



**Verified Carbon
Standard**

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



Document Prepared by South Pole Carbon Asset Management Ltd.

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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', involves the installation and operation of a methane recovery and utilization system (an open anaerobic effluent treatment system) 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 ton¹ of dried starch, generating 2,000 m³ of wastewater per operational day.

Table 1 Summary of baseline and project conditions

Project/Baseline Component	Brief Description
Lagoon system	11 lagoons commissioned along with the operation start date of the starch plant in 1988. The approximate retention time of the open lagoon system is around 200 days.
Covered lagoons	Two covered lagoons have been converted from existing open lagoons. Typically, the Chemical Oxygen Demand (COD) removal efficiency of this system is around 80%. The hydraulic retention time is approximately 90 days. The covered lagoon system started operation in October 2006 (first month of biogas usage).
Boiler	There are two dual-fired boilers with a thermal capacity of 4.070 MW _{th} and 3.78 MW _{th} respectively. The first boiler, which previously capacity of 3.488 MW _{th} , was replaced by the new one with capacity 4.070 MW _{th} in year 2010. The reason for replacement is to increase the biogas utilization capacity of boiler. The new burner can operate with only biogas (100%) instead of oil-biogas mixed fuel. ²
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) has 2 generators and the capacity of 450 kW _{el} which are not included in this 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.

¹ Calculated by historical data

² The yearly report to Safety Technology Office of Department of Industrial Work for the old and new boilers are provided.

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.
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This monitoring report involves with the monitoring duration under the first crediting period from 15-July-2009 to 14-July-2019. The monitoring duration covers the monitored data from 01-January-2019 to 14-July-2019. The project has achieved 32,993 tCO₂e.

Further background information on this project activity can be found on the Verified Carbon Standard 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 : 13

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 : 14

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 : 15

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
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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.

1.6 Project Crediting Period

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

- First crediting period: 15-July-2009 to 14-July-2019 (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

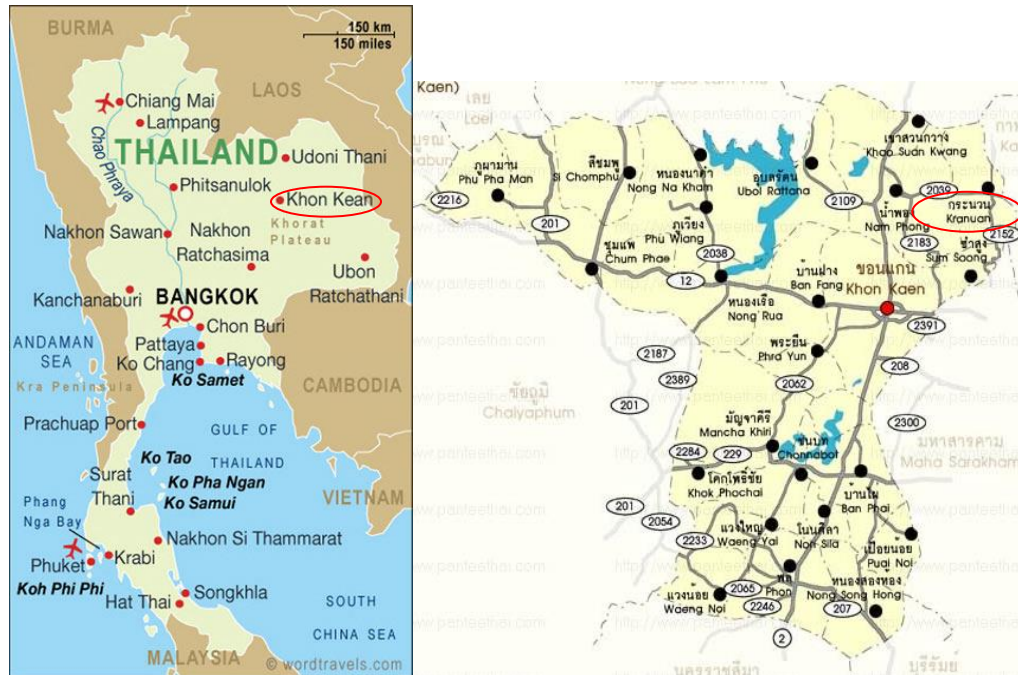


Figure 1: Location



Figure 2: Project activity

1.8 Title and Reference of Methodology

The following methodologies are applicable to the project activity during first 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 13 refers to:

- “Tool to determine project emissions from flaring gases containing methane”, Annex 13 of EB28

AMS-I.C. version 15 refers to:

- “Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion” version 1.2
- “Tool to calculate baseline, project and/or leakage emissions from electricity consumption” version 1.0

AMS-I.D. version 14 refers to:

- “Tool to calculate the emission factor for an electricity system” version 1.1

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 relationships 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 pond in the old anaerobic lagoon, the overflow can only happen from the post-treatment ponds 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 Gold Standard 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.

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 is 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 are provided in Table 3.

Table 2: The implementation status of the project activity

Date	Events
02-December-2006	Operation start date
15-July-2009	Crediting period start date
2010	Boiler 1 replacement
29-June-2012 ³	Issuance of 1 st verification report for 1 st monitoring period from 03-December-2009 to 31-December-2011

³ First issuance date of the credits from the mentioned monitoring period.

