewable sources)
Version	: 21

1.3 Project Proponent

Organization name	Kean Chareon Co., Ltd.
Contact person	Mr. Ung Mengchua
Title	Managing Director
Address	1004/201 Rama 3 Road, Bangpongpan, Yannawa, 10120
Telephone	+ 66 2 294 5315-6, 2945646
Email	sales@thaitapiocastarch.com

1.4 Other Entities Involved in the Project

Organization name	South Pole Carbon Asset Management Ltd.
Role in the Project	Project developer for development of emission reduction through the Voluntary Carbon Standard
Contact person	Renat Heuberger
Title	CEO
Address	Technoparkstrasse 1, Zurich, Switzerland, 8005
Telephone	+41 43 501 35 50
Email	registration@southpole.com

1.5 Project Start Date

The project activity began on 02-October-2006. This is the date that the biogas began to be utilized in the hot oil boiler.

It was noted that crediting period start date is on 15th July 2009. Due to insufficiency of monitoring equipments, the operational period prior 15th July 2009 was neglected from our claim of emission reduction. This is in line with the principle of conservativeness as per VCS 2007.1 and complies with VCS program criteria for GHG projects and programs VCS Program Guide v.4.0.

1.6 Project Crediting Period

The project crediting period under this monitoring period involves the following detail.

- Second crediting period: 15-July-2019 to 14-July-2029 (10 years)

1.7 Project Location

The proposed project activity is located at Kean Charoen Co., Ltd, in Kranuan district, Khonkaen province, situated in the northeast region of Thailand, approximately 450 km from Bangkok. The project activity location is depicted in Figure 1 and Figure 2.

Street address: 261 Moo 4, Huanakhum, Kranuan, Khonkaen, 40170, Thailand

Geographical coordinates: 16° 48.498'N Latitude and 103° 05.148'E Longitude



Figure 1: Location



Figure 2: Project activity

1.8 Title and Reference of Methodology

The following methodologies are applicable to the project activity during second crediting period.

Methane avoidance component:

AMS-III.H “Methane recovery in wastewater treatment”

Thermal displacement component:

AMS-I.C “Thermal energy production with or without electricity”

Electricity generation component:

AMS-I.D “Grid connected renewable electricity generation”

The version of applied methodologies and relevant tools are defined as follows.

AMS-III.H. version 19 refers to:

- “Project emission from flaring”, version 02.0.0

AMS-I.C. version 21 refers to:

- “Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion” version 02
- “Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation” version 02.0

AMS-I.D. version 18 refers to:

- “Tool to calculate the emission factor for an electricity system” version 07.0

These methodologies and tools can be found on the UNFCCC’s website at the following address:

<http://cdm.unfccc.int/methodologies/SSCmethodologies/approved.html>

1.9 Participation under other GHG Programs

This section is not applicable since the project does not involve with any other GHG programs.

1.10 Other Forms of Credit

Emission Trading Programs and Other Binding Limits:

The project is registered under VCS and does not reduce GHG emissions from activities that are included in an emissions trading program or any other mechanism that included GHG allowance.

Other Forms of Environment Credit:

The project does not seek or receive another form of GHG-related environmental credit, including renewable energy certificates during this monitoring period.

1.11 Sustainable Development

Legislative:

The project meets all the statutory requirements. Evidence of permits for the implementation of the project such as operation permit, and property deed, among others, is provided to the validation/verification body (VVB) for the validation process.

Technical:

The covered lagoon biogas reactor system is implemented for reusing biogas as fuel for heat and electricity generation. As compared to the baseline scenario, the installed wastewater treatment system consists of a highly efficient process for wastewater treatment, which brings about the promotion of new technology in Thailand with replication options.

The anaerobic digester requires special training of skilled staff to operate and maintain the plant, creating employment and leading to knowledge transfer to the Northeastern region of the country. The use of this technology in wastewater treatment by the project owner will popularize the technological knowhow in the nearby areas and in plants looking for similar technology in the country.

Economic:

New jobs were created during the construction and operation phases of the biogas reactor system. Also, regional economic development can foster through contracts to local firms. In addition, the partial reimbursement on the vast investment cost can be made through the utilization of the captured biogas, the additional revenue from the sale of VCUs will also make the project financially feasible.

Sectoral:

The use of Clean Development Mechanism (CDM) approved methodology will be applied under the VCS framework; this is a good example of an effective waste to energy project which in turn improves the long-term sustainability of the Thai starch industry.

Social:

The project activity provides direct and indirect employment to the local community during construction of the project activity, as well as during operation. During construction, employment

was offered for a lot of local unskilled labors contributing to social well-being and economic well-being. The involvement of local employees in the project activity will help to enhance the skill of the laborers in the region by training them in different technical areas. In addition, the close collaboration between external experts and local counterparts is expected to promote long-term sustainable partnerships, benefiting the local stakeholders.

The substitution of fuel oil with biogas from the project activity will result in increased availability of these fuels in the local market. The noise, arising from pumps and blowers operating in the biogas plant, is minor. There are no other occupational health issues identified. The safety aspects of operating the biogas plant will be sufficiently addressed.

Environment:

Due to the higher efficiency and improved process control, the quality of treated wastewater is expected to improve substantially with the implementation of the project activity. In fact, the biogas reactor system allows the starch factory to recycle the treated effluent in a starch production process; this constitutes sustainably in the water supply while ensuring that groundwater shortage should not be a problem for the local community. It must be mentioned that the project activity has zero discharge to the river or other natural sources such as soils and groundwater. Note that the wastewater overflow might happen during the rainy season if the precipitation rate is higher than the outflow rate of the final pond for a sustained period of time. As can be seen from Figure 2, under Section 1.7, the starch plant and pond systems are surrounded by agricultural land. Wastewater overflow can lead to a variety of problems that have significant environmental impacts. Excess nutrients in the wastewater will stimulate excessive plant growth which can disrupt normal functioning of the ecosystem, known as eutrophication. Such a problem could lead to social conflicts within the community. While wastewater can overflow from any ponds in the old anaerobic lagoon, the overflow can only happen from the post-treatment pond in the closed anaerobic system. Since the average water quality at the outlet of the project activity is better than that in the anaerobic lagoon ponds, the environmental impacts from overflow of wastewater will be significantly reduced. Overall, the project will have a positive impact on the local environment by improving air quality through reduction in odor and cleaner emissions. This can in turn improve the standard of living of the local population. The capacity of this technological process to replace fuel oil and generating electricity can also be regarded as a potential for reducing dependency on fossil fuels and for promoting diversification of energy resources. Ensuring energy security in this way can be seen as a contribution to sustainable development, particularly during this era of growing fuel prices.

Geographic/site specific:

The project can be uniquely identified with no barriers regarding logistic. In addition, it is not located in sensitive area such as protected area or where there is any fragile or vulnerable habitats close by. Thus, there are no issues preventing the eligibility of the project in this regard.

2 SAFEGUARDS

2.1 No Net Harm

There is no negative environmental and socio-economic impact. The project is a renewable energy biogas based thermal and electrical generation activity. In line with the operation license issued by the department of industrial work, the project follows the local regulation in order to maintain and prevent the environmental impact.

2.2 Local Stakeholder Consultation

Invitation procedure

The Voluntary Carbon Standard(VCS) Initial Stakeholder Consultation was carried out by Kean Charoen Co. Ltd., with assistance from South Pole Carbon Asset Management Ltd. (Switzerland based company responsible for VCS project development).

Stakeholder groups (as defined by Gold Standard procedures) were identified and informed through verbal and written means. Invitation letters were sent by fax and regular mails to participants located far away from the project site. The invitation process was conducted within 2 weeks prior to the meeting date.

Place and date of meeting

The initial stakeholder consultation was held in the Auditorium of Huanakhum Sub-district Administration Organization, which is located 10km away from the tapioca factory, on 10-July-2008 starting at 13:00. All invited stakeholder groups were able to participate the meeting and they were also able to examine the site location where the proposed project activity is to take place.

Meeting participants

The meeting was attended by local residents and representatives from the following stakeholder categories:

1. Local residents
2. Local government representatives

There were 23 participants attending the meeting.

Language

The documentation and meeting were conducted in Thai (local language)

Meeting procedures

- Opening (10 min)
- Purpose of the consultation (10 min)
- Description of the project and environmental impacts by Kean Chareon Co. Ltd. (20 min)
- Description of the Environmental Credits Scheme by South Pole Carbon Asset Management Ltd. (15 min)
- Description of the Gold Standard sustainable development matrix (10 min)
- Questions and Answers session (10 min)
- Completing checklists (Appendix E in the Gold Standard Project Developer's Manual) (20 min)

Meeting documents and protocols

On completion of the various meetings, the following documentation was collected and attested by the signatures of the stakeholders that were present:

1. Presence list with name, address and occupation.
2. Non-technical description of the project
3. Documentation on environmental impacts of the project
4. Filled out Appendix E of the Gold Standard (checklist)
5. Notes for additional comments on the project activity

Compilation of comments received

Verbal hearing for local stakeholders:

The project activity and its environmental impacts were described to the stakeholders during the meeting. The stakeholders acknowledged that the improvement of the current wastewater treatment system by introducing covered lagoons would reduce odor emissions to the surrounding area, which was previously a major concern for the surrounding community. According to the feedback during the meeting, which was provided both verbally and in writing through the Gold Standard questionnaires filled out by 23 participants, the stakeholder's give their support and have a positive opinion about the project activity. They further believe that the project activity will benefit them and their families through reduction in odor nuisance. Therefore, this project activity is perceived as an environmentally friendly project, which can improve the quality of life of the surrounding community. The project activity is expected to deliver multiple benefits in respect of sustainable development in Thailand including environmental, social and economic benefits, which are summarized below:

- Reduction of methane emission which is a potent greenhouse gas (GHG);
- Reduction of the odor nuisance associated with the open lagoon wastewater system, improving quality of life and health of the surrounding communities
- Conservation of groundwater resources from the use of high-density polyethylene (HDPE) lining at the bottom of the lagoons, which can prevent wastewater from contaminating groundwater;
- Reduction in the use of non-renewable energy such as fuel oil, while at the same enhancing energy security by increasing diversity of fuel supply;
- Involvement of local communities through public participation meeting, in which most people are encouraged by the project activity;
- Increased employment by employing local people to construct and operate the project activity;
- Promoting technological excellence and innovation in Thailand by implementing a cleaner technology solution for wastewater treatment in the tapioca starch sector, which could be replicated across Thailand and the region; and
- Demonstrating the use of a new financial mechanism for the funding of waste management projects via CDM revenues.

Current Practice

The project proponent maintains a register at the plant, to make sure any current feedback is provided by local people in fair and transparent manner.

The registry form has been provided at the security guard house and the recording is controlled by the HR. The project participants also have strong connection with the people in the community for example supporting in giving scholarship, participating in the community event i.e. children day, sport days, Buddhist ceremony etc.

