

MONITORING REPORT OF WASTEWATER TREATMENT WITH BIOGAS PRODUCTION (UASB) AND HEAT UTILIZATION AT GENERAL STARCH CO., LTD.



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

The project activity involves the installation of an anaerobic wastewater treatment facility, based on Upflow Anaerobic Sludge Blanket (UASB) technology, at a starch manufacturing plant that has been in operation since 1995. Prior to project implementation, the wastewater was treated using an open lagoon system.

The first phase of the project (UASB 1) was implemented at General Starch Co., Ltd. in 2003 with startup of operations in January 2004, and the second phase of the project (UASB 2) began in 2005 with startup of operations in January of 2006. The biogas produced from anaerobic digestion is captured and then used as fuel for heat generation.

The project's crediting period has been renewed for the second crediting period and available on the V-C-S under project number 82 ; http://vcsprojectdatabase.org/#/project_details/82. This is the first verification of the second crediting period.

1.2 Sectoral Scope and Project Type

The project sectoral scope, as defined by the UNFCCC, is: 13 – Waste handling and disposal.

1.3 Project Proponent

Organization name	Papop Renewable Co.,Ltd
Contact person	Likit Nimtrakul
Title	Mr.
Address	43 Soi Prasertmanookij 5 , Jorakaebua , Ladphrao Bangkok 10230
Telephone	+66 2 570 5580
Email	likit@papop.com

1.4 Other Entities Involved in the Project

Organization name	South Pole Carbon Asset Management Ltd.
Role in the project	Carbon consultant
Contact person	Ingo Puhl
Title	Mr.
Address	Technoparkstrasse 1 , Zurich , Switzerland 8005
Telephone	+66 2 678 8979
Email	i.puhl@southpolecarbon.com

1.5 Project Start Date

The commissioning date of the first UASB reactor was 1st Jan 2004.

1.6 Project Crediting Period

The second crediting period is from 1st January 2014 to 31st December 2023. The subsequent renewals of the crediting time might be considered according to the status of the project activity and baseline revision at that time.

1.7 Project Location

The proposed project site is located on Ratchasima-Chokchai Road, Amphur Kornburi in Nakorn Ratchasima Province, which is in the northeast of Thailand. Nakorn Ratchasima, about 250 km away from Bangkok, is one of the five biggest cities in Thailand. Most of the tapioca starch plants in Thailand are located in this province. The closest Railway station is Jira Station, and the closest airport is Nakorn Ratchasima.

Physical Address No.99 , Chokchai – Kornburi Road , Amphur Kornburi ,Nakornratsima

GPS coordinate N 14.58375, E 102.186728



Figure 1 : Project Location

1.8 Title and Reference of Methodology

The project applies the approved consolidated baseline and monitoring methodology
ACM0014 : Large-scale Consolidated Methodology , Treatment of wastewater (Version 06.0).

1.9 Other Programs

N/A

2 IMPLEMENTATION STATUS

2.1 Implementation Status of the Project Activity

In this monitoring period , as a result of production capacity increment at starch factory.

- The new reactors (CL3 and CL4) have been installed , which are addition from the project boundary in the first crediting period and not included in the calculation of emission reductions.
- Due to the lower utilization of UASBs , all biogas produced from UASBs were sent to boilers. There was no excess biogas sent to the flare from UASB system.
As per this actual situation , the amount of biogas produced from UASBs (GM1,GM2) is assumed to be equal to the amount of biogas from UASBs which was utilized at boilers (some part of the total of biogas measured by GM4 and GM5).

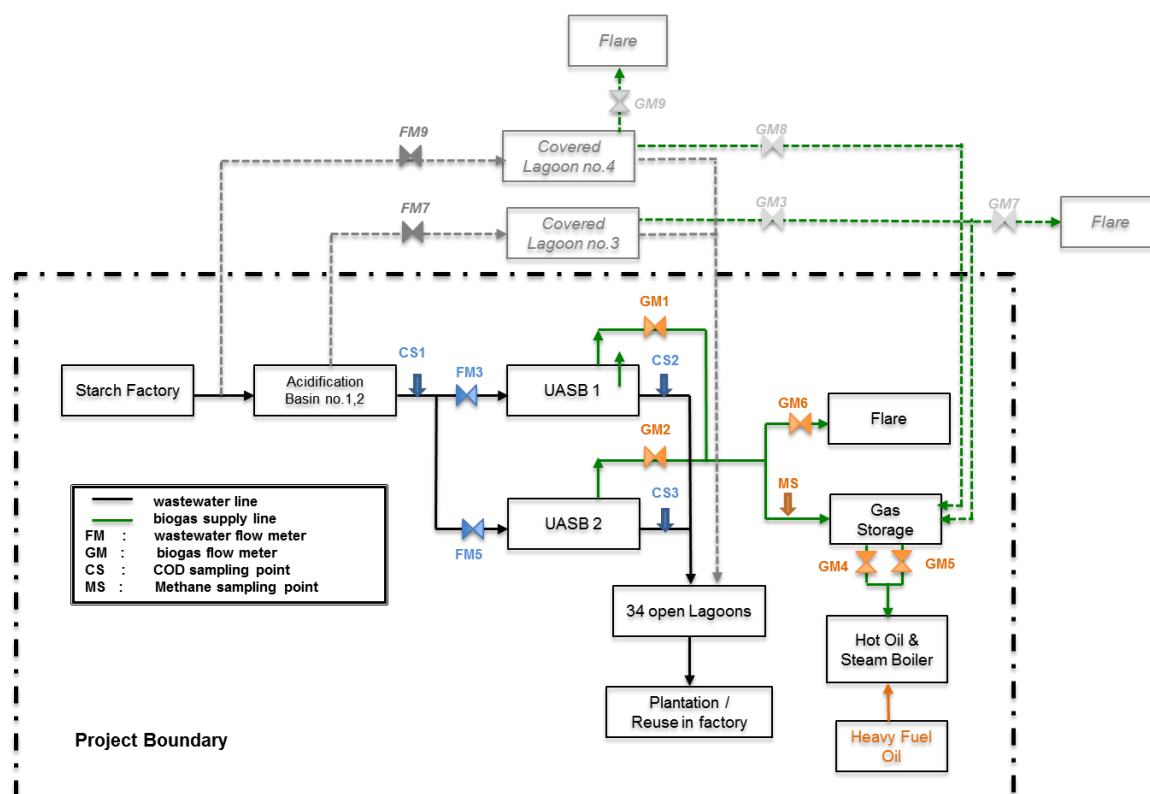


Figure 2 : Monitoring diagram from the registered PD

Table 1 : The chronology of events

Description of event	Date occur
Overhaul UASB no.1	14-Jan-14
Overhaul UASB no.2	21-Jan-14
Start operating of UASB no.1	10-Feb-14
Start operating of UASB no.2	4-Apr-14
Commissioning of CL4	19-Sep-14
Start pulp feeding system for CL3	24-Feb-15
Stop UASB no.1 of internal cleaning	26-Feb-15
Start operating of UASB no.1	4-Apr-15

2.2 Deviations

2.2.1 Methodology Deviations

There is no methodology deviations applied in this monitoring period.

2.2.2 Project Description Deviations

There is no methodology deviations applied in this monitoring period.

