Monitoring report form

(Version 05.1)

MONITORING REPORT		
Title of the project activity	Chao Khun Argo Biogas Energy Project	
UNFCCC reference number of the project activity	2138	
Version number of the monitoring report	03.1	
Completion date of the monitoring report	11/07/2016	
Monitoring period number and duration of this monitoring period	5th Monitoring period; 01/11/2014 – 29/02/2016 (Both dates are included)	
Project participant(s)	• Thai Biogas Energy Company • Swedish Energy Agency	
Host Party	Thailand	
Sectoral scope(s)	Sectoral scope 13: Waste handling and disposal	
Selected methodology(ies)	AM0022: Avoided Wastewater and On-site Energy Use Emission in the Industrial Sector, Version 04	
Selected standardized baseline(s)	N/A	
Estimated amount of GHG emission reductions or net GHG removals by sinks for this monitoring period in the registered PDD	**64,134** tCO_2e	
Total amount of GHG emission reductions or net GHG removals by sinks achieved in this monitoring period	GHG emission reductions or net GHG removals by sinks reported up to 31 December 2012	GHG emission reductions or net GHG removals by sinks reported from 1 January 2013 onwards
	N/A	**77,635** tCO_2e

SECTION A. Description of project activity

A.1. Purpose and general description of project activity

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The Chao Khun Agro Biogas Energy Project was developed by Thai Biogas Energy Company Ltd is an industrial anaerobic wastewater treatment which treats wastewater from the cassava processing factory located in Saraburi, Thailand. The Covered In-Ground Anaerobic Reactor (CIGAR) has been installed as an anaerobic digester before the series of open lagoons. As the wastewater flow in to CIGAR, organic material is digested and resulting biogas. Then the generated biogas is captured and utilized. The capture biogas replaces the fossil fuel using for heat generation and surplus biogas is flared in open flaring system. The detail description of the main equipment is given in the section "B.1 Implementation status of the project description of the project activity".

The purpose of the project activity is to reduce the greenhouse gas emission from the anaerobic open lagoons wastewater treatment. The methane generated from anaerobic digesting was directly released to atmosphere and not utilized. Also the fossil fuel was used in heat generation and generated the greenhouse gas to atmosphere; however, the fossil fuel is replaced by biogas generated from new anaerobic wastewater treatment technology. Therefore, the project activity can reduce the greenhouse gas emission from direct methane emission and replacing the fossil fuel consumption from heat generation.

Since the project activity has been started from 16/12/2006, the relevant dates for the project activity are presented in the Table 1.

Table 1: The relevant date for the project activity

Status	Date	Description
Operation starts date of project activities.	16/12/2006	The new anaerobic wastewater treatment facility had started its operation.
Start date of boiler/burner operation	16/12/2006	The new burner had started its operation.
UNFCCC Registered date	09/03/2009	The project activity was registered as CDM project.

The amount of emission reductions during this monitoring period; 01/11/2014 – 29/02/2016 (both dates are included) is **77,635** tCO_2e

A.2. Location of project activity

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(a) Thailand
(b) Saraburi province
(c) Kaengkoi city / Songkorn district
(d) Physical location: Chao Khun Argo Products Project,
44 Moo 2, Songkorn, Kaengkoi, Saraburi, 18110, Thailand
(e) Geographical location: Latitude 14°35'59.28"N Longtitude 101°00'41.30"E

The geographical map of the project activity has been showed in the Figure 1.

Figure 1: The geographical map of project activity

A.3. Parties and project participant(s)

Party involved ((host) indicates a host Party)	Private and/or public entity(ies) project participants (as applicable)	Indicate whether the Party involved wishes to be considered as project participant (yes/no)
Kingdom of Thailand (Host)	Thai Biogas Energy Company	No
Sweden	Swedish Energy Agency	No

The Asian Development Bank, as trustee of the Asian Pacific Carbon Fund, a representative of Spain and Sweden, and Kingdom of Spain has been withdrawn according to MoC Annex 2 (Withdrawn Project Participant). All details can be found on the UNFCCC website; http://cdm.unfccc.int/Projects/DB/DNV-CUK1218616482.16