During this monitoring period, it was found that the two Gauscor engines with the installed capacity of 952 kW_e each have been replaced by the new gas engine Jenbacher with installed capacity of 1.5 MW_e. The replacement was due to the low performance of the old engines. The installed capacity at the site is not exceeding the limit as mentioned in the operation license nor the registered PD. The replacement also has no impact on the applicability of the methodology, additionality or the appropriateness of the baseline scenario. Further detail has been provided under Project description deviation section 3.2.2

2.3 AFOLU-Specific Safeguards

For non-AFOLU projects, this section is not required.

3 IMPLEMENTATION STATUS

3.1 Implementation Status of the Project Activity

The operation of the project activity was under normal conditions, where all of the monitoring parameters were conducted as per the registered monitoring plan. There was no change in the project activity as per the registered Project Description (PD). The equipment/machine was also maintained according to the registered PD. In case of any calibration delay, the maximum error was applied to the relevant monitoring data and the conservative values are used for the calculation of emission reductions. The events that may impact the GHG emission reductions were provided in *Table 2*.

Table 2: The implementation status of the project activity

Date	Events
15/07/2009	First crediting period start date
2010	Boiler 1 replacement
03/03/2020 to 31/03/2021	Third monitoring period under second crediting period; refer to this report
30/06/2020	Decommissioning of generator no.1 (Gen's 01, Gauscor 366, installed capacity 952 kW _{el})
26/12/2020	Stop operation of generator no.2 (Gen's 02, Gauscor 377, installed capacity 952 kW _{el})
07/01/2021	Test run of the new Gas Engine (Jenbacher, installed capacity at 1.5 MW _{el}) which replace the generator set (Gauscor 366 & Gauscor 377)
09/01/2021	Commissioning of the new gas engine ³

³ Referring to the commissioning certificate by INNIO (Form of Equipment Acceptance Report)

3.2 Deviations

3.2.1 Methodology Deviations

The methodology deviation is defined below.

Deviations applied for second crediting period

Background

This approach was deviated in Paragraph 34 of the methodology AMS-I.C version 21. It was proposed and validated by the validation and verification body during the validation of the project activity. The deviation was accepted, and the detail was addressed in Section 3.6 of the updated PD.

$$BE_{\text{thermal},\text{CO}_2,y} = (EG_{\text{thermal},y} / \eta_{\text{BL},\text{thermal}}) \times EF_{\text{FF},\text{CO}_2}$$

Where:

$EG_{\text{thermal},\text{CO}_2,y}$ Net quantity of steam/heat supplied by the project activity during the year y in TJ

$EF_{\text{FF},\text{CO}_2}$ CO₂ emission factor per unit of energy of the fuel that would have been used in the baseline plant in tCO₂/TJ, obtained from reliable local or national data if available, alternatively, IPCC default emission factors can be used.

$\eta_{\text{BL},\text{thermal}}$ Efficiency of the plant using fossil fuel that would have been used in the absence of the project activity

Since the monitoring mechanism was not available for the measurement of the baseline input/output thermal energy, a conservative approach has been adopted as explained in the validated PD.

Explanation of the deviation

A quantity of dry starch that is produced during a particular year, a minimum required quantity of fossil fuel (fuel oil) can be estimated from a quantity of fossil fuel used per unit of dry starch, historically. For the same year, if the data for fossil fuel consumed is available, then the remaining energy must be supplied by biogas. This is a conservative approach to estimate the fuel oil that, in the absence of the project activity, would be used in the starch drying process. It must be noted that the efficiency of the boiler when used in dual-fuel mode is lower than at regular single-fuel conditions (HFO only). This drop in efficiency leads to a lower biogas to HFO displacement rate.

On the basis of historical records fossil fuel used per tonne of starch production is determined. For the subsequent monitoring, the starch production is monitored and used to estimate the amount of fossil fuel that would be used in absence of project activity. This represents baseline consumption of fossil fuel and takes into account the historical efficiency of the fossil fuel heat generating device. In a particular year the actual amount of fossil fuel used is subtracted from baseline fossil fuel consumption (calculated) value to estimate the amount of fossil fuel replaced. This assumption is conservative as all the effect of efficiency loss is borne by biogas and not by fossil fuel.

$$BE_{\text{thermal,CO2,y}} = (Q_{\text{starch,y}} * Q_{\text{FO,starch}} - q_{\text{FO,y}}) * D_{\text{FO}} * NCV_{\text{FO}} * EF_{\text{CO2}} / 10^6$$

Deviation 1

Where:

$Q_{\text{starch,y}}$ Quantity of dry starch produced in year “y” (tonnes)

$Q_{\text{FO,starch}}$ Quantity of fossil fuel per unit of dry starch (liter/tonne)

$q_{\text{FO,y}}$ Quantity of fossil fuel consumed at the project site in year “y” (litres)

D_{FO} Density of fossil fuel (kg/litre)

NCV_{FO} Net Calorific value of the fuel oil (TJ/ton)

It must be noted that the deviation does not only estimate baseline emissions on the amount of heat/steam generated by the boiler, it also takes into account CO2 emissions from on-site consumption of fossil fuels due to the project activity. In other words, it represents the emission reduction from the heat generation component.

3.2.2 Project Description Deviations

Deviation 1

Background

This approach is deviated according to the FAR M3 of the validation report during the first crediting period. Since the replacement of first boiler (boiler 1) was addressed during the validation of the project activity, the FAR M3 was raised in the validation report. The first boiler was replaced during the first verification and has been used since then, therefore, the same deviation from the first verification is also applied for this verification.

Explanation of the deviation

Boiler 1 was replaced by the newer and bigger boiler one. The capacity of thermal energy output was changed from 3.488 to 4.070 MW_{th}. As per the description in FAR M3 of the validation report, if an existing boiler is replaced with a new one during any verification no emission reduction shall be granted for heat displacement. Hence the heat displacement at this boiler was neglected from the emission reductions.

Compliance with the deviation

The deviated approach was adopted by considering only the thermal energy supplied from the second hot oil boiler (boiler 2) for the thermal energy displacement of AMS-I.C.

This is the conservative approach as per VCS guidelines because the emission reductions achieved from AMS-I.C was reduced.

Description of deviation

The thermal energy supplied and displaced at boiler 2 was calculated as per the steps below;

1. Determine the fuel oil consumption of each boiler in liters

Fuel oil usage	2020	2021
Boiler 1	17,610	80
Boiler 2	57,510	141,485

2. Determine the biogas consumption of each boiler in Nm³

Biogas usage	2020	2021
Boiler 1	111,406	62,361
Boiler 2	1,975,926	876,926

3. Calculate the thermal energy supplied from each boiler in GJ

Thermal energy	2020	2021
Boiler 1	702,674	4,487
Boiler 2	2,328,505	5,645,154
Total	3,031,179	5,649,641

4. Calculate the percentage of thermal energy supplied from each boiler

Percentage	2020	2021
Boiler 1	23%	0%
Boiler 2	77%	100%

5. The BE_{thermal} calculation as per the description in Deviation 1 of the registered PD was considered only for the fuel oil displacement in the boiler 2. Then the equation for Deviation 1 was revised to:

$$BE_{\text{thermal},CO2,y} = (Q_{\text{starch}} * Q_{FO,\text{starch}} * \%B2 - Q_{FO,y,\text{Boiler2}}) * D_{FO} * NCV_{FO} * EF_{CO2}/10^6$$

Parameter	Description
Q _{starch,y}	Quantity of dry starch produced in year “y” (tons)
Q _{FO,starch}	Quantity of fossil fuel per unit of dry starch (liter/ton)
Q _{FO,y,boiler2}	Quantity of fossil fuel consumed by hot oil boiler no.2 in year “y” (liters)
D _{FO}	Density of fossil fuel (kg/liter)
NCV _{FO}	Net Calorific value of the fuel oil (TJ/ton)
%B2	The percentage of thermal energy supplied from the boiler 2 from step 4 above

Deviation 2

Background

The project activity registered with two electricity generation sets; the first set (no.'s 1 and 2) has 2 generators and the capacity of 952 kW_{el} each. The second generator set (no.'s 3 and 4) with 2 generators capacity of 450 kW_{el} which are not included in this project boundary. During this monitoring period, 03/03/2020 to 31/03/2021, it was noted that there was the replacement of the gas engine. The first gas engine set has been replaced by the new gas engine with the installed capacity of 1.5 MW_{el}. The new gas engine was commissioning on 09/01/2021. The reason of the replacement was due to lower performance of the existing engines.

Explanation of the deviation

The approach is deviated as the change of the monitoring point for electricity generation by the project activity; $EG_{PJ,y}$ and the installed capacity of the gas engine is lower than what have been written in the registered PD.

Compliance with the deviation

As per the registered PD, it was mentioned that the installed capacity of the gas engine set 1 is (952*2) approximately 2 MW_{el}. The new gas engine which took place the generator set 1 has the installed capacity of 1.5 MW_{el} which is lower than what have been than the registered PD and within the operation license limit. The change does not have an impact on the applicability of the methodology, additionality nor the appropriateness of the baseline scenario.

3.3 Grouped Projects

The project activity is not a grouped project.

4 DATA AND PARAMETERS

4.1 Data and Parameters Available at Validation

Data/Parameter	GWP _{CH4}							
Data unit	tCO ₂ e/tCH ₄							
Description	Global warming potential for methane gas							
Source of data	According EB 69 - Annex 3, the second commitment period GWP shall be effective from 01/01/2013							
Value applied	<table><tr><th>Monitoring period</th><th>Applied value</th></tr><tr><td>03/03/2020 to 31/12/2020</td><td>25</td></tr><tr><td>01/01/2021 to 31/03/2021</td><td>28</td></tr></table>		Monitoring period	Applied value	03/03/2020 to 31/12/2020	25	01/01/2021 to 31/03/2021	28
Monitoring period	Applied value							
03/03/2020 to 31/12/2020	25							
01/01/2021 to 31/03/2021	28							
Justification of choice of data or description of measurement methods and procedures applied	Intergovernmental Panel on Climate Change, Climate Change 1995: The Science of Climate Change (Cambridge, UK: Cambridge University Press, 1996).							
Purpose of data	Calculation of baseline and project emissions							
Comments	According to paragraph 3.14.4 of VCS standard 4.1 mentions that All GHG emission reductions shall be converted to CO₂e using 100-year global warming potential (GWP) values. For GHG emission reductions occurring on or after 1 January 2021, all ex-ante estimates and ex-post calculations shall be converted to							