2.3 Grouped Project

This project is not a grouped project

3 DATA AND PARAMETERS

3.1 Data and Parameters Available at Validation

a) From ACM0014 version 06.0.0

Data / Parameter	$COD_{out,x}$ $COD_{in,x}$
Data unit	t COD
Description	COD of the effluent in the period x COD directed to the open lagoons (Scenario 1) in the period x
Source of data	Previous registered PD – Annex 3 : Baseline Information
Value applied:	$COD_{out,x}$ 2,674.52 $COD_{in,x}$ 22,066.99
Justification of choice of data or description of measurement methods and procedures applied	$COD_{out,x}$: Calculated from $COD_{in,x}$ with the removal ratio for lagoon from CDM project no.1040 – Korat Waste To Energy at 87.88% $COD_{in,x}$: From operating data of 2006
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	X
Data unit	Time
Description	Representative historical reference period
Source of data	Previous registered PD – Annex 3 : Baseline Information
Value applied:	1 year
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	ρ
Data unit	-
Description	Discount factor for historical information
Source of data	For existing plants: - If one year of historical data is available $\rho=1$; - If a measurement campaign of at least 10 days is available $\rho=0.89$.
Value applied:	0.89

Justification of choice of data or description of measurement methods and procedures applied	The value of 0.89 for the case where there is no one year historical data is to account for the uncertainty range (of 30% to 50%) associated with this approach as compared to one-year historical data.
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	B ₀
Data unit	tCH ₄ /tCOD
Description	Maximum methane producing capacity, expressing the maximum amount of CH ₄ that can be produced from a given quantity of chemical oxygen demand (COD)
Source of data	2006 IPCC Guidelines
Value applied:	0.25
Justification of choice of data or description of measurement methods and procedures applied	No measurement procedures.
Purpose of Data	Calculation of baseline emissions
Comments	Taking into account the uncertainty of this estimate, a value of 0.25 tCH ₄ /tCOD is chosen as a conservative assumption for B ₀ .

Data / Parameter	D
Data unit	m
Description	Average depth of the lagoons
Source of data	Lagoon system layout
Value applied:	5.32
Justification of choice of data or description of measurement methods and procedures applied	Determine the average depths of the whole lagoon under normal operating condition
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	EC _{BL}
Data unit	MWh/yr
Description	Annual quantity of electricity that would be consumed in the absence of the project activity for the treatment of the wastewater (Scenario 1).

Source of data	In case of existing plants: Average yearly electricity consumption of the most recent three years prior to the implementation of the project activity.
Value applied:	0
Justification of choice of data or description of measurement methods and procedures applied	The open lagoon system is designed for gravity flow. There is no electricity consumed equipment installed in the absence of project activity.
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	EF _{CO2,FF,boiler}
Data unit	tCO ₂ /GJ
Description	CO ₂ emission factor of the fossil fuel type used in the boiler for heat generation in the absence of the project activity
Source of data	IPCC 2006
Value applied:	0.0774
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of Data	Calculation of baseline emissions
Comments	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Double-checked against IPCC defaults (for consistency) if data is local or regional.

Data / Parameter	GWP _{CH4}
Data unit	tCO ₂ e/tCH ₄
Description	Global warming potential for CH ₄
Source of data	IPCC
Value applied:	21
Justification of choice of data or description of measurement methods and procedures applied	Global warming potential for CH ₄ valid for the relevant commitment period
Purpose of Data	- Calculation of baseline emissions - Calculation of project emissions - Calculation of leakage
Comments	Shall be updated according to any future COP/MOP decisions

- b) From "Tool to determine the mass flow of a greenhouse gas in a gaseous stream" version 02.0.0

Data / Parameter	R_u
Data unit	Pa.m ³ /kmol.K
Description	Universal ideal gases constant
Source of data	Tool to determine the mass flow of greenhouse gas in as gaseous team version 02
Value applied:	8,314
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of Data	• Calculation of baseline emissions • Calculation of project emissions • Calculation of leakage
Comments	-

Data / Parameter	MM _i		
Data unit	kg/kmol		
Description	molecular mass of greenhouse gas i		
Source of data	Tool to determine the mass flow of greenhouse gas in as gaseous team version 02		
Value applied:			
	Compound	Structure	Molecular mass (kg / kmol)
	Carbon dioxide	CO ₂	44.1
	Methane	CH ₄	16.04
	Nitrous oxide	N ₂ O	44.02
	Sulfur hexafluoride	SF ₆	146.06
	Perfluoromethane	CF ₄	88.00
	Perfluoroethane	C ₂ F ₆	138.01
	Perfluoropropane	C ₃ F ₈	188.02
	Perfluorobutane	C ₄ F ₁₀	238.03
	Perfluorocyclobutane	c-C ₄ F ₈	200.03
	Perfluoropentane	C ₅ F ₁₂	288.03
	Perfluorohexane	C ₆ F ₁₄	338.04
Justification of choice of data or description of measurement methods and procedures applied	-		

Purpose of Data	- Calculation of baseline emissions - Calculation of project emissions - Calculation of leakage
Comments	-

Data / Parameter	P_n
Data unit	Pa
Description	Total pressure at normal condition
Source of data	Tool to determine the mass flow of greenhouse gas in as gaseous team version 02
Value applied:	101,325
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of Data	- Calculation of baseline emissions - Calculation of project emissions - Calculation of leakage
Comments	-

Data / Parameter	T_n
Data unit	K
Description	Temperature at normal condition
Source of data	Tool to determine the mass flow of greenhouse gas in as gaseous team version 01
Value applied:	273.15
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of Data	- Calculation of baseline emissions - Calculation of project emissions - Calculation of leakage
Comments	-

c) From "Project and leakage emissions from anaerobic digesters" version 01.0.0

Data / Parameter	ρ_{CH_4}
Data unit	t CH ₄ / Nm ³ CH ₄
Description	Density of methane at normal condition
Source of data	Methodology tool

Value applied:	0.00067
Justification of choice of data or description of measurement methods and procedures applied	Technical literature
Purpose of Data	Calculation of project emissions and leakage
Comments	Normal conditions are defined as 20°C and 1 atm pressure

Data / Parameter	$EF_{CH_4, default}$
Data unit	t CH ₄ leaked / t CH ₄ produced
Description	Default emission factor for the fraction of CH ₄ produced that leaks from the anaerobic digester
Source of data	IPCC (2006), Flesch et al. (2011) and Kurup (2003)
Value applied:	0.05: UASB type digesters, floating gas holders with no external water seal;
Justification of choice of data or description of measurement methods and procedures applied	Use the default value corresponding to the type of digester used in the project activity.
Purpose of Data	Calculation of leakage
Comments	Applicable to the step "Determination of project emissions of methane from the anaerobic digester"

Data / Parameter	$F_{EC, default}$
Data unit	MWh / t CH ₄ produced
Description	Default factor for the electricity consumption associated with the anaerobic digester per ton of CH ₄ generated
Source of data	Methodology tool
Value applied:	0.01 - UASB / filter bed reactor for wastewater / fluidized bed reactor
Justification of choice of data or description of measurement methods and procedures applied	The values were derived based on a review of registered CDM projects, other projects using digesters and reference books (Metcalf & Eddy, 2003; and for solid waste Sri Bala et al., 2009).
Purpose of Data	Calculation of leakage
Comments	Applicable to the step "Determination of project emissions of methane from the anaerobic digester"

Data / Parameter	$EF_{EL, default}$
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Data unit	t CO ₂ / MWh
Description	Default emission factor for the electricity consumed in year y
Source of data	Methodological tool ; Baseline , project and/or leakage emissions from electricity consumption and monitoring of electricity generation
Value applied:	0.5897
Justification of choice of data or description of measurement methods and procedures applied	The scenario A : Electricity consumption from the grid is chosen in this case. The combined margin emission factor for Grid system in Thailand is calculated and reported by Thailand Greenhouse Gas Management Organization or TGO¹. The data used for national grid emission calculation² is provided by Energy Regulatory Commission or ERC. The data from period of 2012 to 2014 is used for calculation in accordance with Tool to calculate the emission factor for an electricity system, Version 04.0. This approach is in line with the condition identified in clause 19 : option A1 of the reference tool.
Purpose of Data	Calculation of project emissions
Comments	-

3.2 Data and Parameters Monitored

Data / Parameter	$F_{PJ,dig,m}$				
Data unit	m ³ /year				
Description	Quantity of wastewater that is treated in the anaerobic digester in the project activity in month <i>m</i>				
Source of data	Measured				
Description of measurement methods and procedures to be applied	Measured continuously by flow meters installed at the inlet of UASB no.1 and 2.				
Frequency of monitoring/recording	Parameter monitored continuously but aggregated monthly and annually for calculations.				
Value monitored:	<table> <tr> <td>01-Jan-14 to 31-Dec-14</td><td>425,335</td></tr> <tr> <td>01-Jan-15 to 30-Sep-15</td><td>145,548</td></tr> </table>	01-Jan-14 to 31-Dec-14	425,335	01-Jan-15 to 30-Sep-15	145,548
01-Jan-14 to 31-Dec-14	425,335				
01-Jan-15 to 30-Sep-15	145,548				
Monitoring equipment	The information of FM3 and FM5 is provided in Table 5.				