Date	Events
16-June-2019	Issuance of 2 nd verification report for 2 nd monitoring period from 01-January-2012 to 11-May-2016
22-August-2019	Issuance of 3 rd verification report for 3 rd monitoring period from 12-May-2016 to 31-December-2018

Table 3: List of events that may impact the GHG emission reductions

Major event	Period	Data management for ER calculation
Long holidays (> 3 days)	- 01-January-2019 to 05-January-2019 - 10-April-2019 to 21-April-2019	No operation at the starch plant during long holidays. Thus, no data available for ER calculation.
Other main events	Unavailability of the logbooks for the amount of electricity generation and no calibration of the electricity meters - 01-January-2019 to 14-July-2019	Unavailability of the logbooks for the amount of electricity generation and no calibration of the electricity meters - Since the logbooks and calibration records were not available, the data during the mentioned period was not claimed for ER calculation.
	Broken HDPE sheet of CL1 - 11-March-2019 to 18-March-2019	Broken HDPE sheet of CL1 - No wastewater fed into CL1 as its HDPE sheet was broken and under repair. Thus, no data for wastewater and COD out of CL1 was available and included in the ER calculation.
	Broken wire of flow meter FM1 - 29-March-2019 to 01-April-2019	Broken wire of flow meter FM1 - No record of wastewater fed into CL1 as the flow meter's wire was broken and under repair. Thus, no data for wastewater of CL1 was available and included in the ER calculation.
	Broken reading monitor of flow meter FM2 - 06-January-2019 to 12-March-2019 - 20-March-2019 to 04-April-2019	Broken reading monitor of flow meter FM2 - No record of wastewater fed into CL2 as the reading monitor of the flow meter was not working properly during 06-January-2019 to 12-March-2019. It was completely broken and under repair during 20-March-2019 to 04-April-2019. Thus, no data for

Major event	Period	Data management for ER calculation
		wastewater of CL2 was available and included in the ER calculation.

3.2 Deviations

3.2.1 Methodology Deviations

There are methodology deviations defined as follows.

Deviations applied for first crediting period
Deviation 1 <u>Background</u> This approach was deviated in Paragraph 15 of the methodology AMS-I.C version 15. 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. <u>Explanation of the deviation</u> Since the complete 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. <u>Compliance with the deviation</u> For verification, with 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. The deviation takes into account the baseline efficiency. A simplified approach is explained here to estimate the baseline emissions. The approach is based on historical consumption of fuel oil per ton of starch generation. The deviation addresses the coherence with Section 15, and 10 of the methodology. It must be noted that the efficiency of the boiler when used in dual-fuel mode is lower than at regular, single-fuel conditions (Heavy Fuel Oil (HFO) only). This drop-in efficiency leads to a lower biogas to HFO displacement rate. Based on the arguments listed below (provided by technical experts on the subject) and energy balance comparisons based on data available before and after implementation of the dual-fuel mode in such boiler systems, an efficiency drop resulting in 10% less HFO displacement (than under theoretical conditions) is a conservative approximation. This can be substantiated based on following arguments: • Higher hydro/moisture loss makes boiler efficiency lower with biogas - The efficiency of heating equipment depends on several factors; one of the important ones being the C:H ratio in the fuel, which is higher for fuel oil and lower for biogas. Lower C:H ratio leads to higher quantity of H₂O as combustion product, which decreases the thermal efficiency of

the boiler. This is typically called "hydrogen loss". In addition, the biogas has a much higher moisture percentage in comparison to fuel oil, thus increasing the moisture losses from the equipment, making it a less efficient fuel for burning. The hydrogen sulfide content in the biogas adds to the hydrogen loss.

- **Higher dry flue gas loss reduces boiler efficiency in dual fuel firing mode** - Air in excess of the theoretical calculations (called "excess air") is always added for proper and complete combustion. In case of a dual fuel firing, due to the different mixing properties of the fuel with the air, this quantity of excess air added is always higher due to the reduced probability of achieving proper air-fuel mixing due to varying fuel properties. At the end of the combustion process, the quantity of unused air is exhausted through the flue gases thus removing unusable heat in the boiler, such a loss being partly accounted for in the dry flue gas loss (the rest is the unusable heat from the high temperature flue gas itself). This can be understood by the fact that the air enters the furnace at ambient temperature, but the flue gases are typically at a much higher temperature, 200 - 300 °C for most low-pressure boiler systems. Thus, if the quantity of excess air pumped into the furnace is higher, which is the case for most dual fuel fired systems, the dry flue gas loss is also higher, bringing down the efficiency of the boiler. The excess air quantity adjustment is a matter of experience, and over a period of time boiler operators will understand how to do this and achieve better efficiencies than what they started with. Thus, it is expected during the initial stages of operation, this loss is higher.
- **Variation in biogas quality and quantity influences the air regulation mechanism**, thus lowering the efficiency of the system - The varying quantity and quality of biogas influences the air regulation mechanism continuously, never allowing it to achieve a steady state operation, thus lowering the efficiency of the system.

The statements above can be confirmed through interviews with technical experts and similar details can be provided. In addition, the energy balance for a particular year, considering the amount of biogas and fossil fuel used, would easily justify the assumption that the energy input required in a dual fuel system is higher than in the baseline system. Based on this, the deviation can be considered as justifiable as it conforms with the requirements of VCS version 3 that it does not impact negatively on the conservativeness of the emission reduction calculation or the additionality of the project.

Starch production are multiplied by this default factor (39.6 liters per ton) to have a minimum fuel oil consumption for each year. For the same year, subtracting the actual amount of fuel oil used, we estimate that the amount of thermal energy supplied by biogas and consequently the amount of GHG emission reductions made from the project is as per the AMS-I.C. version 15 component.

Deviation 2

Background

This approach was deviated according to the answers for the authors' queries by the SSC WG⁴. 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.

Explanation of the deviation

As per the answers to the authors' queries by the 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 P

aragraph 32 for the portion of biogas that is combusted for a gainful use". Based on this, the calculation approach of MD_y has been deviated from the methodology as justified and accepted in the validation report.

Compliance with the deviation

A destruction efficiency of 100% is used for the portion of biogas that is combusted for gainful use i.e. in boiler and gas engines. For the portion of biogas that is sent to flare, a flare efficiency of 0% has been adopted for the current monitoring period to account for non-operation of the flare system due to unavailability of excess biogas.