	CO₂e using GWP values from the IPCC Fifth Assessment Report (AR5). The GWP from AR4 (GWP-methane = 25) is applied for the emission reduction achieved from 03/03/2020 to 31/12/2020. However, the latest GWP from AR5 (GWP-methane = 28) has been applied for the emission reduction achieved from 01/01/2021 to 31/03/2021 which is comply with latest VCS standard.
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Data/Parameter	B _{0,ww}
Data unit	kg CH ₄ /kg COD
Description	Methane producing capacity of the wastewater
Source of data	IPCC default value as per AMS-III.H version 19
Value applied	0.25
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of data	Calculation of baseline and project emissions
Comments	-

Data/Parameter	UF _{BL}
Data unit	Factor
Description	Model correction factor to account for model uncertainties
Source of data	AMS-III.H version 19
Value applied	0.89
Justification of choice of data or description of measurement methods and procedures applied	As per AMS-III.H
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	UF _{PJ}
Data unit	Factor
Description	Model correction factor to account for model uncertainties
Source of data	AMS-III.H version 19
Value applied	1.12
Justification of choice of data or description of measurement methods and procedures applied	As per AMS-III.H
Purpose of data	Calculation of project emissions
Comments	-

Data/Parameter	MCF _{ww,treatment,BL,Lagoon}
Data unit	Fraction
Description	Methane correction factor for baseline wastewater treatment systems i
Source of data	Table 2 from AMS-III.H version 19
Value applied	0.8
Justification of choice of data or description of measurement methods and procedures applied	The baseline wastewater treatment system consists in a succession of deep lagoons (depth more than 2 meters) therefore MCF value is chosen as 0.8.
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	MCF _{ww,treatment,PJ,lagoon}
Data unit	Fraction
Description	Methane correction factor for project secondary wastewater treatment system k
Source of data	Table 2 from AMS-III.H version 19

Value applied	0.8
Justification of choice of data or description of measurement methods and procedures applied	In the project scenario the post treatment of wastewater treatment system without biogas recovery consists of a succession of lagoons, with depth greater than 2 meters, thus the value of 0.8 has been chosen.
Purpose of data	Calculation of project emissions
Comments	IPCC Default values from chapter 6 of volume 5. Waste in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Data/Parameter	$\eta_{\text{COD,BL,I}}$ or COD removal efficiency-baseline
Data unit	%
Description	Chemical oxygen demand removal efficiency of baseline treatment system
Source of data	Historical data of baseline lagoons based on colorimetric analysis
Value applied	87.16%
Justification of choice of data or description of measurement methods and procedures applied	The removal efficiency based on a measurement campaign. The efficiency was 97.93% that must be multiplied with 0.89 for a conservative estimation as per AMS-III.H. The resulting COD removal efficiency factor of the baseline system is thus 87.16%.
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	CFE_{ww}
Data unit	Fraction
Description	Capture efficiency of the biogas recovery equipment in the wastewater treatment systems.
Source of data	AMS-III.H version 19
Value applied	0.9
Justification of choice of data or description of measurement methods and procedures applied	A default value as per AMS-III.H.

Purpose of data	Calculation of project emissions
Comments	-

Data/Parameter	$EF_{grid,y}$
Data unit	tCO ₂ e/MWh
Description	Combined margin CO ₂ emission factor for grid power generation in year y
Source of data	A Study on Thailand Grid Emission Factor by Thai DNA
Value applied	0.5637
Justification of choice of data or description of measurement methods and procedures applied	The study of the estimation of grid emission factor is carried out by Thai DNA in accordance with the Methodological Tool: Tool to calculate the emission factor for an electricity system. The choice of data has been detailed in the published study by Thai DNA.
Purpose of data	Calculation of baseline and project emissions
Comments	-

Data/Parameter	$EF_{HFO,CO2}$
Data unit	tCO ₂ /TJ
Description	Emission factor of fossil fuel replaced – residual fuel oil
Source of data	IPCC 2006 default value for residual fuel oil, volume 2, chapter 1, 1.23
Value applied	77.4
Justification of choice of data or description of measurement methods and procedures applied	IPCC default value used for unavailability of national data. Prior project activity, the residual fuel oil has been main source of thermal energy for the processes.
Purpose of data	Calculation of baseline emissions
Comments	

Data/Parameter	NCV_{HFO}
----------------	-------------

Data unit	GJ/ton
Description	NCV of heavy fuel oil
Source of data	Page 4 of the Energy Situation Report of January to August 2019 published by the Department of Alternative Energy Development and Efficiency, Ministry of Energy ⁴
Value applied	42.763
Justification of choice of data or description of measurement methods and procedures applied	The data source (c) Regional or national default values as per the applied tool “Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion”, version 03. The value based on the Energy Situation Report is 39.77 MJ/l. The density of heavy fuel oil 0.93 kg/l is applied for net calorific value. = 39.77 MJ/l / 0.93 kg/l = 42.763 MJ/kg or GJ/ton
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	NCV _{biogas}
Data unit	MJ/Nm ³
Description	NCV of biogas
Source of data	Thailand Energy Situation Report ⁵
Value applied	20.93
Justification of choice of data or description of measurement methods and procedures applied	Default value from official source in Thailand
Purpose of data	Calculation of baseline emissions
Comments	-

⁴ https://www.dede.go.th/download/stat62/frontpage_jan_nov62.pdf (accessed on 13/03/2020)

⁵ https://www.dede.go.th/download/stat62/frontpage_jan_nov62.pdf (accessed on 13/03/2020)

Data/Parameter	$Q_{FO, starch}$
Data unit	l/ton
Description	Liters of fossil fuel required per ton of dry starch
Source of data	Historical data
Value applied	39.6
Justification of choice of data or description of measurement methods and procedures applied	Based on average values from 2005 and 2006 (January – October) 2005 = 40.0 liters/ton 2006 (January – October) = 39.2 liters/ton
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	D_{CH_4}
Data unit	kg/m ³
Description	Density of methane at normal conditions
Source of data	Tool to determine project emissions from flaring gases containing methane.
Value applied	0.716
Justification of choice of data or description of measurement methods and procedures applied	CDM EB as per EB28 Meeting report (Annex 13)
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	ρ_{HFO}
Data unit	kg/liter
Description	Density of fuel oil

Source of data	Thai local value (PTT) ⁶
Value applied	0.93
Justification of choice of data or description of measurement methods and procedures applied	Thai local value is used
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	DE
Data unit	%
Description	Destruction efficiency of the electricity generator
Source of data	SSC WG
Value applied	100%
Justification of choice of data or description of measurement methods and procedures applied	According to the clarification from SSC WG “in the case that the biogas is combusted for a gainful use of the released energy as in an engine or a power plant, a destruction efficiency of 100% can be used for the portion of biogas that is combusted when applying AMS-III.H., i.e. use a value of 100% for FE in equation 16 in Paragraph 32 for the portion of biogas that is combusted for a gainful use”
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	P _{el}
Data unit	kW
Description	Total electrical capacity of the equipment installed in the project activity
Source of data	List of electrical consumption from name plates of installed electrical equipment

⁶ https://www.pttplc.com/th/Media-Center/Energy-Knowledge/Documents/MD25%20knowledge02/nc_en_ee-01_01.pdf (accessed on 13-March-2020)

Value applied	458
Justification of choice of data or description of measurement methods and procedures applied	Extract from nameplate of the electrical equipment.
Purpose of data	Calculation of project emissions
Comments	-

4.2 Data and Parameters Monitored

Data/Parameter	$Q_{ww,y}$											
Data unit	m ³											
Description	Volume of wastewater treated in the year y											
Source of data	Volumetric flow meter: FM1 and FM2 (measured continuously)											
Description of measurement methods and procedures to be applied	The electromagnetic volumetric flow meter with an acceptable level of accuracy is installed at the plant. In recording this parameter, plant’s operators shall first manually archive the monitored data onto log sheets then transfer to the computer for electronic storage. Please note that continuous measurement has been made, and cumulative reading was recorded daily. In case the flow meter value is not available for a particular day, the same shall be estimated in a conservative manner.											
Frequency of monitoring/recording	The monitoring was done continuously using the flow meter. Recording was conducted on the daily basis.											
Value monitored	<table><tr><th rowspan="2">Monitoring period</th><th colspan="2">Average value</th></tr><tr><th>Lower</th><th>Higher</th></tr><tr><td>03/03/2020 to 31/12/2020</td><td>387,301</td><td>387,697</td></tr><tr><td>01/01/2021 to 31/03/2021</td><td>263,114</td><td>263,114</td></tr></table>	Monitoring period	Average value		Lower	Higher	03/03/2020 to 31/12/2020	387,301	387,697	01/01/2021 to 31/03/2021	263,114	263,114
Monitoring period	Average value											
	Lower	Higher										
03/03/2020 to 31/12/2020	387,301	387,697										
01/01/2021 to 31/03/2021	263,114	263,114										
Monitoring equipment	There were replacement of the wastewater flow meters both FM1 & FM2 during this monitoring period. The meter has been replaced with the similar type/ brand. The detail of the instrument and the period of installation are as follow. <table><tr><td>Meter tag</td><td>FM1</td></tr><tr><td>Serial number</td><td>LA020720000</td></tr><tr><td>Brand</td><td>Endress Hauser</td></tr></table>	Meter tag	FM1	Serial number	LA020720000	Brand	Endress Hauser					
Meter tag	FM1											
Serial number	LA020720000											
Brand	Endress Hauser											

Type	PROMAG 10L		
Accuracy	±0.50%		
Calibration frequency	Once in 3 years		
Installation	Commissioning to 30/06/2020		
Calibration	Cal. Date	Validity	
	18/05/2017	17/05/2020	
	23/10/2020	22/10/2023	

The replacement of FM1 happens on 30/06/2020. The detailed of the meter installed at the location of FM1 can be found below.

Meter tag	FM1		
Serial number	N4065620000		
Brand	Endress Hauser		
Type	PROMAG 10L		
Accuracy	±0.50%		
Calibration frequency	Once in 3 years		
Installation	30/06/2020 onwards		
Calibration	Cal. Date	Validity	
	14/06/2018	13/06/2021	

Meter tag	FM2		
Serial number	M102FC20000		
Brand	Endress Hauser		
Type	PROMAG 10L		
Accuracy	±0.50%		
Calibration frequency	Once in 3 years		
Installation	Commissioning to 31/08/2020		
Calibration date	Cal. Date	Validity	
	19/05/2017	18/05/2020	
	30/01/2021	29/01/2024	

The replacement of FM2 happened on the 01/09/2020. The detail of the meter can be found below.

Meter tag	FM2		
Serial number	N308AD20000		
Brand	Endress Hauser		

	Type	PROMAG 10L		
	Accuracy	±0.50%		
	Calibration frequency	Once in 3 years		
	Installation	01/09/2020 onwards		
	Calibration date	Cal. Date	Validity	
		08/05/2020	07/05/2021	
QA/QC procedures to be applied	Once in three-year calibrations for flow meter is to be conducted via an external agency according to an approved national or international standard. This calibration is plan for off season to ensure data accuracy and sufficiency in operation days.			
Purpose of data	Calculation of baseline and project emissions			
Calculation method	Not applicable			
Comments	For the FM1 the calibration gap of 17/05/2020 to 30/06/2020 was found, the adjustment⁷ of values was conducted by applying the maximum permissible error as per specification to the monitored value. For the FM2 there was one calibration gap which fall from 18/05/2020 to 31/08/2020. The maximum error as per the equipment specification has been applied to the monitored value during the calibration gap.			