¹ http://tver.tgo.or.th/2015/thai/news_detail.php?id=53

² http://tver.tgo.or.th/2015/file/download/Grid_Emission_Factor_124.pdf

QA/QC procedures to be applied	Flow meters will undergo maintenance / calibration subject to appropriate industry standards , at least once every 3 years,
Purpose of the data	Calculation of baseline and project emissions
Calculation method	-
Comments	In case of Scenario 1, if the solid materials are also treated in the baseline and project scenario, the $F_{PJ,dig,m}$ does not account the amount of solid materials treated or separated from the wastewater stream in the anaerobic digester, if applicable.

Data / Parameter	$COD_{dig,m}$				
Data unit	t COD / m ³				
Description	Chemical oxygen demand in the wastewater that is treated in the anaerobic digester in the project activity in month m				
Source of data	Measurements				
Description of measurement methods and procedures to be applied	Measure the COD according to national or international standards. If COD is measured more than once per month, the average value of the measurements should be used.				
Frequency of monitoring/recording	Regularly, calculate average monthly and annual values				
Value monitored:	<table> <tr> <td>01-Jan-14 to 31-Dec-14</td><td>0.019</td></tr> <tr> <td>01-Jan-15 to 30-Sep-15</td><td>0.021</td></tr> </table>	01-Jan-14 to 31-Dec-14	0.019	01-Jan-15 to 30-Sep-15	0.021
01-Jan-14 to 31-Dec-14	0.019				
01-Jan-15 to 30-Sep-15	0.021				
Monitoring equipment	The information of spectrophotometer is provided in Table 5.				
QA/QC procedures to be applied	Sampling and analysis will be carried out adhering to internationally recognized procedures. The spectrophotometer is calibrated at least once every 3 years.				
Purpose of the data	Calculation of baseline and project emissions				
Calculation method	-				
Comments	In case of Scenario 1, if the solid materials are also treated in the baseline and project scenario, the $F_{PJ,dig,m}$ does not account the amount of solid materials treated or separated from the wastewater stream in the anaerobic digester, if applicable.				

Data / Parameter	$T_{2,m}$
Data unit	K

Description	Average temperature at the project site in month <i>m</i>				
Source of data	Measurement in the project site, or national or regional weather statistics				
Description of measurement methods and procedures to be applied	Refer to National published report ; the monthly average temperature of Nakornratchasima province. http://www.e-report.energy.go.th/weather.html				
Frequency of monitoring/recording	Continuously, aggregated in monthly average values				
Value monitored:	<table border="1"> <tr> <td>01-Jan-14 to 31-Dec-14</td><td>298.05</td></tr> <tr> <td>01-Jan-15 to 30-Sep-15</td><td>300.05</td></tr> </table>	01-Jan-14 to 31-Dec-14	298.05	01-Jan-15 to 30-Sep-15	300.05
01-Jan-14 to 31-Dec-14	298.05				
01-Jan-15 to 30-Sep-15	300.05				
Monitoring equipment	-				
QA/QC procedures to be applied	-				
Purpose of data	Calculation of baseline emissions				
Calculation method	-				
Comments	-				

Data / Parameter	EG _{PJ,y}
Data unit	MWh/year
Description	Net quantity of electricity generated in year <i>y</i> with biogas from the new anaerobic
Source of data	Measurements
Description of measurement methods and procedures to be applied	-
Frequency of monitoring/recording	-
Value monitored:	0
Monitoring equipment	-
QA/QC procedures to be applied	-
Purpose of data	Calculation of baseline emissions
Calculation method	-
Comments	The project activity does not concern the generation of electricity.

Data / Parameter	HG _{PJ,y}
Data unit	GJ/year
Description	Net quantity of heat generated in year <i>y</i> with biogas from the new anaerobic digester
Source of data	Measurement of the volume of biogas captured and used for heat generation multiplied by methane content of

	biogas , NCV of methane , and the efficiency of the boiler during the project (i.e. with biogas).				
Description of measurement methods and procedures to be applied	The biogas flow meters are installed at the outlet of gas storage , before entering blower station (GM4,GM5).				
Frequency of monitoring/recording	Parameter monitored continuously but aggregated annually for calculations.				
Value monitored:	<table border="1"> <tr> <td>01-Jan-14 to 31-Dec-14</td><td>95,965.28</td></tr> <tr> <td>01-Jan-15 to 30-Sep-15</td><td>57,326.30</td></tr> </table>	01-Jan-14 to 31-Dec-14	95,965.28	01-Jan-15 to 30-Sep-15	57,326.30
01-Jan-14 to 31-Dec-14	95,965.28				
01-Jan-15 to 30-Sep-15	57,326.30				
Monitoring equipment	The information of GM4 and GM5 is provided in Table 5.				
QA/QC procedures to be applied	Flow meters will undergo maintenance/calibration subject to appropriate industry standards , at least once every 3 years.				
Purpose of data	Calculation of baseline emissions				
Calculation method	-				
Comments	-				

Data / Parameter	$S_{LA,m}$ $DWW_{LA,m}$
Data unit	t/month
Description	Amount of sludge applied to land in month m
Source of data	Measured
Description of measurement methods and procedures to be applied	-
Frequency of monitoring/recording	Parameter monitored continuously but aggregated monthly for calculations.
Value monitored:	0 – no sludge applied to land
Monitoring equipment	-
QA/QC procedures to be applied	-
Purpose of data	Calculation of baseline emissions
Calculation method	-
Comments	-

Data / Parameter	$F_{biogas,y}$ or $Q_{biogas,y}$
Data unit	Nm^3/yr
Description	Total amount of biogas collected in the outlet of the new digester in year y

Source of data	Measured				
Description of measurement methods and procedures to be applied	The biogas flow meters are installed at the outlet of biogas from UASB no.1 and 2 (GM1 and GM2).				
Frequency of monitoring/recording	Parameter monitored continuously but aggregated annually for calculations.				
Value monitored:	<table border="1"> <tr> <td>01-Jan-14 to 31-Dec-14</td><td>4,865,986</td></tr> <tr> <td>01-Jan-15 to 30-Sep-15</td><td>2,799,432</td></tr> </table>	01-Jan-14 to 31-Dec-14	4,865,986	01-Jan-15 to 30-Sep-15	2,799,432
01-Jan-14 to 31-Dec-14	4,865,986				
01-Jan-15 to 30-Sep-15	2,799,432				
Monitoring equipment	The information of GM1 and GM2 is provided in Table 5.				
QA/QC procedures to be applied	Flow meters will undergo maintenance/calibration subject to appropriate industry standards , at least once every 3 years.				
Purpose of data	Calculation of baseline emissions				
Calculation method	-				
Comments	Applied to estimate emissions associated with physical leakage from the digester.				