A.4. Reference of applied methodology and standardized baseline

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(a) AM0022 “Avoided Wastewater and On-site Energy Use Emissions in the Industrial Sector” (Version 04)

(b) “Tool to determine project emissions from flaring gases containing methane” (EB28, Annex 13)

The applied methodology and tool refer to UNFCCC website;
http://cdm.unfccc.int/methodologies/DB/BM4NZO7YAH9373G9P0UZHN6G1XM3IW/view.html

A.5. Crediting period of project activity

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Type of crediting period:	Fixed at 10 years
Starting date of the crediting period:	09/03/2009
The corresponding to this monitoring period:	01/11/2014 – 29/02/2016 (both dates are included)

A.6. Contact information of responsible persons/entities

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Entity name

Contact Person:	Mr. Gustaf Godenhielm
Organization Name:	Thai Biogas Energy Company Limited (TBEC)
Address:[1]	888/109, 10th Fl., Mahatun Plaza Bldg., Ploenchit Rd., Lumpini, Pathumwan, Bangkok 10330 THAILAND
Email:	gustaf@tbec.co.th

Responsible persons for completing the CDM-MR-FORM

Contact Person:	Mr. Pasu Sirisareewan / Mr. Weeravit Kulsitthichaiya
Organization Name:	Thai Biogas Energy Company Limited (TBEC)
Address:	888/109, 10th Fl., Mahatun Plaza Bldg., Ploenchit Rd., Lumpini, Pathumwan, Bangkok 10330 THAILAND
Email:	pasu@tbec.co.th / weeravit@tbec.co.th

SECTION B. Implementation of project activity

B.1. Description of implemented registered project activity

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This section will include a description of the implementation and operation status of the project as of this monitoring period. The project activity has installed the main machines with a specification as shown in the Table 2 and fully been operating since 16/12/2006 as mentioned in section A.1. In addition, a diagram of the project activity is shown in Figure 2.

Table 2: The specification of main machines installed in the project activity

Main Machine	Type of Equipment	Specification
New wastewater treatment reactor	CIGAR	41,000 m^3
Boiler	Loos – Steam boiler	15,000 kg/hr, 13 bar, 195°C
Burner	Weishaupt WKGMS 70/2-A	S/N: 5591839 Rating: min 1,400kW / max 10,800kW
Flare system	Open flare	Flow rate 2,000 m^3/hr

However, during this monitoring period there were downtimes of equipment which mainly due to no supplies of wastewater from the host factory. There were several reasons to stop operation of the host factory such as raw material shortage. The total downtime of the project activity during this monitoring period is presented in the Table 3.

Table 3: The summary of downtimes during 01/11/2014 – 29/02/2016 (both dates are included)

Total downtimes (mins)
38,880

From Table 3, it can be summarized that the total downtimes during this monitoring period of equipment is approximately **27** days. All information on the downtimes is provided in Annex I.

B.2. Post-registration changes

B.2.1. Temporary deviations from registered monitoring plan, applied methodology or applied standardized baseline

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There was a temporary deviations in the 1st monitoring period (09/03/2009 – 31/03/2011), both dates are included), referred to the UNFCCC PRC approval reference #PRC-2138-001.

However, there are **NO** temporary deviations in this monitoring period.

B.2.2. Corrections

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N/A

B.2.3. Changes to start date of crediting period

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N/A

B.2.4. Inclusion of a monitoring plan to the registered PDD that was not included at registration

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N/A

B.2.5. Permanent changes from registered monitoring plan, applied methodology or applied standardized baseline

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N/A

B.2.6. Changes to project design of registered project activity

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N/A

B.2.7. Types of changes specific to afforestation or reforestation project activity

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N/A

SECTION C. Description of monitoring system

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The monitoring diagram of the project activity