Data/Parameter	COD _{ww,untreated,y}
Data unit	t COD/m ³
Description	COD of wastewater entering the covered lagoon reactor system
Source of data	Measured – Colorimetric analysis
Description of measurement methods and procedures to be applied	The COD content was analyzed using a colorimetric method in the on-site laboratory of the treatment plant. The result was logged by the operators in the plant operation report on a daily basis. In case the COD value is not available for a particular day, the same shall be estimated in a conservative manner or ignored out of emission reduction estimation. The COD sampling point was before covered lagoons.
Frequency of monitoring/recording	The monitoring and recording was conducted on daily basis in every operational day.

⁷ As per section 3.4.2 of the Validation and Verification Manual, v3.2.

Value monitored	Monitoring period	Average value	
		Lower	Higher
	03/03/2020 to 31/12/2020	0.0381	0.0435
	01/01/2021 to 31/03/2021	0.0475	0.0541
Monitoring equipment	The colorimeter meter was used for COD analysis. The equipment is in line with the requirement of national or international standards.		
	Meter tag	Colorimeter	
	Serial number	H19945I	
	Brand	Hanna	
	Type	HI 83214	
	Accuracy	10 mg/l (HR) 1 mg/l (LR)	
	Calibration frequency	Once in 3 years	
	Calibration	Cal. Date	Validity
		12/12/2018	11/12/2021
QA/QC procedures to be applied	The colorimetric method is well documented and well accepted either by national or international standards. In addition, to ensure accuracy in our measurements, the plant shall periodically send wastewater samples to be tested by external laboratory and compare these results with internal measurements at least once per year.		
Purpose of data	Calculation of project emissions		
Calculation method	Not applicable		
Comments	All the monitoring equipment was calibrated on time; thus, no error was applied.		

Data/Parameter	COD _{ww,treated,y}
Data unit	t COD/m ³
Description	The chemical oxygen demand of the wastewater after the treatment system affected by the project activity
Source of data	Measured – Colorimetric analysis
Description of measurement methods and procedures to be applied	The COD content was analyzed using a colorimetric method in the on-site laboratory of the treatment plant. The COD sampling point was after the covered lagoons.

	In case the COD value was not available for a particular day, the value was estimated in a conservative manner by excluding from emission reduction estimation.		
Frequency of monitoring/recording	The test was carried out in every operational day.		
Value monitored	Monitoring period	Average value	
		Lower	Higher
	03/03/2020 to 31/12/2020	0.0012	0.0014
	01/01/2021 to 31/03/2021	0.0013	0.0016
Monitoring equipment	Please see COD _{ww,untreated,y}		
QA/QC procedures to be applied	Please see COD _{ww,untreated,y}		
Purpose of data	Calculation of project emissions		
Calculation method	Not applicable		
Comments	Please see COD _{ww,untreated,y}		

Data/Parameter	COD _{discharge,PJ,y}													
Data unit	t COD/m ³													
Description	The chemical oxygen demand of water after the secondary treatment process, before being reused													
Source of data	Measured – Colorimetric analysis													
Description of measurement methods and procedures to be applied	The COD content was analyzed using a colorimetric method in the on-site laboratory of the treatment plant. The COD sampling point was after the last lagoon. In case the COD value was not available for a particular day, the value was estimated in a conservative manner by excluding from emission reduction estimation.													
Frequency of monitoring/recording	The test was carried out in every operational day.													
Value monitored	<table><tr><th rowspan="2">Monitoring period</th><th colspan="2">Average value</th></tr><tr><th>Lower</th><th>Higher</th></tr><tr><td>03/03/2020 to 31/12/2020</td><td>0.0001</td><td>0.0001</td></tr><tr><td>01/01/2021 to 31/03/2021</td><td>0.0001</td><td>0.0001</td></tr></table>			Monitoring period	Average value		Lower	Higher	03/03/2020 to 31/12/2020	0.0001	0.0001	01/01/2021 to 31/03/2021	0.0001	0.0001
Monitoring period	Average value													
	Lower	Higher												
03/03/2020 to 31/12/2020	0.0001	0.0001												
01/01/2021 to 31/03/2021	0.0001	0.0001												

Monitoring equipment	Please see COD _{ww,untreated,y}
QA/QC procedures to be applied	Please see COD _{ww,untreated,y}
Purpose of data	Calculation of project emissions
Calculation method	Not applicable
Comments	Please see COD _{ww,untreated,y}

Data / Parameter	S _{final,PJ,y}		
Data unit	Tons		
Description	Amount of dry matter in the sludge		
Source of data	Weighing equipment that is available at the site are used. Plant records every time sludge is removed from the system		
Description of measurement methods and procedures to be applied	Proper log records were maintained for the sludge removal and disposal at the project site.		
Frequency of monitoring/recording	Recorded every time sludge was removed from the system		
Value monitored	Monitoring period		Total value (tons)
	03/03/2020 to 31/12/2020		0
	01/01/2021 to 31/03/2021		0
Monitoring equipment	Meter tag	Weighbridge	
	Serial number	0008666	
	Brand	Commandor	
	Type	HP-05K	
	Accuracy	±20 kg	
	Calibration frequency	Once in 2 years	
	Calibration	Cal. Date	Validity
		04/06/2019	03/06/2021
QA/QC procedures to be applied	The plant manager's signature was required on the record.		
Purpose of data	Calculation of project emissions		

Calculation method	Not applicable
Comments	This parameter is included in the unlikely event that the sludge is removed from the covered lagoons. The instrument has been calibration on time, no error shall be applied to the monitoring data.

Data/Parameter	BG _{burnt,y}																		
Data unit	Nm ³																		
Description	Amount of biogas combusted for gainful use																		
Source of data	Calculated from a summation of total biogas utilized in boilers, generation sets																		
Description of measurement methods and procedures to be applied	BG_{burnt,y} was estimated by summing-up the volume of biogas sent to the boiler and generation set. Measurements of volume of biogas sent to boiler and gas engines was continuously using gas flow meters. In recording these parameters, plant's operators was first manually archive the monitored data onto log sheets then transfer to the computer for electronic storage. The archive was done on a daily basis.																		
Frequency of monitoring/recording	Continuous monitoring with daily recording																		
Value monitored	The amount of biogas combusted was the summation of the volume of biogas sent to boiler 2 and gas engine as boiler 1 was excluded from the estimation of emission reductions as per Deviation 1 of the project description deviation. <table border="1"> <thead> <tr> <th>Monitoring period</th><th>Applied value</th></tr> </thead> <tbody> <tr> <td>03/03/2020 to 31/12/2020</td><td>3,053,277</td></tr> <tr> <td>01/01/2021 to 31/03/2021</td><td>2,225,429</td></tr> </tbody> </table> BG to boiler2 (GM4) <table border="1"> <thead> <tr> <th>Monitoring period</th><th>Applied value</th></tr> </thead> <tbody> <tr> <td>03/03/2020 to 31/12/2020</td><td>1,975,926</td></tr> <tr> <td>01/01/2021 to 31/03/2021</td><td>876,926</td></tr> </tbody> </table> BG to engines (GM3) <table border="1"> <thead> <tr> <th>Monitoring period</th><th>Applied value</th></tr> </thead> <tbody> <tr> <td>03/03/2020 to 31/12/2020</td><td>1,077,351</td></tr> <tr> <td>01/01/2021 to 31/03/2021</td><td>1,348,503</td></tr> </tbody> </table>	Monitoring period	Applied value	03/03/2020 to 31/12/2020	3,053,277	01/01/2021 to 31/03/2021	2,225,429	Monitoring period	Applied value	03/03/2020 to 31/12/2020	1,975,926	01/01/2021 to 31/03/2021	876,926	Monitoring period	Applied value	03/03/2020 to 31/12/2020	1,077,351	01/01/2021 to 31/03/2021	1,348,503
Monitoring period	Applied value																		
03/03/2020 to 31/12/2020	3,053,277																		
01/01/2021 to 31/03/2021	2,225,429																		
Monitoring period	Applied value																		
03/03/2020 to 31/12/2020	1,975,926																		
01/01/2021 to 31/03/2021	876,926																		
Monitoring period	Applied value																		
03/03/2020 to 31/12/2020	1,077,351																		
01/01/2021 to 31/03/2021	1,348,503																		

Monitoring equipment				
	Meter location	Boiler 2		
	Meter tag	GM4		
	Serial number	N1-V905-9663007		
	Brand	Siemens		
	Type	7MF4433-1BA22-1AC96-Z		
	Accuracy	±0.075%		
	Calibration frequency	Once in 3 years		
	Calibration	Cal. Date	Validity	
		11/01/2018	10/01/2021	
		15/06/2021	14/06/2024	
	Meter location	Generator		
	Meter tag	GM3		
	Serial number	5314		
	Brand	FOX		
	Type	FT2		
	Accuracy	1%R + 0.2%FS		
	Calibration frequency	Once in 3 years		
	Calibration	Cal. Date	Validity	
		29/11/2018	28/11/2021	
QA/QC procedures to be applied	The flow meters were calibrated at least once every 3 years. This certainly help in ensuring that ER calculation was of a reasonable level in terms of accuracy.			
Purpose of data	Calculation of baseline emissions			
Calculation method	The summation from GM3 and GM4 was calculated.			
Comments	The calibration gap has been identified for GM4 for the monitoring period from 11/01/2021 to 31/03/2021. The maximum error as found in the equipment specification has been selected and applied to the monitoring data during the gap. For GM3, the meter has been calibrated on time. Hence no adjustment is needed.			
Data/Parameter	WCH ₄ ,y			