Data / Parameter	$W_{CH_4, biogas, y}$				
Data unit	kg CH ₄ / m ³				
Description	Concentration of methane in the total biogas supply in the outlet of the new digester				
Source of data	Measured				
Description of measurement methods and procedures to be applied	Using calibrated continuous gas analyzer.				
Frequency of monitoring/recording	Either with continuous analyzer or alternatively with periodical measurement at 95% confidence level.				
Value monitored:	<table border="1"> <tr> <td>01-Jan-14 to 31-Dec-14</td><td>0.37</td></tr> <tr> <td>01-Jan-15 to 30-Sep-15</td><td>0.38</td></tr> </table>	01-Jan-14 to 31-Dec-14	0.37	01-Jan-15 to 30-Sep-15	0.38
01-Jan-14 to 31-Dec-14	0.37				
01-Jan-15 to 30-Sep-15	0.38				
Monitoring equipment	The information of gas analyzer is provided in Table 5.				
QA/QC procedures to be applied	Gas analyzer will undergo maintenance/calibration subject to appropriate industry standards , at least once every 3 years.				
Purpose of the data	Calculation of baseline and project emissions.				
Calculation method	-				
Comments	-				

Data / Parameter	$V_{RG,y}$				
Data unit	Nm ³ /yr				
Description	Volumetric flow of the residual gas on a dry basis at reference conditions				
Source of data	Measured				
Description of measurement methods and procedures to be applied	The biogas flow meters are installed at the flare (GM6).				
Frequency of monitoring/recording	Parameter monitored continuously but aggregated annually for calculations.				
Value monitored:	<table> <tr> <td>01-Jan-14 to 31-Dec-14</td><td>0</td></tr> <tr> <td>01-Jan-15 to 30-Sep-15</td><td>0</td></tr> </table>	01-Jan-14 to 31-Dec-14	0	01-Jan-15 to 30-Sep-15	0
01-Jan-14 to 31-Dec-14	0				
01-Jan-15 to 30-Sep-15	0				
Monitoring equipment	The information of GM6 is provided in Table 5.				
QA/QC procedures to be applied	Flow meters will undergo maintenance/calibration subject to appropriate industry standards , at least once every 3 years.				
Purpose of the data	Calculation of project emissions				
Calculation method	-				
Comments	-				

3.3 Monitoring Plan

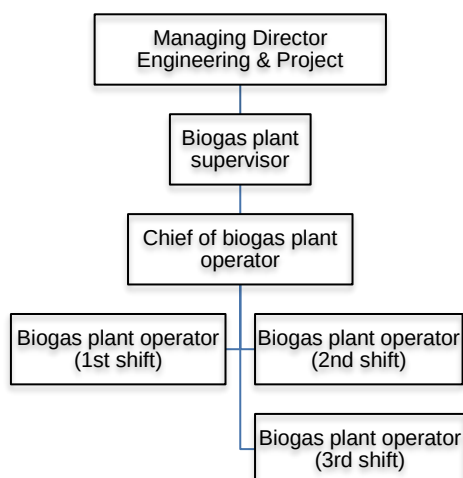
The operation of the wastewater treatment system is responsible by General Starch Limited (GSL). The wastewater treatment system operational and management systems have been certified under ISO 14001 version 2004 by UKAS , the validity of certification is maintained. This certificate ensures that requirements and procedures for parameter monitoring, data recording and data archiving for environmental management system of biogas section are well managed according to ISO14001 requirements³.

The plant operator carries out the daily operation recording and laboratory analysis. The monitored data is collected and recorded in the excel spread sheet by chief of biogas operator. The report will be checked and approved by the plant supervisor. The summary reports are submitted to management on daily basis.

All equipment calibrations are controlled by the biogas plant supervisor. All documents are managed according to the requirements of ISO14001.

³ http://www.fs.fed.us/ems/includes/sum_ems_elements.pdf

Organization structure



Data Collection and management system

Biogas plant operator

- Data recording from flow meter into log sheet at least once a day.
- The wastewater analysis is carried out once per shift or three times per day.

Chief of biogas plant operator

- Transfer and check recorded data from log sheet into electronic format on daily basis.
- Summarize data and submit to Biogas plant supervisor on daily basis.

Biogas plant supervisor

- Submit the report to consultant on monthly basis.
- Prepare summary report and submit to concerned department.

Data storage and backup

- The original log sheets are collected and stored at biogas plant office by Chief of biogas operator.
- The data in excel format is stored at two computers at biogas plant. The backup of hard disk is done by IT department on monthly basis.
- The data submitted to consultant is stored and backup via consultant's internal server on monthly basis.

4 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

4.1 Baseline Emissions

Baseline emissions are estimated as follows:

$$BE_y = BE_{CH_4,y} + BE_{EL,y} + BE_{HG,y} \quad (1)$$

Where:

Parameter	Details
BE_y	Baseline emissions in year y (tCO ₂ e / yr)
$BE_{CH_4,y}$	Methane emissions from anaerobic treatment of the wastewater in open lagoons in the absence of the project activity in year y (tCO ₂ e / yr)
$BE_{EL,y}$	CO ₂ emissions associated with electricity generation that is displaced by the project activity and / or electricity consumption in the absence of the project activity in year y (tCO ₂ e / yr)
$BE_{HG,y}$	CO ₂ emissions associated with fossil fuel consumption for heating equipment that is displaced by the project in year y (tCO ₂ e / yr)

The project will only claim emission reductions from the methane avoidance due to the installation of a new, closed, anaerobic, wastewater-treatment system. Heat generated from the project activity will replace the heat generated from heavy fuel oil that would be occurred in the absence of project activity.

Step 1: Calculation of baseline emissions from anaerobic treatment of the wastewater or sludge

The methodology proposes to use the minimum value between the methane produced after the implementation of the project activity and methane conversion factor method for the estimation of methane emissions from open lagoons in case of the waste water lagoons.

$$BE_{CH_4,y} = \min \{ Q_{CH_4,y} ; BE_{CH_4,MCF,y} \} \quad (2)$$

Methane produced

Projects proponent shall use Step 1 “Determination of the quantity of methane produced in the digester ($Q_{CH_4,y}$)” of the latest version of the tool “Project and leakage emissions from anaerobic digesters” version 01.0.0 to determine the amount of methane produced after the implementation of the project activity ($Q_{CH_4,y}$).

Step 1: Determination of the quantity of methane produced in the digester ($Q_{CH_4,y}$)

For large scale projects only Option 1 shall be used.

Option 1: Procedure using monitored data

$Q_{CH_4,y}$ shall be measured using the “Tool to determine the mass flow of a greenhouse gas in a gaseous stream” version 02.0.0.

The mass flow of a greenhouse gas i in a gaseous stream ($F_{i,t}$) is determined through measurement of the flow and volumetric fraction of the gaseous stream. The Table 2 shows the different ways to make these measurements and the corresponding calculation option for $F_{i,t}$.

Table 2 : Measurement options

Option	Flow of gaseous stream	Volumetric fraction
A	Volume flow – dry basis	dry or wet basis
B	Volume flow – wet basis	dry basis
C	Volume flow – wet basis	wet basis
D	Mass flow - dry basis	dry or wet basis
E	Mass flow - wet basis	dry basis
F	Mass flow - wet basis	wet basis

For this project activity , the installed flow meter measured the volume of biogas in Nm^3 . There is no system to remove the humidity in biogas. And the methane content in biogas is measured in wet basis. Hence option C is applicable for this case.

Option C

The mass flow of greenhouse gas i ($F_{i,t}$) is determined as follows:

$$F_{i,t,db} = V_{t,wb,n} * v_{i,t,wb} * \rho_{i,n} \quad (9)$$

with

$$\rho_{i,n} = \frac{P_n * MM_i}{R_u * T_n} \quad (10)$$

Where:

Parameter	Details
$F_{i,t,db}$	Mass flow of greenhouse gas i in the gaseous stream in time interval t (kg gas/h)
$V_{t,wb,n}$	Volumetric flow of the gaseous stream in time interval t on a wet basis at normal conditions (m^3 wet gas/h)
$v_{i,t,wb}$	Volumetric fraction of greenhouse gas i in the gaseous stream in time interval t on a wet basis (m^3 gas i/m^3 wet gas)
$\rho_{i,n}$	Density of greenhouse gas i in the gaseous stream at normal conditions (kg gas i/m^3 wet gas i)
P_n	Absolute pressure at normal conditions (Pa)
T_n	Temperature at normal conditions (K)
MM_i	Molecular mass of greenhouse gas i (kg/kmol)
R_u	Universal ideal gases constant (Pa.m ³ /kmol.K)

The following equation should be used to convert the volumetric flow of the gaseous stream

from actual conditions to normal conditions of temperature and pressure:

$$V_{t,wb,n} = V_{t,wb} * [(T_n/T_t) * (P_t/P_n)] \quad (11)$$

Where:

Parameter	Details
$V_{t,wb,n}$	Volumetric flow of the gaseous stream in a time interval t on a wet basis at normal conditions (m ³ wet gas/h)
$V_{t,wb}$	Volumetric flow of the gaseous stream in time interval t on a wet basis (m ³ wet gas/h)
P_t	Pressure of the gaseous stream in time interval t (Pa)
T_t	Temperature of the gaseous stream in time interval t (K)
P_n	Absolute pressure at normal conditions (Pa)
T_n	Temperature at normal conditions (K)