3.2.2 Project Description Deviations

Deviation 1

Background

This approach is deviated according to the FAR M3 of the validation report. Since the replacement of the 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 at newer and bigger boiler. 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	Value
Boiler 1	75,970
Boiler 2	68,566

2. Determine the biogas consumption of each boiler in Nm³

Biogas usage	Value
Boiler 1	320,938
Boiler 2	1,438,304

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

Thermal energy	Value
Boiler 1	9,738
Boiler 2	32,830
Total	42,569

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

Percentage	Value
Boiler 1	0.23
Boiler 2	0.77

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 boiler 2. Then the equation for Deviation 1 was revised to,

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

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

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	25
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	-

Data/Parameter	B _{o,ww}
Data unit	kg CH ₄ /kg COD
Description	Methane producing capacity of the wastewater
Source of data	IPCC default value. Based as per AMS-III.H, version 13
Value applied	0.21
Justification of choice of data or description of measurement methods and procedures applied	IPCC adjusted value
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 13
Value applied	0.94
Justification of choice of data or description of measurement methods and procedures applied	Default value
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	UF _{PJ}
Data unit	Factor
Description	Model correction factor to account for model uncertainties
Source of data	AMS-III.H, version 13
Value applied	1.06
Justification of choice of data or description of measurement methods and procedures applied	Default value
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 III.H 1 from AMS-III.H, version 13
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	$MCF_{ww,treatment,PJ,CL}$
Data unit	Fraction
Description	Methane correction factor for project wastewater treatment system covered lagoon equipped with biogas recovery
Source of data	Table III.H 1 from AMS-III.H, version 13
Value applied	0.8
Justification of choice of data or description of measurement methods and procedures applied	The project wastewater treatment system equipped with biogas recovery is a cover lagoon, therefore MCF value is chosen as 0.8.
Purpose of data	Calculation of project 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 III.H 1 from AMS-III.H, version 13
Value applied	0.8
Justification of choice of data or description of measurement methods and procedures applied	The project wastewater treatment system without biogas recovery (secondary treatment) consists in a succession of deep lagoons, with depth more than 2 m, so the value of 0.8 has been used.
Purpose of data	Calculation of project emissions
Comments	-

Data/Parameter	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	-
Description	Capture efficiency of the biogas recovery equipment in the wastewater treatment systems.
Source of data	AMS-III.H, version 13
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 _y
Data unit	tCO ₂ /MWh
Description	CO ₂ emission factor for grid power

Source of data	The calculation of emission factor for an electricity system in Thailand 2007, DEDE
Value applied	0.5057
Justification of choice of data or description of measurement methods and procedures applied	EF _y is calculated according to the “Tool to calculate the emission factor for an electricity system” as determined in the respective small-scale methodology for grid connected electricity generation (AMS-I.D, version 14).
Purpose of data	Calculation of baseline and project emissions
Comments	-

Data/Parameter	EF _{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 the main source of thermal energy for the processes.
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	NCV _{FO}
Data unit	GJ/ton
Description	NCV of fuel oil i.e. fossil fuel displaced by biogas
Source of data	Thailand Energy situation 2005
Value applied	42.76
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	-

Data/Parameter	NCV _{biogas}
Data unit	MJ/Nm ³
Description	NCV of biogas
Source of data	Thailand Energy situation 2005
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	-

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 _{CH4}
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	D _{FO}
Data unit	kg/liter
Description	Density of fuel oil
Source of data	Public source ⁵
Value applied	0.93
Justification of choice of data or description of measurement methods and procedures applied	Publicly available information
Purpose of data	Calculation of baseline emissions
Comments	-

Data/Parameter	FE
Data unit	%
Description	Flare efficiency
Source of data	“Tool to determine project emissions from flaring gases containing methane”
Value applied	50%

⁵ https://www.engineeringtoolbox.com/fuels-densities-specific-volumes-d_166.html (accessed on 13-March-2020)

Justification of choice of data or description of measurement methods and procedures applied	Default value for open flare as per the “Tool to determine project emissions from flaring gases containing methane” has been applied.
Purpose of data	Calculation of project 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

	Tag	Description	Motor (HP)
	ST1	Stirrer - NaoH Tank	3
	ST2	Stirrer - Mixing tank	3
	ST3	Stirrer - Pump sump	20
	Bi1	WW Feed pump	40
	Bi2	WW Feed pump	40
	Bi3	WW recycle pump	25
	Bi4	Sludge recycle pump 1	15
	Bi5	Sludge recycle pump 2	15
	Bi6	Reuse water pump	75
	Bi7	Reuse water pump	40
	Bi8	Reuse water pump	40
	OG	Oxygen pumpfor Bio-scrubber	0.25
	SP	Super pump for gas washer	1
	FL	Flare	0.25
	CH 1	Chiller No. 1	12.68
	CH 2	Chiller No. 2	12.68
	CH 3	Chiller No. 3	12.68
	CH 4	Chiller No. 4	12.68
	CH 5	Chiller No. 5	12.68
	CLP1	Water pump - CT1	15
	CLP2	Water pump - CT2	15
	CLP3	Water pump - CT3	15
	FBC1	Fan Blower of Cooling Tower 1	5
	FBC2	Fan Blower of Cooling Tower 2	5
	FB1	Fan Blower No. 1	0.5
	FB2	Fan Blower No. 2	0.5
	FB3	Fan Blower No. 3	1
	FB4	Fan Blower No. 4	1
	BA1	Blower air No. 1	5
	BA2	Blower air No. 2	5
	BL 1	Gas Blower No. 1	30
	BL 2	Gas Blower No. 2	30
	BL 3	Gas Blower No. 3	30
	BL 4	Gas Blower No. 4	30
	BL 5	Gas Blower No. 5	30
	BP1	Spray pump	7.5
	BP2	Spray pump	7.5
	Total - HP		614
	Total - kW		458
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	$Q_{y,ww}$	
Data unit	m^3	
Description	Volume of wastewater treated in the year y	
Source of data	Volumetric flow meter: FM1 and FM2	
Description of measurement methods and procedures to be applied	The electromagnetic volumetric flow was installed before covered lagoons. In case the flow meter value was not available for a particular day, the value was estimated in a conservative manner by excluding from the emission reduction estimation.	
Frequency of monitoring/recording	Continuous monitoring with daily recording	
Value monitored	Monitoring period	Total value (m^3)
	01/01/2019 to 14/07/2019	368,579
Monitoring equipment	Meter tag	FM1
	Serial number	LA020720000
	Brand	Endress Hauser
	Type	PROMAG 10L
	Accuracy	$\pm 0.50\%$
	Calibration frequency	Once in 3 years
	Calibration date	18/05/2017
	Validity	17/05/2020
	Meter tag	FM2
	Serial number	M102FC20000
	Brand	Endress Hauser
	Type	PROMAG 10L

	Accuracy	±0.50%
	Calibration frequency	Once in 3 years
	Calibration date	19/05/2017
	Validity	18/05/2020
QA/QC procedures to be applied	The flow meter was calibrated at least every 3 years.	
Purpose of the data	Calculation of baseline and project emissions	
Calculation method	Not applicable	
Comments	All the monitoring equipment were calibrated on time, thus no error was applied.	