Data unit	%																													
Description	Methane content in biogas																													
Source of data	Measured – Gas analyzer system to monitor % of methane in biogas																													
Description of measurement methods and procedures to be applied	Online monitoring equipment is incorporated to increase the accuracy. Data from here is recorded and stored electronically on a continuous basis. In the case the online gas analyzer is not available or not functioning, periodic measurements would be done using portable gas analyzer at 90/10 confidence level.																													
Frequency of monitoring/recording	The methane content in biogas is continuously measured. The average value is calculated on daily basis. In case of malfunction or unavailability of online gas analyzer, portable gas analyzer should be used ensuring 90/10 confidence level. The recording would be conducted on daily basis.																													
Value monitored	During the monitoring period, as the online monitoring equipment was not available for continuous measurement, the portable gas analyzer was used for periodic measurement and the measured values were applied at a 95% confidence level. The lower and upper values were used for the calculation of the baseline and project emissions in a conservative manner. <table><tr><th rowspan="2">Monitoring period</th><th colspan="2">Methane content</th></tr><tr><th>Lower</th><th>Upper</th></tr><tr><td>03/03/2020 to 31/12/2020</td><td>58</td><td>59</td></tr><tr><td>01/01/2021 to 31/03/2021</td><td>56</td><td>58</td></tr></table>			Monitoring period	Methane content		Lower	Upper	03/03/2020 to 31/12/2020	58	59	01/01/2021 to 31/03/2021	56	58																
Monitoring period	Methane content																													
	Lower	Upper																												
03/03/2020 to 31/12/2020	58	59																												
01/01/2021 to 31/03/2021	56	58																												
Monitoring equipment	<table><tr><td>Meter tag</td><td colspan="2">MS</td></tr><tr><td>Serial number</td><td colspan="2">G503004</td></tr><tr><td>Brand</td><td colspan="2">Geotech</td></tr><tr><td>Type</td><td colspan="2">BIOGAS 5000</td></tr><tr><td>Accuracy</td><td colspan="2">0.5%</td></tr><tr><td>Calibration frequency</td><td colspan="2">Once in 3 years</td></tr><tr><td>Calibration</td><td colspan="2"><table><tr><th>Cal. Date</th><th>Validity</th></tr><tr><td>12/06/2018</td><td>11/06/2021</td></tr><tr><td>30/03/2021</td><td>29/03/2024</td></tr></table></td></tr></table>			Meter tag	MS		Serial number	G503004		Brand	Geotech		Type	BIOGAS 5000		Accuracy	0.5%		Calibration frequency	Once in 3 years		Calibration	<table><tr><th>Cal. Date</th><th>Validity</th></tr><tr><td>12/06/2018</td><td>11/06/2021</td></tr><tr><td>30/03/2021</td><td>29/03/2024</td></tr></table>		Cal. Date	Validity	12/06/2018	11/06/2021	30/03/2021	29/03/2024
Meter tag	MS																													
Serial number	G503004																													
Brand	Geotech																													
Type	BIOGAS 5000																													
Accuracy	0.5%																													
Calibration frequency	Once in 3 years																													
Calibration	<table><tr><th>Cal. Date</th><th>Validity</th></tr><tr><td>12/06/2018</td><td>11/06/2021</td></tr><tr><td>30/03/2021</td><td>29/03/2024</td></tr></table>		Cal. Date	Validity	12/06/2018	11/06/2021	30/03/2021	29/03/2024																						
Cal. Date	Validity																													
12/06/2018	11/06/2021																													
30/03/2021	29/03/2024																													
QA/QC procedures to be applied	The portable gas analyzer was calibrated once every 3 years.																													

	Since there was an online gas analyzer used during the monitoring period, the periodic measurement was conducted using a portable gas analyzer at 95% confidence level.
Purpose of data	Calculation of baseline emissions
Calculation method	Not applicable
Comments	The monitoring equipment was calibrated on time; thus, no error was applied.

Data/Parameter	BG _{burnt, flared, y}		
Data unit	Nm ³		
Description	Amount of biogas that is flared		
Source of data	Measured using biogas flow meter: GM2		
Description of measurement methods and procedures to be applied	The gas flow meter with an accepted level of accuracy was installed at the plant. Please note that continuous measurement was made and cumulative reading was recorded daily.		
Frequency of monitoring/recording	Continuous monitoring with daily recording		
Value monitored	Monitoring period		Applied value
	03/03/2020 to 31/12/2020		0
	01/01/2021 to 31/03/2021		0
Monitoring equipment	Meter tag	GM2	
	Serial number	7568	
	Brand	FOX	
	Type	FT2-12I	
	Accuracy	1%R + 0.2%FS	
	Calibration frequency	Once in 3 years	
	Calibration	Cal. Date	Validity
		28/04/2016	27/04/2019
		28/04/2020	27/04/2023
QA/QC procedures to be applied	Once in three year calibrations for flow meter is to be conducted via an external agency. This calibration is planned for off season to ensure data accuracy and sufficiency in operation days.		

	In case the flow meter values are not available for reason such as faulty meter, the same shall be estimated in a conservative manner or ignored out of emission reduction estimation.
Purpose of data	Calculation of baseline emissions
Calculation method	Not applicable
Comments	The calibration of the equipment was delayed during 03/03/2020 to 27/04/2020. However, the adjustment of the values was not conducted because no biogas was flared during the monitoring period.

Data/Parameter	QFO,y	
Data unit	Liters	
Description	Quantity of fossil fuel in the boiler in year y	
Source of data	Usage data (monitored from boiler panel).	
Description of measurement methods and procedures to be applied	Fuel oil meter was incorporated to the hot oil boiler. There are 2 boilers at the starch factory. However, as per Deviation 1 of the project description deviation, the value from boiler 1 was excluded from the emission reduction. In recording this parameter, plant's operators would first manually archive the monitored data onto log sheets then transfer to the computer for electronic storage. The archive was done on a daily basis. In case the oil meter values are not available for reason such as faulty meter, the same should be estimated in a conservative manner.	
Frequency of monitoring/recording	Continuous monitoring with daily recording	
Value monitored	Monitoring period	Total value (liters)
	03/03/2020 to 31/12/2020	57,510
	01/01/2021 to 31/03/2021	141,485
Monitoring equipment	Meter location	Boiler 2
	Meter tag	OM2
	Serial number	5449943
	Brand	CONTOIL
	Type	VZF20RC 130/16
	Accuracy	±1%

	Calibration frequency	Once in 3 years		
	Calibration	Cal. Date	Validity	
		29/11/2018	28/11/2021	
QA/QC procedures to be applied	The liquid flow meters were calibrated at least once every 3 years.			
Purpose of data	Calculation of project emissions			
Calculation method	Not applicable			
Comments	The was a problem with the blower of the boiler resulting in significantly high fuel consumption from 01/01/2021 to 31/03/2021. Though the blower of the boiler 2 has been fixed during the long public holiday in April 2021.			

Data/Parameter	Q _{starch,y}		
Data unit	Tons		
Description	Quantity of dry starch produced		
Source of data	Based on operational log sheet at the plant		
Description of measurement methods and procedures to be applied	A proper record of all starch produced was maintained at the project site.		
Frequency of monitoring/recording	Daily recording		
Value monitored	Monitoring period	Applied value	
	03/03/2020 to 31/12/2020	46,059	
	01/01/2021 to 31/03/2021	24,270	
Monitoring equipment	Please see S _{final,PJ,y} for further detail of the weighbridge		
QA/QC procedures to be applied	The production data was cross-checked with sales records, if necessary.		
Purpose of data	Calculation of baseline emissions		
Calculation method	Not applicable		
Comments	The monitoring equipment was calibrated on time; thus, no error was applied.		

Data/Parameter	EG _{PJ,y}	
Data unit	MWh/y	
Description	Net electricity production by the generators during year y	
Source of data	Measured – Electricity meters installed at the generation sets	
Description of measurement methods and procedures to be applied	Measured electronically on a continuous basis The power meters were installed after generators.	
Frequency of monitoring/recording	Continuous monitoring with daily recording	
Value monitored	As there was no calibration conducted for the electricity meters at the generators no.1 & no. 2, therefore no electricity generation is claimed from 03/03/2020 to 31/12/2020. It was also noted that the new gas engine (Jenbacher) with installed capacity of 1.5 MW _e has been commissioning on 07/01/2021. The applied value for 07/01/2021 to 31/03/2021 has been considered from the Jenbacher generator.	
	Monitoring period	Applied value
	03/03/2020 to 31/12/2020	Not include for the ER
	01/01/2021 to 31/03/2021	2,052
Monitoring equipment	Meter tag	EM1
	Serial number	62560 1 00N0030
	Brand	CARLO GAVAZZI
	Type	WM3-06
	Accuracy	±0.5%
	Calibration frequency	Once in 3 years
	Calibration	Not available
	Meter tag	EM2
	Serial number	62560 1 00N0034
	Brand	CARLO GAVAZZI
	Type	WM3-06
	Accuracy	±0.5%
	Calibration frequency	Once in 3 years
Calibration	Not available	

	Meter tag	EM
	Serial number	N/A
	Brand	B&R Automation
	Model	X20CM0985-1 ⁸
	Accuracy	5.0%
	Calibration frequency	Once in 3 years
	Calibration	09/01/2021 Referring to commissioning report of the gas engine.
QA/QC procedures to be applied	The electricity meter should be subject to periodic calibration according to the equipment's specifications and applicable industrial standards (generally on a once in three-year basis).	
Purpose of data	Calculation of baseline emissions	
Calculation method	Not applicable	
Comments	-	

Data/Parameter	EC _y						
Data unit	MWh/y						
Description	Electricity consumption by wastewater treatment plant in year y						
Source of data	Maximum rated consumption was calculated by multiplying total electrical capacity with operational hour and an additional factor of 20%.						
Description of measurement methods and procedures to be applied	Calculation based on maximum rated consumption was conducted in a conservative manner (as per Paragraph 35 in AMS-III.H., version 19).						
Frequency of monitoring/recording	Not applicable. This was based on the calculation mentioned above.						
Value monitored	<table> <tr> <th>Monitoring period</th><th>Applied value</th></tr> <tr> <td>03/03/2020 to 31/12/2020</td><td>2,955</td></tr> <tr> <td>01/01/2021 to 31/03/2021</td><td>1,095</td></tr> </table>	Monitoring period	Applied value	03/03/2020 to 31/12/2020	2,955	01/01/2021 to 31/03/2021	1,095
Monitoring period	Applied value						
03/03/2020 to 31/12/2020	2,955						
01/01/2021 to 31/03/2021	1,095						

⁸ https://download.br-automation.com/BRP4440000000000000643756/X20CM0985-1-en_V1.45.pdf?px-hash=33b15f49ee5a3460f1d006151bfd6a21&px-time=1625215958

Monitoring equipment	Not applicable
QA/QC procedures to be applied	Not applicable
Purpose of data	Calculation of project emissions
Calculation method	Not applicable
Comments	The project only consumed the electricity generated by the generators using biogas.