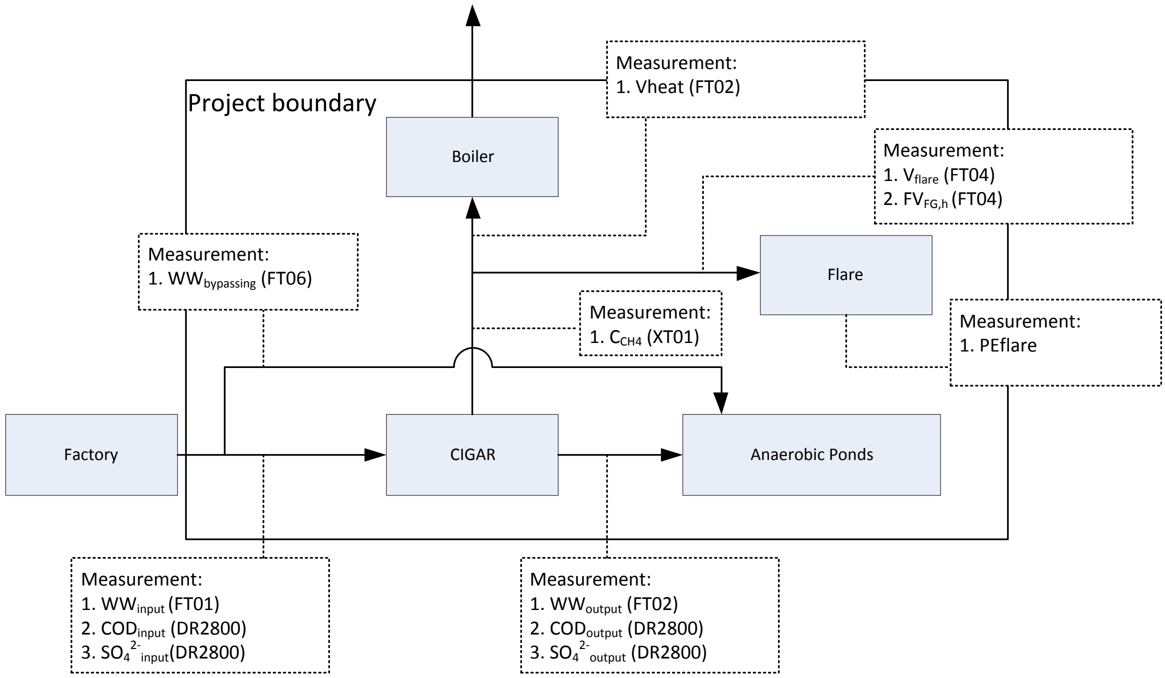

Figure 2: The project activity process diagram

TBEC is the responsible person for the on-site monitoring and implementation of the quality assurance and quality management system (ISO 9001:2008) that has been certified since June 2011. Both ISO 9001:2008 and ISO 14001:2004 are compiling the CDM monitoring report for verification. Its objectives are to achieve assured quality and consistency of the output. The standard prescribes formal documentation of procedures, performance measurements and records, which can be audited internally and externally. TBEC focus on statements of requirements, prevention and detection of problems, corrective actions, inspection and testing, and monitoring and review. TBEC is practical documents, emphasizing workplace acceptance. The operational and management structure that is implemented to monitor emission reductions is described in the following diagram.

Figure 3: The organization structure to monitor the emission reductions

The roles and responsibility of position presented in the diagram above has been clearly identified below;

a. **Shift Leader/Process Operator**

TBEC will designate shift leader/process operator to fulfil the primary monitoring activities. The shift leader/process operator will be responsible for checking SCADA midnight report, Electricity reports, and daily gas & liquid system daily check sheet on daily basis and share data with Senior Lab technician.

b. Senior Lab Technician

TBEC will designate Senior Lab Technician to fulfil the primary monitoring activities, mostly on wastewater analysis. Senior Lab Technician will be responsible for checking wastewater analysis report on daily basis and share with Shift leader. The Senior Lab technician is also responsible for collating all monitored data into the monitoring and verification workbook and submitting to the plant manager daily.

c. Plant Manager

Plant manager will be responsible for checking all monitoring data which they receive from the senior lab technician daily and ensure that the data continues to be recorded as per the monitoring requirements for each parameter. The Plant manager is responsible for sending the data on a weekly basis to QEHS Engineer.

d. QESH Engineer

TBEC will designate a QESH Engineer to administer the monitoring plan and ensure Quality Assurance and Quality Control Procedures are adherent. The QESH Engineer will be responsible for internal integrating the Monitoring Plan to TBECs operation and maintenance procedures for the site. The QESH Engineer will be responsible for training the Shift leader/Process operator and Senior lab technician in the correct procedures and to ensure that they understand the requirements of the monitoring plan.