Data/Parameter	COD _{ww,untreated,y}	
Data unit	mg/l	
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 COD sampling point was before 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 (mg/l)
	01/01/2019 to 14/07/2019	35,178
Monitoring equipment	Meter tag	Spectrophotometer
	Serial number	HI19945I
	Brand	Hanna
	Type	HI 83214

	Accuracy	10 mg/l (HR) 1 mg/l (LR)
	Calibration frequency	Once in 3 years
	Calibration date	25/07/2016
	Validity	24/07/2019
QA/QC procedures to be applied	The spectrophotometer was calibrated at least once every 3 years.	
Purpose of the data	Calculation of project emissions	
Calculation method	Not applicable	
Comments	All of the monitoring equipment was calibrated on time; thus, no error was applied.	

Data/Parameter	COD _{out,lagoon,PJ,y}	
Data unit	tons/m ³	
Description	COD of water coming out of the last lagoon	
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 the emission reduction estimation.	
Frequency of monitoring/recording	The test was carried out in every operational day.	
Value monitored	Monitoring period	Average value (tons/m ³)
	01/01/2019 to 14/07/2019	0.000203
Monitoring equipment	Please see COD _{ww,untreated,y}	
QA/QC procedures to be applied	Please see COD _{ww,untreated,y}	
Purpose of the data	Calculation of project emissions	

Calculation method	Not applicable
Comments	Please see COD _{ww,untreated,y}

Data/Parameter	COD _{out,CL,y}	
Data unit	tons/m ³	
Description	COD of water coming out of the covered lagoon	
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 (tons/m ³)
	01/01/2019 to 14/07/2019	0.00119
Monitoring equipment	Please see COD _{ww,untreated,y}	
QA/QC procedures to be applied	Please see COD _{ww,untreated,y}	
Purpose of the data	Calculation of project emissions	
Calculation method	Not applicable	
Comments	Please see COD _{ww,untreated,y}	

Data/Parameter	BG _{combusted,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_{combusted,y} was estimated by summing-up the volume of biogas sent to the boiler and generation set. In case the flow meter value was not available for a particular day, the value was estimated in a conservative manner by excluding from the emission reduction estimation.					
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><tr><th>Monitoring period</th><th>Total value (Nm³)</th></tr><tr><td>01/01/2019 to 14/07/2019</td><td>3,262,040</td></tr></table>		Monitoring period	Total value (Nm³)	01/01/2019 to 14/07/2019	3,262,040
Monitoring period	Total value (Nm³)					
01/01/2019 to 14/07/2019	3,262,040					
Monitoring equipment	Meter location	Boiler 1				
	Meter tag	GM1				
	Serial number	N1-TD02-9544598				
	Brand	Siemens				
	Type	7MF4433-1BA22-1AC96-Z				
	Accuracy	±0.075%				
	Calibration frequency	Once in 3 years				
	Calibration date	24/04/2016 12/01/2018				
	Validity	11/01/2021				
	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 date	25/04/2016 11/01/2018
	Validity	10/01/2021
	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 date	11/05/2016 29/11/2018
	Validity	28/11/2021
QA/QC procedures to be applied	The flow meters were calibrated at least once every 3 years.	
Purpose of the data	Calculation of baseline emissions	
Calculation method	The summation from GM3 and GM4 was calculated.	
Comments	All of the monitoring equipment was calibrated on time; thus, no error was applied.	

Data/Parameter	W_{CH_4}
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.													
Frequency of monitoring/recording	The methane content in biogas is continuously measured. The average value is calculated 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="3">Value (%)</th></tr><tr><th>Average</th><th>Lower</th><th>Upper</th></tr><tr><td>01/01/2019 to 14/07/2019</td><td>53.1</td><td>52.5</td><td>53.7</td></tr></table>			Monitoring period	Value (%)			Average	Lower	Upper	01/01/2019 to 14/07/2019	53.1	52.5	53.7
Monitoring period	Value (%)													
	Average	Lower	Upper											
01/01/2019 to 14/07/2019	53.1	52.5	53.7											
Monitoring equipment	Meter tag	MS												
	Serial number	G503004												
	Brand	Geotech												
	Type	BIOGAS 5000												
	Accuracy	0.5%												
	Calibration frequency	Once in 3 years												
	Calibration date	21/11/2016												
	Validity	20/11/2019												
QA/QC procedures to be applied	The portable gas analyzer was calibrated at least 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 the 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 _{TOFlare,y}	
Data unit	Nm ³	
Description	Amount of biogas flared	
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.	
Frequency of monitoring/recording	Continuous monitoring with daily recording	
Value monitored	Monitoring period	Total value (Nm ³)
	01/01/2019 to 14/07/2019	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 date	28/04/2016
	Validity	27/04/2019
QA/QC procedures to be applied	The flow meters were calibrated at least once every 3 years.	
Purpose of the data	Calculation of baseline emissions	
Calculation method	Not applicable	
Comments	The calibration of the equipment was delayed during 28/04/2019 to 31/12/2019. However, the adjustment of the values was not conducted as per Section 3.4.2 of the Validation and Verification Manual, v3.2 since there was no biogas flared during the monitoring period.	

Data/Parameter	$Q_{HFO,y}$	
Data unit	Liters	
Description	Quantity of fossil fuel in the boiler in year y	
Source of data	Usage data (monitored from boiler panel). The value was used for a conservative estimation of biogas/methane used in the replacement of fossil fuel during year y.	
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 the Deviation 1 of the project description deviation, the oil meter value of boiler 1 was excluded in a conservative manner.	
Frequency of monitoring/recording	Continuous monitoring with daily recording	
Value monitored	Monitoring period	Total value (liters)
	01/01/2019 to 14/07/2019	68,566
Monitoring equipment	Meter location	Boiler 1
	Meter tag	OM1
	Serial number	4546871
	Brand	CONTOIL
	Type	VZO 20FL 130/25
	Accuracy	1%
	Calibration frequency	Once in 3 years
	Calibration date	24/04/2016 22/11/2018
	Validity	21/11/2021
	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 date	07/05/2016 29/11/2018
	Validity	28/11/2021
QA/QC procedures to be applied	The liquid flow meters were calibrated at least once every 3 years.	
Purpose of the data	Calculation of project emissions	
Calculation method	Not applicable	
Comments	As per the Deviation 1 of the project description deviation, the oil meter value for boiler 1 was exclude in a conservative manner. All of the monitoring equipment was calibrated on time; thus, no error was applied.	