Data/Parameter	$F_{RG,m}$						
Data unit	Nm ³						
Description	Volumetric flow of the residual gas on dry basis at normal conditions in the minute <i>m</i>						
Source of data	Measured using biogas flow meter: GM2						
Description of measurement methods and procedures to be applied	The gas flow meter was installed at the plant. Measurements of volume of biogas sent to flare was done continuously using gas flow meter. In recording this parameter, plant's operators were first manually archive the monitored data onto log sheets then transfer to the computer for electronic storage. The archive should be done daily. Please note that continuous measurement has been made and cumulative reading will be recorded daily.						
Frequency of monitoring/recording	Continuous monitoring with daily recording						
Value monitored	There was no flame detection being implemented at the project site, and no biogas was flare during the monitoring period. <table border="1"> <thead> <tr> <th>Monitoring period</th><th>Applied value</th></tr> </thead> <tbody> <tr> <td>03/03/2020 to 31/12/2020</td><td>0</td></tr> <tr> <td>01/01/2021 to 31/03/2021</td><td>0</td></tr> </tbody> </table>	Monitoring period	Applied value	03/03/2020 to 31/12/2020	0	01/01/2021 to 31/03/2021	0
Monitoring period	Applied value						
03/03/2020 to 31/12/2020	0						
01/01/2021 to 31/03/2021	0						
Monitoring equipment	Please see BG _{burnt,flared,y}						
QA/QC procedures to be applied	The flow meters were calibrated at least once every 3 years. In case the flow meter values are not available for reason such as faulty meter, the same shall be estimated in a conservative manner or ignored out of emission reduction estimation.						
Purpose of data	Calculation of baseline emissions						

Calculation method	Not applicable
Comments	The calibration of the equipment was delayed. However, the adjustment of values was not conducted because there was no biogas flared during the monitoring period.

Data/Parameter	Flame _m						
Data unit	Flame on or Flame off						
Description	Flame detection of flare in the minute m						
Source of data	Plant data						
Description of measurement methods and procedures to be applied	Measure using a fixed installation optical flame detector						
Frequency of monitoring/recording	Continuous monitoring, record on the daily basis						
Value monitored	There was no record of flame detection since no biogas was flared during the monitoring period. <table border="1"> <thead> <tr> <th>Monitoring period</th><th>Applied value</th></tr> </thead> <tbody> <tr> <td>03/03/2020 to 31/12/2020</td><td>0</td></tr> <tr> <td>01/01/2021 to 31/03/2021</td><td>0</td></tr> </tbody> </table>	Monitoring period	Applied value	03/03/2020 to 31/12/2020	0	01/01/2021 to 31/03/2021	0
Monitoring period	Applied value						
03/03/2020 to 31/12/2020	0						
01/01/2021 to 31/03/2021	0						
Monitoring equipment	There was no detail of flame detector available.						
QA/QC procedures to be applied	Maintenance of flare system shall be conducted periodically as per supplier's specifications to ensure optimal operation.						
Purpose of data	Calculation of project emissions						
Calculation method	Not applicable						
Comments	The condition was not met as per the monitoring plan. The flare efficiency of 0% default was taken into account for the conservative project emission calculation However, there was no record of flame detection since no biogas was flared during the monitoring period.						

Data/Parameter	$\eta_{\text{flare},m}$
Data unit	%

Description	Flare efficiency in the minute m						
Source of data	Default value for open flares as per tool “project emission from flaring”						
Description of measurement methods and procedures to be applied	The flare efficiency of 50% in the minute m is applied when the flare is detected in the minute m ($Flame_m$). If these conditions are not met, 0% default value should be used for this period.						
Frequency of monitoring/recording	Continuous monitoring, recording on the daily basis						
Value monitored	<table border="1"> <thead> <tr> <th>Monitoring period</th><th>Applied value</th></tr> </thead> <tbody> <tr> <td>03/03/2020 to 31/12/2020</td><td>0</td></tr> <tr> <td>01/01/2021 to 31/03/2021</td><td>0</td></tr> </tbody> </table>	Monitoring period	Applied value	03/03/2020 to 31/12/2020	0	01/01/2021 to 31/03/2021	0
Monitoring period	Applied value						
03/03/2020 to 31/12/2020	0						
01/01/2021 to 31/03/2021	0						
Monitoring equipment	There was no detail of the flame detector available.						
QA/QC procedures to be applied	Maintenance of flare system shall be conducted periodically as per supplier’s specifications to ensure optimal operation.						
Purpose of data	Calculation of project emissions						
Calculation method	Not applicable						
Comments	There was no installation of flame detection equipment, and no biogas was flared during the monitoring period. The condition was not met as per the monitoring plan. To be conservative on the project emission calculation, the flare efficiency of 0% default was taken into account.						

4.3 Monitoring Plan

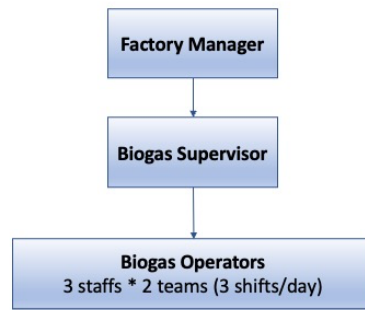
The monitoring plan was as described in Section 5.3 of the updated PD for 2nd crediting period. The daily operation data recording and laboratory analysis was carried out by plant operators. The reports and all equipment calibrations were checked and approved by the biogas plant supervisor.

The biogas plant supervisor collected all the information and submitted it to a consultant for emission calculation.

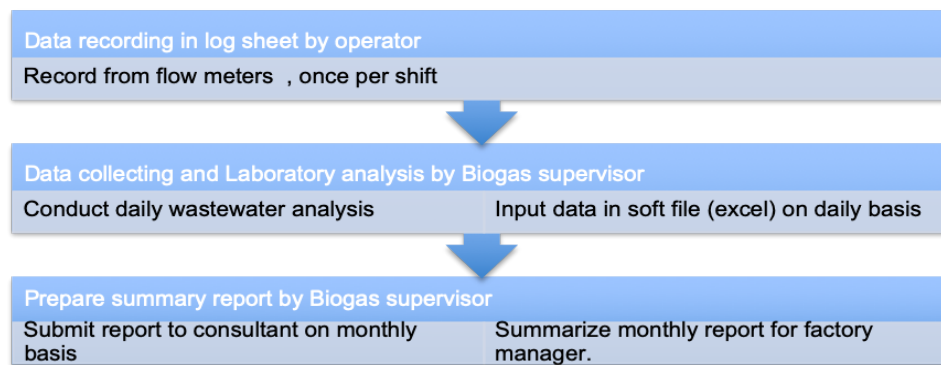
All monitoring data was available in an Excel spreadsheet. This spreadsheet consisted of:

1. A summary worksheet containing the results of the monitoring for every day of the monitoring period on a yearly basis;
2. The monitored parameters during the monitoring period.

Organization structure



Data Collection and management system



The monitoring diagram for the project activity during the monitoring period of 03/03/2020 to 31/03/2021 (Figure 3).

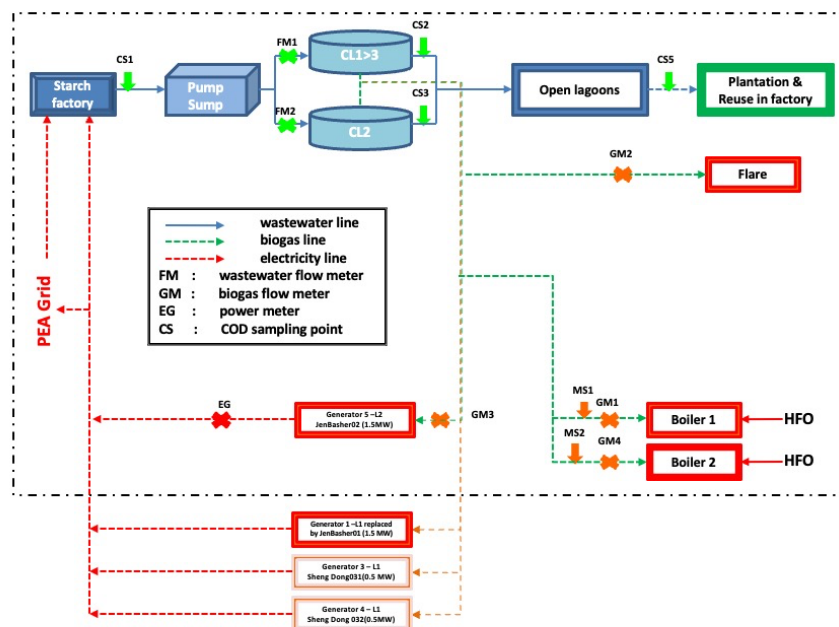


Figure 3: The project system boundary

Data storage and backup

- The original log sheets were collected and stored in the starch production office by the biogas supervisor.
- The data was saved in an Excel format on a computer at biogas control room and backed up onto computer at the production office every month by the biogas supervisor.
- The Excel spreadsheet that was submitted to consultant was stored and backed up via the consultant's internal server on monthly basis.

5 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

5.1 Baseline Emissions

Baseline Emissions for AMS-III.H

$$BE_y = BE_{power,y} + BE_{ww,treatment,y} + BE_{s,treatment,y} + BE_{ww,discharge,y} + BE_{s,final,y} \quad (1)$$

Where:

BE_y	Baseline emissions in year y (tCO ₂ e)
$BE_{power,y}$	Baseline emissions from electricity or fuel consumption in year y (tCO ₂ e)
$BE_{ww,treatment,y}$	Baseline emissions from the wastewater treatment systems affected by the project activity in year y (tCO ₂ e)
$BE_{s,treatment,y}$	Baseline emissions from the sludge treatment systems affected by the project activity in year y (tCO ₂ e)
$BE_{ww,discharge,y}$	Baseline methane emissions from degradable organic carbon in treated wastewater discharged into sea/river/lake in year y (tCO ₂ e)
$BE_{s,final,y}$	Baseline methane emissions from anaerobic decay of the final sludge produced in year y (t CO ₂ e). If the sludge is controlled combusted, disposed in a landfill with biogas recovery, or used for soil application in the baseline scenario, this term shall be neglected

$BE_{power,y}$:

The baseline emissions from electricity and fossil fuel consumption were not considered. The power consumed in a baseline case was negligible and disregarded for conservative estimation of baseline emissions. No fossil fuels were consumed in the operation of the open anaerobic lagoons in the baseline scenario, therefore, the baseline emissions from fuel consumption were zero as.

Therefore, $BE_{power,y}$ was zero.

$BE_{ww,treatment,y}$:

Methane emissions from the baseline wastewater treatment systems affected by the project were determined using the COD removal efficiency of the baseline plant:

$$BE_{ww,treatment,y} = \sum (Q_{ww,i,y} \times COD_{inflow,i,y} \times \eta_{COD,BL,i} \times MCF_{ww,treatment,BL,i}) \times B_{o,ww} \times UF_{BL} \times GWP_{CH4}$$

Where:

$Q_{ww,i,y}$	Volume of wastewater treated in a baseline wastewater treatment system i in year y (m ³)
$COD_{inflow,i,y}$	Chemical oxygen demand of the wastewater inflow to the baseline treatment system i in year y (t/m ³). Average value may be used through sampling with the confidence/precision level 90/10
$\eta_{COD,BL,i}$	COD removal efficiency of the baseline treatment system i
$MCF_{ww,treatment,BL,i}$	Methane correction factor for baseline wastewater treatment systems i
i	Index for the baseline wastewater treatment system
$B_{o,ww}$	Methane producing capacity of the wastewater (IPCC value of 0.25 kgCH ₄ /kg COD)
UF_{BL}	Model correction factor to account for model uncertainties (0.89)
GWP_{CH4}	Global Warming Potential for methane

$BE_{ww,discharge,y}$:

In the baseline scenario, treated wastewater was not discharged into a sea/lake/river, therefore methane emissions from degradable organic carbon in treated wastewater discharged ($BE_{ww,discharge,y}$) was taken as zero.