Methane conversion factor

The baseline methane emissions from anaerobic treatment of the wastewater in open lagoons (Scenario 1) are estimated based on the chemical oxygen demand (COD) of the wastewater that would enter the lagoon in the absence of the project activity ($COD_{BL,y}$), the maximum methane producing capacity (B_0) and a methane conversion factor ($MCF_{BL,y}$) which expresses the proportion of the wastewater that would decay to methane, as follows:

$$BE_{CH_4,MCF,y} = GWP_{CH_4} * MCF_{BL,y} * B_0 * COD_{BL,y} \quad (3)$$

Where:

Parameter	Details
$BE_{CH_4,MCF,y}$	Methane emissions from anaerobic treatment of the wastewater in open lagoons (Scenario 1) or the anaerobic treatment of sludge in sludge pits (Scenario 2) in the absence of the project activity in year y (tCO ₂ e/yr)
GWP_{CH_4}	Global Warming Potential of methane valid for the commitment period (tCO ₂ e/tCH ₄)
$MCF_{BL,y}$	Average baseline methane conversion factor (fraction) in year y , representing the fraction of ($COD_{PJ,y} \times B_0$) that would be degraded to CH ₄ in the absence of the project activity
B_0	Maximum methane producing capacity, expressing the maximum amount of CH ₄ that can be produced from a given quantity of chemical oxygen demand (tCH ₄ /tCOD)
$COD_{BL,y}$	Quantity of chemical oxygen demand that would be treated in open lagoons (Scenario 1) in the absence of the project activity in year y (tCOD/yr)

Determination of $COD_{BL,y}$

The baseline chemical oxygen demand ($COD_{BL,y}$) is equal to the chemical oxygen demand that is treated under the project activity ($COD_{PJ,y}$), unless there would have been effluent from

the lagoons (Scenario 1) in the baseline, in this case the $COD_{PJ,y}$ should be adjusted by an adjustment factor which relates the COD supplied to the lagoon or sludge pit with the COD in the effluent.

$$COD_{BL,y} = \rho \left[1 - \frac{COD_{out,x}}{COD_{in,x}} \right] * COD_{PJ,y} \quad (4)$$

Where:

Parameter	Details
$COD_{BL,y}$	Quantity of chemical oxygen demand that would be treated in open lagoons (Scenario 1) in the absence of the project activity in year y (tCOD/yr)
ρ	Discount factor for historical information
$COD_{out,x}$	COD of the effluent in the period x (t COD)
$COD_{in,x}$	COD directed to the open lagoons (Scenario 1) or in sludge pits (Scenario 2) in the period x (t COD)
x	Representative historical reference period
$COD_{PJ,y}$	Quantity of chemical oxygen demand that is treated in the anaerobic digester or under clearly aerobic conditions in the project activity in year y (t COD/yr)

$COD_{PJ,y}$ is determined as follows:

$$COD_{PJ,y} = \sum_{m=1}^{12} F_{PJ,dig,m} * COD_{dig,m} \quad (5)$$

Where:

Parameter	Details
$COD_{PJ,y}$	Quantity of chemical oxygen demand that is treated in the anaerobic digester or under clearly aerobic conditions in the project activity in year y (t COD/yr)
$F_{PJ,dig,m}$	Quantity of wastewater or sludge that is treated in the anaerobic digester or under clearly aerobic conditions in the project activity in month m (m ³ /month)
$COD_{dig,m}$	Chemical oxygen demand in the wastewater or sludge that is treated in the anaerobic digester or under clearly aerobic conditions in the project activity in month m (t COD / m ³)
m	Months of year y of the crediting period

Determination of $MCF_{BL,y}$

The quantity of methane generated from COD disposed to the open lagoon (Scenario 1) depends mainly on the temperature and the depth of the lagoon or sludge pit. Accordingly, the methane conversion factor is calculated based on a factor f_d , expressing the influence of the depth of the lagoon or sludge pit on methane generation, and a factor $f_{T,y}$ expressing the influence of the temperature on the methane generation. In addition, a conservativeness factor of 0.89 is applied to account for the considerable uncertainty associated with this approach. $MCF_{BL,y}$ is calculated as follows:

$$MCF_{BL,y} = f_d * f_{T,y} * 0.89 \quad (6)$$

Where:

Parameter	Details
$MCF_{BL,y}$	Average baseline methane conversion factor (fraction) in year y , representing the fraction of $(COD_{PJ,y} \times B_0)$ that would be degraded to CH_4 in the absence of the project activity
f_d	Factor expressing the influence of the depth of the lagoon or sludge pit on methane generation
$f_{T,y}$	Factor expressing the influence of the temperature on the methane generation in year y
0.89	Conservativeness factor

Determination of f_d

f_d represents the influence of the average depth of the lagoons or sludge pit on methane generation.

$$f_d = \begin{cases} 0 ; & \text{if } D < 1m \\ 0.5 ; & \text{if } 1m \leq D < 2m \\ 0.7 ; & \text{if } D \geq 2m \end{cases} \quad (7)$$

Where:

Parameter	Details
f_d	Factor expressing the influence of the depth of the lagoon or sludge pit on methane generation
D	Average depth of the lagoons or sludge pits (m)

Determination of $f_{T,y}$

An increase in temperature in the lagoon has several benefits to generate more methane, including an increasing solubility of the organic compounds, enhanced biological and chemical reaction rates. The factor $f_{T,y}$ is calculated using a monthly stock change model which aims at assessing how much COD degrades in each month.

For each month m , the quantity of wastewater directed to the lagoon or sludge directed to a pit, the quantity of organic compounds that decay and the quantity of any effluent water from the lagoon is balanced, giving the quantity of COD that is available for degradation in the next month: the amount of organic matter available for degradation to methane ($COD_{available,m}$) is assumed to be equal to the amount of organic matter directed to the open lagoon or sludge pit, less any effluent, plus the COD that may have remained in the lagoon or sludge pit from previous months, as follows:

$$COD_{available,m} = COD_{BL,m} + (1 - f_{T,m-1}) * COD_{available,m-1} \text{ with} \quad (8)$$

$$COD_{BL,m} = \left(1 - \frac{COD_{out,x}}{COD_{in,x}}\right) * COD_{PJ,m} \quad \text{and} \quad (9)$$

$$COD_{PJ,m} = F_{PJ,dig,m} * COD_{dig,m} \quad (10)$$

Where:

Parameter	Details
$COD_{available,m}$	Quantity of chemical oxygen demand available for degradation in the open lagoon in month m (t COD/month)
$COD_{BL,m}$	Quantity of chemical oxygen demand that would be treated in open lagoons (Scenario 1) in the absence of the project activity in month m (t COD/month)
$COD_{PJ,m}$	Quantity of chemical oxygen demand that is treated in the anaerobic digester or under clearly aerobic conditions in the project activity in month m (t COD/month)
$F_{PJ,dig,m}$	Quantity of wastewater that is treated in the anaerobic digester or under clearly aerobic conditions in the project activity in month m (m ³ /month)
$COD_{dig,m}$	Chemical oxygen demand in the wastewater that is treated in the anaerobic digester or under clearly aerobic conditions in the project activity in month m (t COD/m ³)
$f_{T,m-1}$	Factor expressing the influence of the temperature on the methane generation in month m
m	Months of year y of the crediting period
$COD_{in,x}$	COD of the effluent in the period x (t COD)
$COD_{out,x}$	COD directed to the open lagoons (Scenario 1) or in sludge pits (Scenario 2) in the period x (t COD)
x	Representative historical reference period

In case of emptying the lagoon, the accumulation of organic matter restarts with the next inflow and the COD available from the previous month should be set to zero. The monthly factor to account for the influence of the temperature on methane generation is calculated based on the following “van’t Hoff – Arrhenius” approach:

$$f_{T,m} = \begin{cases} 0 ; & \text{if } T_{2,m} < 278 \text{ K} \\ e^{\frac{E*(T_{2,m}-T_1)}{R*T_1*T_{2,m}}} ; & \text{if } 278 \text{ K} \leq T_{2,m} \leq 302.5 \text{ K} \\ 0.95 ; & \text{if } T_{2,m} > 302.5 \text{ K} \end{cases} \quad (11)$$