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	Total value (tons)
	01/01/2019 to 14/07/2019	39,886
Monitoring equipment	Meter tag	Indicators for floor scale
	Serial number	B406274156

		B406274200 B301690263 B315226070 B316230849
	Brand	Ohaus
	Type	T32XW
	Accuracy	±2%
	Calibration frequency	Once a year
	Calibration date	06/06/2018 15/05/2019
	Validity	14/05/2020
QA/QC procedures to be applied	The production data was cross-checked with sales records, if necessary.	
Purpose of the 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 _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 and no available record, the values were not included in the conservative baseline emission calculation (BE _{gen,y}).

	Monitoring period	Total value (MWh)
	01/01/2019 to 14/07/2019	0
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 date	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 date	Not available
QA/QC procedures to be applied	The power meters shall be calibrated at least once every 3 years.	
Purpose of the data	Calculation of baseline emissions	
Calculation method	Not applicable	
Comments	- As there was no calibration conducted for the electricity meters and no available record, the values were not included in the conservative baseline emission calculation ($BE_{gen,y}$). - The electricity supplied from generator no.'s 3 and 4 were excluded from the calculation since there were installed after the project start date.	

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 10%.	
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 13).	
Frequency of monitoring/recording	Not applicable. This was based on the calculation mentioned above.	
Value monitored	Monitoring period	Total value (MWh)
	01/01/2019 to 14/07/2019	2,358
Monitoring equipment	Not applicable	
QA/QC procedures to be applied	Not applicable	
Purpose of the data	Calculation of project emissions	
Calculation method	Not applicable	
Comments	The project only consumed the electricity generated by the generators using biogas.	

Data/Parameter	Sludge removed and its application
Data unit	Tons/type of application
Description	The quantity of organic material / sludge removed from treatment plant and its application
Source of data	Weighing equipment that is available at the site are used.
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)
	01/01/2019 to 14/07/2019	0
Monitoring equipment	Meter tag	Weighbridge
	Serial number	0008666
	Brand	Commandor
	Type	HP-05K
	Accuracy	±20 kg
	Calibration frequency	Once in 2 years
	Calibration date	18/05/2017 04/06/2019
	Validity	03/06/2021
QA/QC procedures to be applied	The plant manager's signature was required on the record.	
Purpose of the data	Calculation of project emissions	
Calculation method	Not applicable	
Comments	The calibration of the equipment was delayed during 18/05/2019 to 03/06/2019. However, the adjustment of values was not conducted as per Section 3.4.2 of the Validation and Verification Manual, v3.2 since there was no sludge removed during the monitoring period.	

Data/Parameter	$Q_{\text{biogas, flare, h}}$
Data unit	Nm ³ /hr
Description	Biogas sent to flare during a particular hour h
Source of data	Measured using biogas flow meter: GM2
Description of measurement methods	The gas flow meter was installed at the plant.

and procedures to be applied		
Frequency of monitoring/recording	Continuous monitoring with daily recording	
Value monitored	Monitoring period	Value (Nm ³ /hr)
	01/01/2019 to 14/07/2019	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 date	28/04/2016
	Validity	27/04/2019
QA/QC procedures to be applied	The flow meters were calibrated at least once every 3 years.	
Purpose of the data	Calculation of baseline emissions	
Calculation method	Not applicable	
Comments	The calibration of the equipment was delayed during 28/04/2019 to 31/12/2019. However, the adjustment of values was not conducted as per Section 3.4.2 of the Validation and Verification Manual, v3.2 since there was no biogas flared during the monitoring period.	

Data/Parameter	$\eta_{\text{flare,h}}$
Data unit	%
Description	Flare efficiency
Source of data	“Tool to determine project emissions from flaring gases containing methane”

Description of measurement methods and procedures to be applied	The efficiency of the flaring process was defined as 50% based on the default factor for open flares.	
Frequency of monitoring/recording	Continuous monitoring, recording on the daily basis	
Value monitored	Monitoring period	Value (%)
	01/01/2019 to 14/07/2019	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 the data	Calculation of project emissions	
Calculation method	Not applicable	
Comments	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. However, there was no record of flame detection since no biogas was flared during the monitoring period.	

4.3 Monitoring Plan

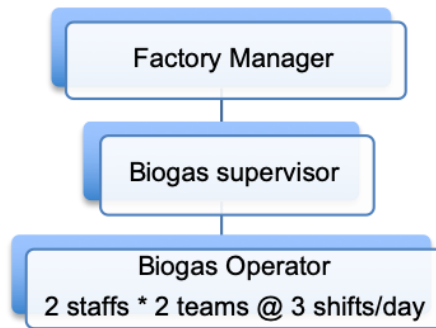
The monitoring plan was as described in Section 3.4 of the registered PD. The daily operation data recording and laboratory analysis was carried out by plant operators. The reports and all equipment calibrations were checked and approved by the biogas plant supervisor.