$BE_{s,treatment,y}$ and $BE_{s,final,y}$:

The generated sludge in the baseline scenario is close to zero in which it is anyway used aerobically for soil application. There is no sludge treatment system, therefore, baseline methane emissions produced from sludge treatment and anaerobic decay of the final sludge ($BE_{s,treatment,y}$ and $BE_{s,final,y}$) were neglected from baseline emissions.

Baseline Emissions for AMS-I.D

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

As per AMS-I. D. Paragraph 22, the baseline was the MWh produced by the renewable generating unit multiplied by an emission coefficient as follows:

$$BE_{elec,y} = EG_{PJ,y} \times EF_{grid,y} \quad (2)$$

Where:

BE_y	Baseline emissions in year y (t CO ₂)
$EG_{PJ,y}$	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 (MWh)

$EF_{grid,y}$ Combined margin CO₂ emission factor for grid connected power generation in year y (t CO₂/MWh)

Since the calibration of the monitoring equipment for measuring the parameter $EG_{PJ,y}$ was not conducted in line with the registered monitoring plan and the record was not found, the data was excluded from the calculation of the baseline emission from electricity generation. This was conservative approach.

Therefore, $BE_y = BE_{elec,y} = 0$.

Baseline Emissions for AMS-I.C

Emissions from steam/heat displacement by the project activity ($BE_{heat,y}$)

According to Paragraph 34 of AMS I.C., the baseline emissions are estimated based on the amount of heat/steam delivered by the equipment (as per equation below).

$$BE_{thermal,CO_2,y} = (EG_{thermal,y} / \eta_{BL,thermal}) * EF_{CO_2} \quad (3)$$

Where:

$EG_{thermal,y}$ The net quantity of steam/heat supplied by the project activity during the year y (TJ)

$\eta_{BL,thermal}$ The efficiency of the plant using fossil fuel that would have been used in the absence of the project activity.

EF_{CO_2} The CO₂ emission factor per unit of energy of the fuel that would have been used in the baseline plant in (tCO₂/TJ), obtained from reliable local or national data if available, otherwise, IPCC default emission factors are used.

However, the deviation explained in Section 3.2 took into account the baseline efficiencies and a simplified approach was explained to estimate the baseline emissions, the approach was based on historical consumption of fuel oil per ton of starch generation. The deviation addresses the coherence with Paragraph 24 (c) and 34 of the methodology. In addition, since the boiler no.1 was replaced and the thermal capacity was increased. Deviation 1 of the project description deviation provided in Section 3.2 was established based on conservative approach for the emission reduction of heat component. Thus, the following deviated equation was applied. It must be noted that the deviation did not only estimates the baseline emissions on the amount of heat/steam generated by the boiler, it also took into account CO₂ emissions from on-site consumption of fossil fuels due to the project activity. In other words, it represents the emission reduction from the heat generation component.

$$BE_{thermal,CO_2,y} = (Q_{starch} * Q_{FO,starch} * \%B2 - q_{FO,y,Boiler2}) * D_{FO} * NCV_{FO} * EF_{CO_2}/10^6 \quad (4)$$

Where:

$Q_{starch,y}$ Quantity of dry starch produced in year y (tons)

$Q_{FO, starch}$	Quantity of fossil fuel per unit of dry starch (liter/ton)
$Q_{FO, y, boiler2}$	Quantity of fossil fuel consumed by hot oil boiler no.2 in year y (liters)
D_{FO}	Density of fossil fuel (kg/liter)
NCV_{FO}	Net Calorific value of the fuel oil (TJ/ton)
%B2	The percentage of thermal energy supplied from the boiler 2 from step 4 under section 3.2.2

During this monitoring period, additional approach based on the amount of biogas utilization has been compared with the historical consumption of fuel oil.

$$BE_{thermal, CO_2, y} = BG_{burnt, combusted, y} * W_{CH_4} * \rho_{CH_4} * BE * NCV_{biogas} * EF_{CO_2} / 10^6 \quad (5)$$

Where:

$BG_{burnt, combusted, y}$	Biogas flared/combusted in year y (m ³)
$W_{CH_4, y}$	Methane content of the biogas in the year y (volume fraction)
ρ_{CH_4}	Density of methane at the temperature and pressure of the biogas in the year y (t/m ³)
BE	Boiler efficiency (%)
NCV_{biogas}	Net Colorific Value of the biogas (TJ/tonne)

Table 3: Detail of baseline emissions calculation for the monitoring period 03/03/2020 to 31/03/2021

AMS-III.H		2nd CP - 2020	2nd CP - 2021
Parameter	Unit	03/03 to 31/12	01/01 to 31/03
COD Approach			
$Q_{ww, y, lower\ value}$	m ³	387,301	263,114
$COD_{removed, i, lower}$	tonnes/m ³	0.0333	0.0414
$MCF_{ww, treatment, BL}$	-	0.8	0.8
$B_{o, ww}$	kg _{CH₄} /kg _{COD}	0.25	0.25
UF_{BL}	-	0.89	0.89
GWP_{CH_4}	-	25.00	28.00
$BE_{ww, treatment, y}$	tCO ₂ e	57,373	54,292
$BE_{power, y}$	tCO ₂ e	0	0
$BE_{s, treatment, y}$	tCO ₂ e	0	0
$BE_{ww, discharge, y}$	tCO ₂ e	0	0
$BE_{s, final, y}$	tCO ₂ e	0	0
$BE_{y, ex\ post}$	tCO ₂ e	57,373	54,292
MD_y Approach			
$BG_{combusted, lower}$	Nm ³	3,053,277	2,225,429
$BG_{TOFlare, lower}$	Nm ³	0	0
FE	-	0	0
DE	-	100%	100%
D_{CH_4}	kg/m ³	0.72	0.72
$W_{CH_4-lower}$	%	58%	56%
MD_y	tCO ₂ e	31,623	24,957

AMS-I.C		2nd CP - 2020	2nd CP - 2021
Parameter	Unit	01/01 to 02/03	01/01 to 31/03
Q _{starch, lower}	Tonnes	46,059	24,270
q _{F0, starch}	liters	57,510	141,485
D _{F0}	kg/liter	0.93	0.93
NCV _{F0}	TJ/tonne	0.04	0.04
EF _{CO2}	t CO ₂ /TJ	77.40	77.40
Q _{F0, starch}	liters/ton	39.60	39.60
NCV _{biogas}	TJ/tonne	0.05	0.05
EG _{thermal} (historical data)	TJ	53.43	32.57
EG _{thermal} (biogas delivered)	TJ	56.92	40.11
BE _{thermal, CO2, y}	tCO _{2e}	4,135	2,520

NOTE: BE_{thermal, CO2, y} = ER_{heat, y}

AMS-I.D		2nd CP - 2020	2nd CP - 2021
Parameter	Unit	03/03 to 31/12	01/01 to 31/03
EG _{PJ, y}	MWh	0	2,052
EF _y	tCO ₂ /MWh	0.56	0.56
BE _{gen, y}	tCO _{2e}	0	1,156

NOTE: BE_{gen, y} = ER_{power, y}

5.2 Project Emissions

$$PE_y = PE_{power, y} + PE_{ww, treatment, y} + PE_{s, treatment, y} + PE_{ww, discharge, y} + PE_{s, final, y} +$$

$$PE_{fugitive, y} + PE_{biomass, y} + PE_{flaring, y} \quad (6)$$

Where:

PE _y	Project activity emissions in year y (tCO _{2e})
PE _{power, y}	Emissions from electricity or fuel consumption in year y (tCO _{2e})
PE _{ww, treatment, y}	Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery, in year y (tCO _{2e})
PE _{s, treatment, y}	Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery, in year y (tCO _{2e})
PE _{ww, discharge, y}	Methane emissions from degradable organic carbon in treated wastewater in year y (tCO _{2e})
PE _{s, final, y}	Methane emissions from anaerobic decay of the final sludge produced in year y (tCO _{2e})
PE _{fugitive, y}	Methane emissions from biogas release in capture systems in year y (tCO _{2e})
PE _{biomass, y}	Methane emissions due to incomplete flaring in year y (tCO _{2e})
PE _{flaring, y}	Methane emissions from biomass stored under anaerobic conditions

PE_{power, y}:

Emissions from electricity consumption by the project activity facilities were calculated based on the Paragraph 26 of AMS-III.H., whereas $PE_{power,y}$ were estimated according to the “Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation”, version 03.0 as given below.

$$PE_{power,y} = \sum EC_{PJ,j,y} \times EF_{EL,j,y} \times (1 + TDL_{j,y})$$

Where:

$EC_{PJ,j,y}$	Electricity consumption by the project activity (MWh)
$EF_{EL,j,y}$	Thailand National Grid emission factor (tCO ₂ e/MWh)
$TDL_{j,y}$	Average technical transmission and distribution losses for providing electricity to source j in year y
j	Source of electricity consumption in the project

In the absence of an electric meter for the electricity consumption of the project activity, a maximum rated consumption was used to calculate the emissions from PE_{power} as follows:

$$PE_{power,y} = \sum P_{el} \times (100\% + TDL_{j,y}) \times 8,760 \times EF_{EL,j,y} / 1000$$

Where:

P_{el}	Total electrical capacity of the equipments installed in the project activity (kW) – for reference, this is 458 kW for this project activity.
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Taking into account the distribution losses, 20% was applied to the total electricity consumption for the sake of simplicity and conservative. The calculated electricity consumption was based on an assumption that the electrical appliances were running for the entire monitoring period duration.

$PE_{ww,treatment,y}$:

Methane emissions from wastewater treatment systems affected by the project activity were calculated as per the Paragraph 27, AMS-III.H. The following equation was used.

$$PE_{ww,treatment,y} = \sum (Q_{ww,k,y} \times COD_{inflow,k,y} \times \eta_{PJ,k,y} \times MCF_{ww,treatment,PJ,k}) \times B_{0,ww} \times UF_{PJ} \times GWP_{CH4}$$

Where:

$Q_{ww,k,y}$	Volume of wastewater treated in a baseline wastewater treatment system k in year y (m ³)
$COD_{inflow,k,y}$	Chemical oxygen demand of the wastewater inflow to the project treatment system k in year y (t/m ³).
$\eta_{PJ,k,y}$	COD removal efficiency of the baseline treatment system k

$MCF_{ww,treatment,PJ,k}$	Methane correction factor for the project wastewater treatment systems k
k	Index for project wastewater treatment system
$B_{0,ww}$	Methane producing capacity of the wastewater (IPCC value of 0.25 kgCH ₄ /kg COD)
UF_{PJ}	Model correction factor to account for model uncertainties (1.12)
GWP_{CH4}	Global Warming Potential for methane

$PE_{s,treatment,y}$:

The project activity did not include sludge treatment system, therefore the emission from sludge treatment system were omitted.