Where:

Parameter	Details
$f_{T,m}$	Factor expressing the influence of the temperature on the methane generation in month m
e	Activation energy constant (15,175 cal/mol)

$T_{2,m}$	Average temperature at the project site in month m (K)
T_1	303.16 K (273.16 K + 30 K)
R	Ideal gas constant (1.987 cal/K mol)
m	Months of year y of the crediting period

The annual value $f_{T,y}$ is calculated as follows:

$$f_{T,y} = \frac{\sum_{m=1}^{12} f_{T,m} * COD_{available,m}}{\sum_{m=1}^{12} COD_{BL,m}} \quad (12)$$

Where:

Parameter	Details
$f_{T,y}$	Factor expressing the influence of the temperature on the methane generation in year y
$f_{T,m}$	Factor expressing the influence of the temperature on the methane generation in month m
$COD_{available,m}$	Quantity of chemical oxygen demand available for degradation in the open lagoon or sludge pit in month m (t COD/month)
$COD_{BL,m}$	Quantity of chemical oxygen demand that would be treated in open lagoons (Scenario 1) or in sludge pits (Scenario 2) in the absence of the project activity in month m (t COD/month)
m	Months of year y of the crediting period

Baseline under a suppressed demand scenario

Suppressed demand scenario may only be applied if the procedure to determine the baseline scenario identifies W2, W6 and/or W8 as the scenario for the treatment of at least 50 per cent of the domestic wastewater in the project boundary. This scenario is not applicable for this project activity.

Step 2: Baseline emissions from generation and/or consumption of electricity

In this step, baseline emissions from consumption of electricity associated with the treatment of wastewater (Scenario 1) are estimated. Since the project activity does not generate the electricity from biogas, the baseline emission from generation and/or consumption of electricity is considered as 0.

Step 3: Baseline emissions from the generation of heat

This step is applicable if the biogas captured from the new anaerobic digester is utilized in the project scenario for heat generation. In this case, for the application of the baseline Scenarios H2, fossil fuels from the generation of heat in boilers are displaced and baseline emissions are calculated as follows:

$$BE_{HG,y} = \frac{HG_{PJ,y} * EF_{CO2,FF,boiler}}{\eta_{BL,boiler}} \quad (14)$$

Where:

Parameter	Details
$BE_{HG,y}$	CO ₂ emissions associated with fossil fuel combustion for heating equipment that is displaced by the project in year y (tCO ₂ /yr)
$HG_{PJ,y}$	Net quantity of heat generated in year y with biogas from the new anaerobic digester (GJ)
$EF_{CO2,FF,boiler}$	CO ₂ emission factor of the fossil fuel type used in the boiler for heat generation in the absence of the project activity (tCO ₂ /GJ)
$\eta_{BL,boiler}$	Efficiency of the boiler that would be used for heat generation in the absence of the project activity

Determination of $EF_{CO2,FF,boiler}$

The heavy fuel oil was used in the industrial facility that generates the wastewater for heating purposes before the implementation of the project activity.

Determination of $\eta_{BL,boiler}$

The heating combustion efficiency is 100% which was determined during commission of heating system.

Determination of $HG_{PJ,y}$

In order to calculate the quantity of fuel that is displaced by biogas, the two fuels are substituted on the basis of equivalent delivered energy. The following energy densities are used:

- The NCV of CH₄ is 39820⁴ kJ/Nm³ or 39.82 MJ/Nm³ and 39.77 MJ/litre for fuel oil (Thailand Energy Statistic Report from DEDE⁵)
- Combustion efficiency on HFO as well as biogas is considered to be 90 %.

Therefore :

$$HG_{PJ,y} \text{ (GJ)} = F_{biogas,boiler,y} \text{ (Nm}^3\text{)} * NCV_{CH4} \text{ (MJ/Nm}^3\text{)} * W_{CH4,biogas,y} * 90\% / 1,000$$

4.2 Project Emissions

Since the project activity introduces an anaerobic digester for the treatment of wastewater. The tool “*Project and leakage emissions from anaerobic digesters version 01.0.0*” is applied to calculate project and leakage emissions.

The following sources of project emissions are accounted for in this tool:

- CO₂ emissions from consumption of electricity associated with the operation of the anaerobic digester;
- CO₂ emissions from consumption of fossil fuels associated with the operation of the anaerobic digester;

⁴ http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html

⁵ http://www.dede.go.th/download/state_58/sit_57_58/Thailand%20Energy%20Efficiency%20Situation%202014.pdf

(c) CH₄ emissions from the digester (emissions during maintenance of the digester, physical leaks through the roof and side walls, and release through safety valves due to excess pressure in the digester); and

(d) CH₄ emissions from flaring of biogas.

The project emissions associated with the anaerobic digester ($PE_{AD,y}$) are determined as follows:

$$PE_{AD,y} = PE_{EC,y} + PE_{FC,y} + PE_{CH_4,y} + PE_{flare,y} \quad (1)$$

Where:

Parameter	Details
$PE_{AD,y}$	Project emissions associated with the anaerobic digester in year y (t CO ₂ e)
$PE_{EC,y}$	Project emissions from electricity consumption associated with the anaerobic digester in year y (t CO ₂ e)
$PE_{FC,y}$	Project emissions from fossil fuel consumption associated with the anaerobic digester in year y (t CO ₂ e)
$PE_{CH_4,y}$	Project emissions of methane from the anaerobic digester in year y (t CO ₂ e)
$PE_{flare,y}$	Project emissions from flaring of biogas in year y (t CO ₂ e)

These parameters are determined through the steps outlined below.

Step 1: Determination of the quantity of methane produced in the digester ($Q_{CH_4,y}$)

The project activity is large scale project. The Option 1 is used to determine the quantity of methane produced in the digester in year y ($Q_{CH_4,y}$).

Option 1: Procedure using monitored data

$Q_{CH_4,y}$ shall be measured using the *Tool to determine the mass flow of a greenhouse gas in a gaseous stream*.

Follow the same calculating step for Option C in baseline emission calculation step1.

Step 2: Determination of project emissions from electricity consumption ($PE_{EC,y}$)

The project activity consumes the electricity supplied from grid. The Option 2 is used for $PE_{EC,y}$ calculation.

Option 2 : Procedure using a default value

Project emissions from electricity consumption associated with the anaerobic digester are calculated as follows:

$$PE_{EC,y} = Q_{CH_4} * F_{EC,default} * EF_{EL,default} \quad (3)$$

Where :

Parameter	Details
$PE_{EC,y}$	Project emissions from electricity consumption in year y (t CO ₂ e)
Q_{CH_4}	Quantity of methane produced in the anaerobic digester in year y (t CH ₄)
$F_{EC,default}$	Default factor for the electricity consumption associated with the anaerobic digester per ton of methane generated (MWh / t CH ₄)
$EF_{EL,default}$	Default emission factor for the electricity consumed in year y (t CO ₂ / MWh)

Step 3: Determination of project emissions from fossil fuel consumption ($PE_{FC,y}$)

Where the anaerobic digester facility uses fossil fuels, project participants shall calculate $PE_{FC,y}$ using the “Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion”. The project emission source j referred to in the tool is fossil fuel consumption associated with the anaerobic digestion facility (not including fossil fuels consumed for transportation of feed material and digester or any other on-site transportation). The $PE_{FC,y}$ is 0 for this project activity.