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

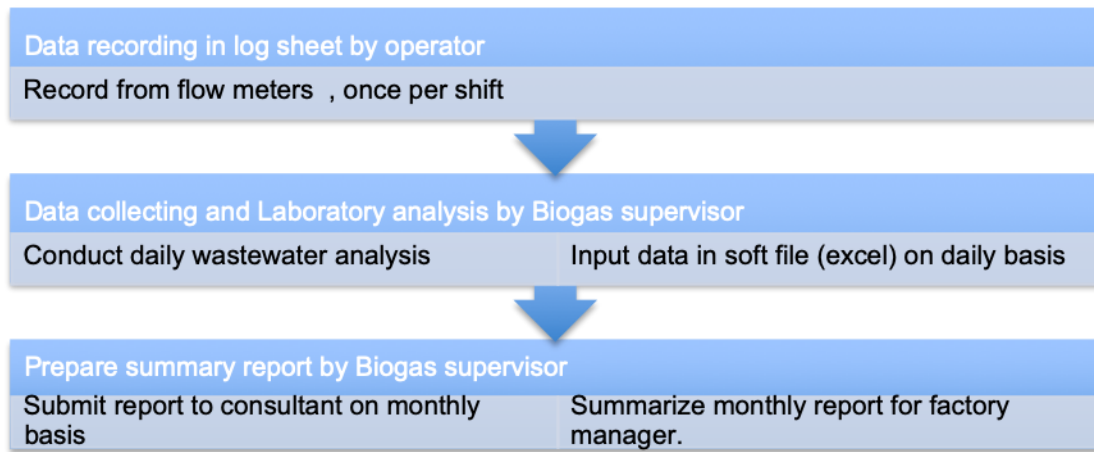
All monitoring data was available in an Excel spreadsheet. This spreadsheet consisted of:

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 01-January-2019 to 14-July-2019 (Figure 3).

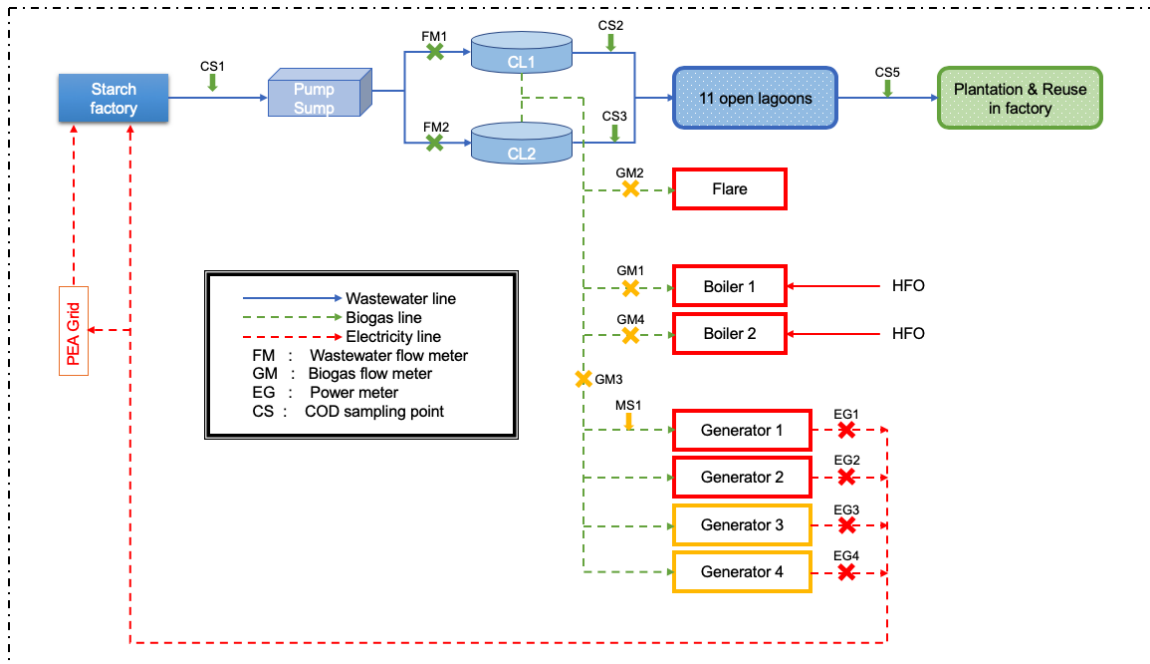


Figure 3: The project system boundary

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 the 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 (tCO₂e)

$BE_{power,y}$ Baseline emissions from electricity or fuel consumption in year y (tCO₂e)

$BE_{ww,treatment,y}$	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 (tCO ₂ e)

Baseline emission from electricity and fuel consumption ($BE_{power,y}$)

As per Paragraph 19 of AMS-III.H. (version 13), the baseline emission from electricity consumption ($BE_{power,y}$) were determined as per the procedures described in AMS-I.D. For emissions from fossil fuel consumption, the emission factor for the fossil fuel was used (tCO₂/ton).

$$BE_{power,y} = (BE_{elec,y} + BE_{heat,y}) \quad (2)$$

Where:

$BE_{power,y}$	Baseline emissions from electricity or fuel consumption in year y
$BE_{elec,y}$	Baseline emissions from electricity consumption in year y
$BE_{heat,y}$	Baseline emissions from fossil fuel consumption in year y

There was no consumption of fossil fuels in waste water treatment systems in a baseline scenario, thereby $BE_{heat,y} = 0$.

For $BE_{elec,y}$ the power consumed in a baseline case was negligible and is disregarded for conservative estimation of baseline emissions.

Baseline emissions of the wastewater treatment systems affected by the project activity:

Methane emissions from the baseline wastewater treatment systems affected by the project ($BE_{ww,treatment,y}$) were determined using the methane generation potential of the wastewater treatment systems as per the paragraph 20 of AMS-III.H. version 13. The following equation was used.

$$BE_{ww,treatment,y} = \sum_i Q_{ww,i,y} * COD_{removed,i,y} * MCF_{ww,treatment,BL,i} * B_{0,ww} * UF_{BL} * GWP_{CH4} \quad (3)$$

$Q_{ww,i,y}$	Volume of wastewater treated in a baseline wastewater treatment system i in year y (m ³)
$COD_{removed,i,y}$	Chemical oxygen demand removed by a baseline treatment system i in year y (tons/m ³) calculated as $COD_{removed,i,y} = COD_{ww,untreated,y} * COD_{removal\ efficiency}$

$MCF_{ww,treatment,BL,i}$	Methane correction factor for the baseline anaerobic wastewater treatment i (MCF values as per table III.H.1)
i	Index for the baseline wastewater treatment system (open lagoon system); i = lagoon
$B_{o,ww}$	Methane producing capacity of the wastewater (IPCC lower value for domestic wastewater of 0.21 kg CH ₄ /kg COD)
UF_{BL}	Model correction factor to account for model uncertainties (0.94)
GWP_{CH4}	Global warming potential

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.