$PE_{ww,discharge,y}$:

In the project activity, the treated wastewater was discharged in existing open lagoons and there was no discharge to a river, sea or lake. Hence, emissions from this component were included in the assessment.

$PE_{s,final,y}$:

During the monitoring period, in the project activity, the final sludge produced was not removed from the wastewater treatment system, therefore, $PE_{s,final,y} = 0$.

$PE_{fugitive,y}$:

Project activity emissions from methane release in capture systems were determined as per Paragraph 40 (a) of AMS-III.H., as given below.

$$PE_{fugitive,y} = PE_{fugitive,ww,y} + PE_{fugitive,s,y}$$

Where:

$PE_{fugitive,ww,y}$	Fugitive emissions through capture inefficiencies in the anaerobic wastewater treatment systems in the year y (t CO _{2e})
$PE_{fugitive,s,y}$	Fugitive emissions through capture inefficiencies in the anaerobic sludge treatment systems in the year y (t CO _{2e})

These emissions are calculated as follow:

$$PE_{fugitive,ww,y} = (1 - CFE_{ww}) \times MEP_{ww,treatment,y} \times GWP_{CH4}$$

Where:

CFE_{ww}	Capture efficiency of the biogas recovery equipment in the wastewater treatment systems (a default value of 0.9 shall be used)
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$MEP_{ww,treatment,y}$ Methane emission potential of wastewater treatment systems equipped with biogas recovery system in year y (t)

$$MEP_{ww,treatment,y} = Q_{ww,y} \times B_{o,ww} \times UF_{PJ} \times \sum COD_{removed,PJ,k,y} \times MCF_{ww,treatment,PJ,k}$$

Where:

$COD_{removed,PJ,k,y}$ The chemical oxygen demand removed by the treatment system k of the project activity equipped with biogas recovery in the year y (t/m³)

$MCF_{ww,treatment,PJ,k}$ Methane correction factor for the project wastewater treatment system k equipped with biogas recovery equipment

UF_{PJ} Model correction factor to account for model uncertainties (1.12)

$PE_{fugitive,s,y}$:

There was no sludge treatment envisaged in the project activity, therefore, the emissions from sludge treatment was omitted.

$PE_{biomass,y}$:

Biomass storage was not envisaged in the project activity. Therefore, methane emissions from biomass stored under anaerobic conditions which did not take place in the baseline situation were omitted.

$PE_{flaring,y}$:

Methane emissions due to incomplete flaring in year y are calculated as per the “Tool to determine project emissions from flaring gases containing methane” (tCO₂e). During this monitoring period since the relevant parameters were not monitored and recorded properly, 0% of the flare efficiency was applied for the calculation of project emissions from flaring gases. However, there was no biogas flared during the monitoring period.

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

Where:

$PE_{flare,y}$ Project emissions from flaring of the residual gas in year y (tCO₂e)

GWP_{CH4} Global warming potential of methane valid for the commitment period (tCO₂e/tCH₄)

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

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

Table 4: Detail of project emissions calculation for the monitoring period 03/03/2020 to 31/03/2021

AMS-III.H		2nd CP - 2020	2nd CP - 2021
Parameter	Unit	03/03 to 31/12	01/01 to 31/03
EC _{PJ,y}	MWh	2,955	1,095
EF _y	t CO ₂ /MWh	0.564	0.564
PE _{power, y}	tCO ₂ e	1,666	618
Q _{ww, higher}	m ³	387,697	263,114
COD _{removed, PJ,lagoon,y}	tonne/m ³	0.00122	0.00151
MCF _{ww, treatment, PJ, k}	-	0.80	0.80
B _{o, ww}	kg CH ₄ /kg COD	0.25	0.25
UF _{PJ}	-	1.12	1.12
GWP _{CH4}	-	25.00	28.00
PE _{ww, treatment, y}	tCO ₂ e	2,651	2,490

COD _{removed, PJ,CL, higher}	tonne/m ³	0.0423	0.0527
MCF _{ww, treatment, PJ, CL}	-	0.80	0.80
MEP _{ww, treatment, higher}	tonnes	3,671	3.108
CFE _{ww}	-	0.90	0.90
PE _{fugitive, ww, y}	tCO ₂ e	9,177.78	7,770.93
PE _{fugitive, s, y}	tCO ₂ e	0	0
PE _{fugitive, y}	tCO ₂ e	9,178	8,704

Q _{biogas, flare, y = FV_{RG,h}}	Nm ³	0.00	0.00
f _{VCH4, RG, h = W_{CH4, higher}}	%	59%	58%
ρ _{CH4, n = D_{CH4}}	-	1.00	1.00
TM _{RG, h}	kg	-	-
η _{flare}	%	0.00	0.00
PE _{flaring, y}	tCO ₂ e	0.00	0.00
PE _{s, treatment, y}	tCO ₂ e	0	0
PE _{ww, discharge, y}	tCO ₂ e	0	0
PE _{s, final, y}	tCO ₂ e	0	0
PE _{biomass, y}	tCO ₂ e	0	0
PE _{y, ex post}	tCO ₂ e	13,495	11,812

AMS-I.C		2nd CP - 2020	2nd CP - 2021
Parameter	Unit	03/03 to 31/12	01/01 to 31/03
FC _{HFO}	ton/yr	53	132
NCV _{HFO}	TJ/tonne	0.0428	0.0428
EF _{HFO}	tCO ₂ e/TJ	77.40	77.40
PE _{FC,y}	tCO ₂ e	178	436

5.3 Leakage

The technology used was not equipment transferred from another activity, therefore, according to the AMS-III.H., there was no leakage to be considered. All the equipment used in the project activity for power and heat generation either already existed or was brought for the purpose of project activity and no shifting of old equipment took place. Therefore, there was no leakage as per AMS-I.C and AMS-I.D.

Table 5: Detail of leakage emissions calculation for the monitoring period 03/03/2020 to 31/03/2021

LEAKAGE		2nd CP - 2020	2nd CP - 2021
Parameter	Unit	03/03 to 31/12	01/01 to 31/03
LE _y	tCO ₂ e	0	0

5.4 Net GHG Emission Reductions and Removals

As per the paragraph 44 of AMS III.H version 19.0, paragraph 81 of AMS-I.C, version 21.0, and paragraph 43 of AMS-I.D, version 18, emission reduction achieved in this project activity using formulas mentioned in baseline, project & leakage emissions sections above. Emission reductions are calculated as follows;

$$ER_{y, \text{ex-post}} = BE_{y, \text{ex-post}} - (PE_{y, \text{ex-post}} + LE_{y, \text{ex-post}})$$

According to the equation above, the emission reduction as per the paragraph 44 of AMS III.H version 19.0, paragraph 81 of AMS-I.C, version 21.0, and paragraph 43 of AMS-I.D, version 18 achieved on any year are as following;

Parameter	Details	Quantification
ER _{y, ex-post}	Emission reductions achieved by the project activity based on monitored values for year y (tCO ₂ e)	For AMS-III.H COD approach AMS-I.D & AMS-I.C 03/03/2020 to 31/12/2020 = 47,835 01/01/2021 to 31/03/2021 = 45,720 For AMS-III.H MD approach AMS-I.D & AMS-I.C 03/03/2020 to 31/12/2020 = 33,914 01/01/2021 to 31/03/2021 = 27,579
BE _{y, ex-post}	Baseline emissions calculated based on monitored values of each methodology BE _y (AMS-I.C.), BE _y (AMS-I.D.), & BE _y (AMS-III.H COD approach)	AMS-I.D 03/03/2020 to 31/12/2020 = 0 01/01/2021 to 31/03/2021 = 1,156 AMS-I.C 03/03/2020 to 31/12/2020 = 4,135 01/01/2021 to 31/03/2021 = 2,520 AMS-III.H (COD approach) 03/03/2020 to 31/12/2020 = 57,373 01/01/2021 to 31/03/2021 = 54,292

BE - MD _y approach	Methane captured and destroyed/gainfully used by the project activity in the year y BE _y (AMS-III.H MD _y approach)	03/03/2020 to 31/12/2020 = 31,623 01/01/2021 to 31/03/2021 = 24,957
PE _y , ex-post	Project emissions calculated as per paragraph ex post monitored values	For AMS-III.H COD approach AMS-I.D & AMS-I.C 03/03/2020 to 31/12/2020 = 13,673 01/01/2021 to 31/03/2021 = 12,248 For AMS-III.H MD_y approach AMS-I.D & AMS-I.C 03/03/2020 to 31/12/2020 = 1,844 01/01/2021 to 31/03/2021 = 1,054

Comparing the result of the emission reduction calculation as per requirement of AMS-III.H paragraph 45 is as follows.

- ER achieved from AMS-III.H COD approach is equal to 43,878 tCO₂e in 2020 and 42,480 tCO₂e in 2021.
- ER achieved from AMS-III.H MD approach is equal to 29,957 tCO₂e in 2020 and 24,339 tCO₂e in 2021.

The most conservative value of the ER under AMS-III.H is based on MD approach for both monitoring periods. Then the selected values are added with the emission reduction achieved under AMS-I.C which could be outlined as follow; 3,957 tCO₂e in 2020 and 3,240 tCO₂e in 2021. The total emission reduction project claims during this monitoring period; 03/03/2020 to 30/04/2021, is **61,493 tCO₂e**.

Where

Year	Baseline emissions or removals (tCO ₂ e)	Project emissions or removals (tCO ₂ e)	Leakage emissions (tCO ₂ e)	Net GHG emission reductions or removals (tCO ₂ e)
03/03/2020 to 31/12/2020	35,758	1,844	0	33,914
01/01/2021 to 31/03/2021	28,633	1,054	0	27,579
Total	64,391	2,898	0	61,493

Remarks on increase in achieved emission reductions

The actual emission reductions during this monitoring period was higher than the ex-ante figure. The justification has been provided as follows.

When comparing the actual monitored data with the ex-ante figures, it was found that COD load is higher than the estimation resulting in higher biogas generation. The justification for the increase may come from the higher availability of cassava roots which subjects to seasonal variations.

At the time of the PD development and validation, conservative values were used and verified by the validating VVB. The higher emission reduction achieved during this monitoring period is not permanent. It may happen that due to the variation in the raw material, the project may achieve lower emission reduction in the future.