Step 4: Determination of project emissions of methane from the anaerobic digester ($PE_{CH_4,y}$)

Project emissions of methane from the anaerobic digester include emissions during maintenance of the digester, physical leaks through the roof and side walls, and release through safety valves due to excess pressure in the digester. These emissions are calculated using a default emission factor ($EF_{CH_4,default}$), as follows:

$$PE_{CH_4,y} = Q_{CH_4,y} * EF_{CH_4,default} * GWP_{CH_4} \quad (4)$$

Where :

Parameter	Details
$PE_{CH_4,y}$	Project emissions of methane from the anaerobic digester in year y (t CO ₂ e)
$Q_{CH_4,y}$	Quantity of methane produced in the anaerobic digester in year y (t CH ₄)
$EF_{CH_4,default}$	Default emission factor for the fraction of CH ₄ produced that leaks from the anaerobic digester (fraction)
GWP_{CH_4}	Global warming potential for CH ₄ (t CO ₂ / t CH ₄)

Step 5: Determination of project emissions from flaring of biogas ($PE_{flare,y}$)

If the project activity includes flaring of biogas, then project emissions from flaring of biogas ($PE_{flare,y}$) shall be estimated using the “Tool to determine project emissions from flaring gases containing methane” version 02.0.0. The following applies:

- For small scale projects, project participants may adopt a default value for the fraction of methane in the biogas ($f_{CH_4,default}$) in applying the tool; and
- The tool provides default factors for the flare efficiency, which can be used for large or small scale projects as described in the tool.

The calculation procedure in this tool determines the project emissions from flaring the residual gas ($PE_{\text{flare},y}$) based on the flare efficiency ($\eta_{\text{flare},m}$) and the mass flow of methane to the flare ($F_{\text{CH}_4,\text{RG},m}$). The flare efficiency is determined for each minute m of year y based either on monitored data or default values.

The project emission calculation procedure is given in the following steps:

Step 1: Determination of the methane mass flow in the residual gas

The “Tool to determine the mass flow of a greenhouse gas in a gaseous stream” shall be used to determine the following parameter:

Parameter	Details
$F_{\text{CH}_4,m}$	Mass flow of methane in the residual gaseous stream in the minute m (kg)

The following requirements apply:

- The gaseous stream tool shall be applied to the residual gas;
- The flow of the gaseous stream shall be measured continuously;
- CH_4 is the greenhouse gas i for which the mass flow should be determined;
- The simplification offered for calculating the molecular mass of the gaseous stream is valid (equations 3 and 17 in the tool); and
- The time interval t for which mass flow should be calculated is every minute m .

$F_{\text{CH}_4,m}$, which is measured as the mass flow during minute m , shall then be used to determine the mass of methane in kilograms fed to the flare in minute m ($F_{\text{CH}_4,\text{RG},m}$). $F_{\text{CH}_4,m}$ shall be determined on a dry basis.

Step 2: Determination of flare efficiency

The flare efficiency depends on the efficiency of combustion in the flare and the time that the flare is operating. For open flares a default value must be applied.

Open flare

In the case of open flares, the flare efficiency in the minute m ($\eta_{\text{flare},m}$) is 50% when the flame is detected in the minute m (Flame_m), otherwise $\eta_{\text{flare},m}$ is 0%.

Step 3: Calculation of project emissions from flaring

Project emissions from flaring are calculated as the sum of emissions for each minute m in year y , based on the methane mass flow in the residual gas ($F_{\text{CH}_4,\text{RG},m}$) and the flare efficiency ($\eta_{\text{flare},m}$), as follows:

$$PE_{\text{flare},y} = GWP_{\text{CH}_4} * \sum_{m=1}^{525600} F_{\text{CH}_4,\text{RG},m} * (1 - \eta_{\text{flare},m}) * 10^{-3} \quad (15)$$

Where:

Parameter	Details
$PE_{flare,y}$	Project emission from flaring of the residual gas stream in year y (tCO ₂ e)
GWP_{CH_4}	Global warming potential of methane valid for the commitment period (tCO ₂ e/tCH ₄)
$F_{CH_4,RG,m}$	Mass flow of methane in the residual gas in the minute m (kg)
$\eta_{flare,m}$	Flare efficiency in minute m

Parameters and data that are not monitored include the constants used in equations , as listed in Table 3 below.

Table 3 : Constants used in equations

Parameter	SI Unit	Description	Value
MM_{CH_4}	kg/kmol	Molecular mass of methane	16.04
MM_{CO}	kg/kmol	Molecular mass of carbon monoxide	28.01
MM_{CO_2}	kg/kmol	Molecular mass of carbon dioxide	44.01
MM_{O_2}	kg/kmol	Molecular mass of oxygen	32.00
MM_{H_2}	kg/kmol	Molecular mass of hydrogen	2.02
MM_{N_2}	kg/kmol	Molecular mass of nitrogen	28.02
AM_C	kg/kmol (g/mol)	Atomic mass of carbon	12.00
AM_H	kg/kmol (g/mol)	Atomic mass of hydrogen	1.01
AM_O	kg/kmol (g/mol)	Atomic mass of oxygen	16.00
AM_N	kg/kmol (g/mol)	Atomic mass of nitrogen	14.01
P_{ref}	Pa	Atmospheric pressure at reference conditions	101 325
R_u	Pa.m ³ /kmol.K	Universal ideal gas constant	0.008314472
T_{ref}	K	Temperature at reference conditions	273.15
$v_{O_2,air}$	Dimensionless	O ₂ volumetric fraction of air	0.21
GWP_{CH_4}	tCO ₂ /tCH ₄	Global warming potential of methane valid for the commitment period	21 (for the first commitment period)
MV_n	m ³ /Kmol	Volume of one mole of any ideal gas at reference conditions	22.414
$\rho_{CH_4,n}$	kg/m ³	Density of methane gas at reference conditions	0.716
$NA_{i,j}$	Dimensionless	Number of atoms of element j in component i , depending on molecular structure	
VM_{ref}	m ³ / kmol	Volume of one mole of any ideal gas at reference temperature and pressure	22.4

4.3 Leakage

The project activity introduces an anaerobic digester for the treatment of wastewater , the latest approved version of the tool “*Project and leakage emissions from anaerobic digesters*” is applied to calculate leakage emissions.

However , according to ACM0014 version 06.0.0 “*Additionally leakage emissions are also calculated for Scenario 1 type projects that include the treatment of solid materials in the*

digester in the project activity". Hence , there is no leakage occurred from this project activity.

4.4 Net GHG Emission Reductions and Removals

Emission reductions for any given year of the crediting period are obtained by subtracting project emissions from baseline emissions:

$$ER_y = BE_y - PE_y - LE_y \quad (24)$$

Where:

Parameter	Details
ER_y	Emissions reductions of the project activity in year y (tCO ₂ e/year)
BE_y	Baseline emissions in year y (tCO ₂ e/year)
PE_y	Project emissions in year y (tCO ₂ e/year)
LE_y	Leakage emissions in year y (tCO ₂ e/year)

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)
Year 2014	27,419	2,022	0	25,397
Year 2015	12,366	1,163	0	11,203
Total	39,785	3,185	0	36,600

During the VCS review of the project for the monitoring period 01/01/2012 to 31/12/2013 , assessment finding was raised on 18/07/2016 and closed on 28/10/2016. The conclusion of the assessment finding required that the project deduct 14,558 tCO₂e from the subsequent monitoring period. In line with the same, 14,558 tCO₂e are deducted from this monitoring period and the revised table with the final emission reductions is presented below:

Year	Net GHG emission reductions or removals (tCO ₂ e)
Year 2014	10,839
Year 2015	11,203
Total	22,042