The generated sludge in the baseline scenario was close to zero in which it was used aerobically for soil application. There was 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 ($BE_{gen, y}$)

As per AMS-I.D. Paragraph 10, the baseline was the MWh produced by the renewable generating unit multiplied by an emission coefficient as follows:

$$BE_y = BE_{gen,y} = EF_y * EG_y \quad (4)$$

Where:

EG_y	The quantity of electricity supplied by the project activity during the year y (MWh)
EF_y	Thailand National Grid emission factor (tCO _{2e} /MWh)

Since the calibration of the monitoring equipment for measuring the parameter EG_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, $BE_y = BE_{gen,y} = 0$.

Baseline Emissions for AMS-I.C

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

According to Paragraph 15 of AMS-I.C., the baseline emissions were estimated based on the amount of heat/steam delivered by the equipment (as per equation below).

$$BE_{\text{thermal},\text{CO}_2,y} = (EG_{\text{thermal},y} / \eta_{\text{BL},\text{thermal}}) * EF_{\text{CO}_2} \quad (5)$$

Where:

$EG_{\text{thermal},y}$	The net quantity of steam/heat supplied by the project activity during the year y (TJ)
$\eta_{\text{BL},\text{thermal}}$	The efficiency of the plant using fossil fuel that would have been used in the absence of the project activity.
EF_{CO_2}	The CO ₂ emission factor per unit of energy of the fuel that would have been used in the baseline plant in (tCO ₂ /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 10 and 15 of the methodology. In addition, boiler 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 a conservative approach for the emission reduction of the 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.

$$BE_{\text{thermal},\text{CO}_2,y} = (Q_{\text{starch}} * Q_{\text{FO},\text{starch}} * \%B2 - q_{\text{FO},y,\text{Boiler2}}) * D_{\text{FO}} * NCV_{\text{FO}} * EF_{\text{CO}_2} / 10^6$$

Where:

$Q_{\text{starch},y}$	Quantity of dry starch produced in year y (tons)
$Q_{\text{FO},\text{starch}}$	Quantity of fossil fuel per unit of dry starch (liter/ton)
$q_{\text{FO},y,\text{boiler2}}$	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

Table 4: Detail of baseline emissions calculation for the monitoring period 01-January-2019 to 14-July-2019

AMS-III.H		
Parameter	Unit	Value
$Q_{ww,y}$	m^3	368,579
$COD_{removed,i,y}$	tons/ m^3	0.029
$B_{o,ww}$	kg CH_4 /kg COD	0.21
$MCF_{ww,treatment,BL,lagoon}$	fraction	0.8
GWP_{CH_4}	tCO ₂ e/tCH ₄	25
UF_{BL}	factor	0.94
BE_{ww,treatment,y} (COD approach)	tCO₂e	41,639

Parameter	Unit	Value
$BG_{combusted,y}$ (boiler2)	Nm ³	1,438,304
$BG_{combusted,y}$ (gas engines)	Nm ³	1,823,736
$BG_{ToFlare,y}$	Nm ³	0
$W_{CH_4,y}$ - lower	%	52%
D_{CH_4}	kg/ m^3	0.716
$Q_{biogas,flare,y}$	Nm ³	0
$h_{flare-h}$	%	0%
BE_{ww,y} (MD approach)	tCO₂e	30,649

AMS-I.C.		
Parameter	Unit	Value
$Q_{FO,boiler}$	liters	68,566
$Q_{starch,y}$	tons	39,886
EF_{CO_2}	tCO ₂ /TJ	77.4
NCV_{FO}	GJ/ton	42.76
$Q_{FO,starch}$	liters/ton	39.6
D_{FO}	kg/ m^3	0.93
BE_{thermal,CO2,y} = ER_{heat,y}	tCO₂e	3,538

AMS-I.D.		
Parameter	Unit	Value
EG_y	MWh	
EF_{CO_2}	tCO ₂ /MWh	
BE_{gen,y} = ER_{power,y}	tCO₂e	The log books were not available

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

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

Emissions from electricity consumption by the project activity facilities are calculated according to the Paragraph 19 of AMS-III.H. as given below.

$$PE_{power,y} = EF_y * EC_y \quad (7)$$

Where:

EC_y	Electricity consumption by the project activity (MWh)
EF_y	Thailand National Grid emission factor (tCO ₂ e/MWh)

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 per prescribed method in Paragraph 35 of AMS-III.H, as follows:

$$PE_{power,y} = (\sum P_{el} * 110\% * 8,760 * EF_y) / 1000 \quad (8)$$

Where:

P_{el}	Total electrical capacity of the equipment installed in the project activity (kW) – for reference, this is 458 kW for this project activity.
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EF_y Thailand National Grid emission factor (tCO₂e/MWh)

Taking into account the distribution losses, 10% has been added to the total electricity consumption. The calculated electricity consumption was based on an assumption that the electrical appliances were running for the entire monitoring period duration.

Emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery in the project situation (PE_{ww,treatment,y})

Methane emissions from wastewater treatment systems affected by the project activity were calculated as per the Paragraph 20, AMS-III.H. The following equation was used.

$$PE_{ww,treatment,y} = Q_{ww,k,y} * COD_{removed,PJ,k,y} * MCF_{ww,treatment,PJ,k} * B_{o,ww} * UF_{PJ} * GWP_{CH4} \quad (9)$$

Where:

Q _{ww,k,y}	Volume of wastewater treated in a baseline wastewater treatment system k in year y (m ³)
COD _{removed,PJ,k,y}	Chemical oxygen demand removed by the project wastewater treatment system k in year y (tons/m ³), measured as the difference between inflow COD and the outflow COD in system k. COD _{y,removed,PJ,k} = COD _{y,out,CL} - COD _{y,out,PJ,lagoon}
MCF _{ww,treatment,PJ,k}	Methane correction factor for the project wastewater treatment systems k
B _{o,ww}	Methane producing capacity of the wastewater (IPCC value of 0.21 kgCH ₄ /kg COD)
UF _{PJ}	Model correction factor to account for model uncertainties (1.06)
GWP _{CH4}	Global Warming Potential for methane
k	Wastewater treatment systems affected by the project activity, and not equipped with biogas recovery in the project situation = series of the 9 anaerobic ponds. k=lagoon

Methane emissions from sludge treatment systems (PE_{s,treatment,y})

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

Methane emissions on account of inefficiency of the project activity wastewater treatment systems and presence of degradable organic carbon in treated wastewater (PE_{ww,discharge,y})

In the project activity, the treated wastewater was discharge in existing open lagoons and there was no discharge to river, sea or lake. Hence, emissions from this component were not included in the assessment.