APPENDIX 1 : ADDITIONAL INFORMATION

Table 4 : Summary of monitored data 2014 and 2015

Ex-ante estimation for monitored parameter				
Parameter	Description / Source	Unit	Source	value
$F_{PJ,dig,m}$	Influent to UASB	m^3/y	calculated	425,335
$F_{PJ,dig,m-UASB1}$	Influent UASB no.1 - FM3	m^3/y	Monitored	174,557
$F_{PJ,dig,m-UASB2}$	Influent UASB no.2 - FM5	m^3/y	Monitored	250,778
$COD_{dig,m}$	COD removed by UASB	T COD/ m^3	calculated	0.019
$COD_{in,UASB}$	COD entering project	kg COD/ m^3	Monitored	20.58
$COD_{out,UASB}$	COD leaving UASB	kg COD/ m^3	Monitored	1.44
$T_{2,m}$	Average ambient temp	K	measured	298.05
$EG_{PJ,y}$	Electricity generated	MWh/y	n/a	0
$HG_{PJ,y}$	Heat generated with biogas	GJ/y	calculated	95,965.28
$F_{biogas,boiler,y}$	Biogas sent to boiler - GM4+GM5	$Nm^3/year$	Monitored	4,865,986
NCV_{CH_4}	NCV of methane	MJ/ Nm^3		39.82
$S_{LA,m}$	Amount of sludge applied to land	t	Monitored	0
$W_{sludge,COD,LA,m}$	COD of sludge applied to land	t COD/t sludge		0
$W_{N,sludge,m}$	N of sludge applied to land	t N/t sludge		0
$F_{biogas,y} = Q_{biogas,y}$	Biogas generated - GM1+GM2	$m^3/year$	Monitored	4,865,986
$W_{CH_4,biogas,y}$	Methane of biogas supplied	kg CH_4/m^3	calculated	0.368701
$W_{CH_4,biogas,y}$	Methane of biogas supplied	%	Monitored	55%
$F_{biogas,flare,y}$	BG flare - GM6	$Nm^3/year$	Monitored	0
$T_{t-CH_4produced}$	Temp of gaseous stream	K	Nm3 basis	273.15
$P_{t-CH_4produced}$	Absolute pressure of gas stream	Pa	Nm3 basis	101325
T_{t-CH_4flare}	Temp of gaseous stream	K	Nm3 basis	273.15
P_{t-FCH_4flare}	Absolute pressure of gas stream	Pa	Nm3 basis	101325

Ex-ante estimation for monitored parameter				
Parameter	Description / Source	Unit	Source	value
$F_{PJ,dig,m}$	Influent to UASB	m^3/y	calculated	145,548
$F_{PJ,dig,m-UASB1}$	Influent UASB no.1 - FM3	m^3/y	Monitored	20,218
$F_{PJ,dig,m-UASB2}$	Influent UASB no.2 - FM5	m^3/y	Monitored	125,330
$COD_{dig,m}$	COD removed by UASB	T COD/ m^3	calculated	0.021
$COD_{in,UASB}$	COD entering project	kg COD/ m^3	Monitored	21.45
$COD_{out,UASB}$	COD leaving UASB	kg COD/ m^3	Monitored	0.71
$T_{2,m}$	Average ambient temp	K	measured	300.05
$EG_{PJ,y}$	Electricity generated	MWh/y	n/a	0
$HG_{PJ,y}$	Heat generated with biogas	GJ/y	calculated	57,326.30
$F_{biogas,boiler,y}$	Biogas sent to boiler - GM4+GM5	$Nm^3/year$	Monitored	2,799,432
NCV_{CH_4}	NCV of methane	MJ/ Nm^3		39.82
$S_{LA,m}$	Amount of sludge applied to land	t	Monitored	0
$W_{sludge,COD,LA,m}$	COD of sludge applied to land	t COD/t sludge		0
$W_{N,sludge,m}$	N of sludge applied to land	t N/t sludge		0
$F_{biogas,y} = Q_{biogas,y}$	Biogas generated - GM1+GM2	$m^3/year$	Monitored	2,799,432
$W_{CH_4,biogas,y}$	Methane of biogas supplied	kg CH_4/m^3	calculated	0.382838
$W_{CH_4,biogas,y}$	Methane of biogas supplied	%	Monitored	57%
$F_{biogas,flare,y}$	BG flare - GM6	$Nm^3/year$	Monitored	0
$T_{t-CH_4produced}$	Temp of gaseous stream	K	Nm3 basis	273.15
$P_{t-CH_4produced}$	Absolute pressure of gas stream	Pa	Nm3 basis	101325
T_{t-CH_4flare}	Temp of gaseous stream	K	Nm3 basis	273.15
P_{t-FCH_4flare}	Absolute pressure of gas stream	Pa	Nm3 basis	101325

Table 5 : Summary of monitoring equipment information

No.	Meter name	Meter Brand/Type	S/N	Max. Error	Calibrated by	2012	2013	2014	2015
FM3	Wastewater flow meter to UASB # 1 - Old	E+H - Promag	6B00EB20000	0.5% OR	E+H	7-Dec-12		9-May-14	
FM5	Wastewater flow meter to UASB # 2 - Old	E+H - Promag	6B00E920000	0.5% OR	E+H	7-Dec-12		9-May-14	
FM3	Wastewater flow meter to UASB # 1 - New	Flow Tech	12090712	0.5% OR	E+H				7-Oct-15
FM5	Wastewater flow meter to UASB # 2 - New	Flow Tech	11060418	0.5% OR	E+H				7-Oct-15
GM1	Biogas flow meter from UASB # 1	E+H - Proline 65I	C3010D02000	1.50%	E+H	1-Nov-12		9-May-14	7-Oct-15
GM2	Biogas flow meter from UASB # 2	E+H - Proline 65I	A9059602000	1.50%	E+H	1-Nov-12		8-May-14	7-Oct-15
GM3	Biogas to boiler >>> changed to GM5	E+H - Proline 65I	9B09BD02000	1.50%	E+H	1-Nov-12			
GM4	Biogas flow meter to Boiler	E+H - Proline 65I	AA083102000	1.50%	E+H			9-May-14	7-Oct-15
GM5	Biogas flow meter to Boiler	E+H - Proline 65I	9B09BD02000	1.50%	E+H	1-Nov-12		9-May-14	7-Oct-15
GM4	Biogas to Flare >>> moved to GM4	E+H - Proline 65I	AA083102000	1.50%	E+H	1-Nov-12			
GM6	Biogas flow meter to Flare 1,2	E+H - Proline 65I	H1120702000	1.50%	E+H		29-Jan-13		7-Oct-15
MS	Gas analyzer at Boiler - Old	VISIT 04	505	2%	Thai Steam	19-Oct-12			
MS	Gas analyzer at Boiler	ABB - EL 3040	3.351195.2	1%	Sysproffess			9-May-14	19-Sep-15
MS	Gas analyzer at Boiler	ABB - EL 1020	3.241376.5	1%	Sysproffess				19-Sep-15
MS	Gas analyzer at UASB1&2	ABB - EL 3040	3.351639.4	1%	Sysproffess				19-Sep-15
CS	Lovibond - Old	Tintometer	38397	3.5%	Lovibond		24-Aug-13		
CS	Vario Photometer Lab1,2	Lovibond : COD Vario MD200	14/45856	53/525 ppm C	My Lab Scale			20-Aug-14	

Old meter

New meter

*New meter is existing monitoring equipment installed at the site.

Table 6 : Biogas Balance Check

Source	Nm3	Meter	2014	2015
Produced	UASB1	GM1	1,401,108	407,320
	UASB2	GM2	3,464,878	2,392,112
	CL3	GM3	7,721,381	3,151,358
	CL4	GM8	2,428,139	7,606,522
	Total		15,015,506	13,557,312
Utilized	Boiler	GM4,5	15,228,178	13,623,763
Flare	UASB1,2	GM6		-
	CL3	GM7	-	-
	CL4	GM9	-	2,281,491
Total usage			15,228,178	13,623,763
Balance			(212,672)	(66,451)
			-1.42%	-0.49%

Recheck

Utilized	Fr.UASB	Cal	5,078,658	2,865,883
Produced	Fr.UASB	Meter	4,865,986	2,799,432
Diff			(212,672)	(66,451)
			-4.37%	-2.37%

From the Table 6 above ;

- The amount of biogas produced (from UASB and CL system) is 1.42% and 0.49% , less than the amount of biogas consumed at boiler , for 2014 and 2015 respectively ;
- The unbalance of biogas produced and consumed is within 5% threshold allowed by VCS , thus this is acceptable.
- The amount of biogas consumed at boiler supplied from UASB1,2 (calculated from the total amount of biogas fired at boiler , minus the amount delivered from CL3 and CL4 , deducted the flare amount of CL3) is 4.37% and 2.37% , higher than the amount of biogas generated at UASB1,2 , in 2014 and 2015 respectively ;
- The amount of biogas produced from UASB is less than the calculated biogas consumption at boiler which is supposed to be supplied from UASB , which is also less than 5% of difference.