Emissions from anaerobic decay of the final sludge produced (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, $PE_{s,final,y} = 0$.

Emissions on account of inefficiencies in capture system ($PE_{fugitive,y}$)

Project activity emissions from methane release in capture systems were determined as per Paragraph 26 of AMS-III.H., as given below.

$$PE_{fugitive,y} = PE_{fugitive,ww,y} + PE_{fugitive,s,y} \quad (10)$$

Where:

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

a. Fugitive emissions through capture inefficiencies in the anaerobic wastewater treatment ($PE_{fugitive,ww,y}$)

These emissions were calculated as follows

$$PE_{fugitive,ww,y} = (1 - CFE_{ww}) * MEP_{ww,treatment,y} * GWP_{CH4} \quad (11)$$

Where:

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

$$MEP_{ww,treatment,y} = Q_{ww,y} * B_{0,ww} * UF_{PJ} * \sum COD_{removed,PJ,k,y} * MCF_{ww,treatment,PJ,k}$$

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 (tons/m ³). $COD_{removed,PJ,k,y} = COD_{ww,untreated,y} - COD_{y,out,CL}$
$MCF_{ww,treatment,PJ,k}$	Methane correction factor for the project wastewater treatment system k equipped with biogas recovery equipment (MCF values as per table III.H.1)
UF_{PJ}	Model correction factor to account for model uncertainties (1.06)
k	Treatment system of the project activity equipped with biogas recovery. k=CL

b. *Fugitive emissions through capture inefficiencies in the anaerobic sludge treatment system*
($PE_{fugitive,s,y}$):

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

Methane emissions due to incomplete flaring ($PE_{flaring,y}$)

Methane emissions due to incomplete flaring in year y are calculated as per the “Tool to determine project emissions from flaring gases containing methane” (tCO_{2e}). 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.

$$PE_{flare,y} = \sum_{h=1}^{8760} TM_{RG,h} * (1 - \eta_{flare-h}) * GWP_{CH_4} / 1000 \quad (12)$$

Where:

$TM_{RG,h}$	Mass flow rate of methane in the residual gas in the hour h (kg/h)
$\eta_{flare-h}$	Flare efficiency in hour h
GWP_{CH_4}	Global Warming Potential of methane valid for the commitment period (tCO _{2e} /tCH ₄)

Methane emissions from biomass stored under anaerobic conditions ($PE_{biomass,y}$)

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.

Table 5: Detail of project emissions calculation for the monitoring period 01-January-2019 to 14-July-2019

Parameter	Unit	Value
EC _y	MWh	2,358
EF _{CO2}	tCO ₂ /MWh	0.5057
PE _{power,y}	tCO ₂ e	1,193

Parameter	Unit	Value
Q _{ww,y}	m ³	368,579
COD _{removed,PJ,k,y}	tons/m ³	0.00104
B _{o,ww}	kg CH ₄ /kg COD	0.21
MCF _{ww,treatment,PJ,lagoon}	fraction	0.8
GWP _{CH4}	tCO ₂ e/tCH ₄	25
UF _{PJ}	factor	1.06
PE _{ww,treatment,y}	tCO ₂ e	1,705

Parameter	Unit	Value
PE _{s,treatment,y}	tCO ₂ e	0
PE _{ww,discharge,y}	tCO ₂ e	0
PE _{s,final,y}	tCO ₂ e	0
PE _{biomass,y}	tCO ₂ e	0

Parameter	Unit	Value
MCF _{ww,treatment,PJ,CL}	fraction	0.8
COD _{removed,PJ,CL,y}	tons/m ³	0.032
MEP _{ww,treatment,y}	tons	2,073
PE _{fugitive,ww,y}	tCO ₂ e	5,184
PE _{fugitive,s,y}	tCO ₂ e	0
PE _{fugitive,y}	tCO ₂ e	5,184

PE _{flaring,y}	tCO ₂ e	0
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PE _{y,ex post}	tCO ₂ e	8,082
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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 6: Detail of leakage emissions calculation for the monitoring period 01-January-2019 to 14-July-2019

Parameter	Unit	Value
LE _y	tCO ₂ e	0

5.4 Net GHG Emission Reductions and Removals

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)
01-January-2019 to 14-July-2019	34,187	1,193	0	32,993
Total	34,187	1,193	0	32,993

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.

1) Change in default parameter of GWP_{CH4}

According to the VCS standard, version 4, the GWP_{CH4} value of 25 was applied for the emission calculation. This caused the overall ERs to increase around 15%⁶.

2) When comparing the actual monitored data with the ex-ante figures, most of the figures were increased. The explanation for the main figures has been provided as follows:

- Ton of starch production: The starch production capacity has not been changed. The higher amount was from the higher utilization of the starch factory.
- Biogas production volume: The actual COD removal efficiency for the covered lagoon system was 97%, while the figure of 80% was applied in ex-ante calculation. This further explains the increased biogas production.
- Quantity of fossil fuel used: The actual quantity of fossil fuel consumed at two boilers was much lower than the ex-ante figure.

At the time of the PD development and validation, conservative values were used and verified by the validating DOE. The quality of raw material also, had an impact on the starch output and resulting in wastewater generation. This was dependent on the crop and is subject to seasonal variations. Therefore, the assumptions made at the time of validation were based on sound judgment and sources and may change during the course of the operation of the project. It may

⁶ Based on GWP_{CH4} 21 and actual data, the total ERs was estimated to be 28,090 tCO₂e.

happen that due to the variation in the raw material, the wastewater generation volume may change again in the future.