Prior to operation of the project, the QESH Engineer will ensure that all meters and monitoring equipment meet the required accuracy and manufacturing standards. During the project, they will ensure the on-going maintenance and calibration of the all meters and monitoring equipment. Any equipment faults recorded by the Shift leader/Process operator and Senior lab technician will be followed up by the QESH Engineer who will ensure that the equipment is repaired/replaced as necessary. QESH Engineer is responsible for compiling the quarterly report and submitting it to TBEC management. Periodically the QESH undertake a cross check with the data report and the raw data.

e. CDM Project Manager

TBEC will designate a Senior Engineer/CDM Project Manager to oversee the preparation of the project annual Monitoring Report. They will review the monitored data provided quarterly by the Quality Control Officer and write the report for submission to the Designated Operational Entity (DOE). The Manager may also participate in and review the annual audit in co-ordination with the QESH Engineer

All data required for verification and issuance will be kept for at least two years after the end of the crediting period or the last issuance of CERs of this project, whichever occurs later. Data will be archived electronically and data backup will be maintained. Paper data backup will also be available.

All equipment calibrated and maintained in accordance to the manufacturer's recommendations to ensure accuracy of measurements. Records of calibration certificates and maintenance retained as part of the CDM monitoring system.

Data collection procedures

<u>Procedures of Monitoring Plan</u>

The proposed monitoring plan for the Project activity should be implemented and followed by the Project developer on-site. The methods and parameters to be monitored are as described in Section D.2. The monitoring plan should be implemented based in the following criteria:

- Data Collection – the parameters should be measured according to the monitoring plan. The frequency of monitoring proposed should be followed based on the proposed monitoring schedule. The results of the monitoring should be recorded and a set of these data should be kept on-site for easier retrieval and reference for operational and maintenance purposes.

The list of procedure is indicated below:

- Procedure for Document control
- Procedure for Clean Development Mechanism
- Procedure for Quality Analysis
- Procedure for Biogas operation process (Liquid & Gas phase)
- Procedure for preventive maintenance
- Procedure for Instrument calibration
- Other documentations

- Reporting and Documentation – All results and observations made during the monitoring should be reported and documented based on a standardized format. The collected data of the monitored parameters should be arranged, filed and documented for easy reference and better management. The retention/ archiving period for verification and CER issuance documents should be kept for at least 2 years after the end of the crediting period or the last issuance of CERs for this project activity whoever occurs later.

- The documents will be kept in both hard and soft copies (where available). For manual recording of monitoring data, the data sheets will be scanned/keyed into computer in soft-copy for safe-keeping.

- Quality Assurance / Quality Control (QA/QC) – The QA/QC procedures should be carried out during each monitoring exercise to ensure best quality and reliable data are obtained. Manual recording will be recorded and verified by different personnel as a cross-checking measure. Observations during the monitoring exercise should be recorded and reported to the CDM manager immediately. The CDM manager should review the findings and update/improve the monitoring plan from periodically to suit the project’s development.

- Communication, training and supervision – the monitoring plan should be communicated with relevant staff at all levels within the company. Relevant staff involved in the monitoring plan should be trained to implement the monitoring plan more effectively. Constant supervision and audits will be conducted to cross-check the results of the monitoring plan.

- Data protection, the data will be protected by creating the password and plant manager is authorize to access the data.

- In case of data loss; all data have been scanned and written into a DVD-rom as backup data. These data are kept at two places, one at site and another one at Headquarters. If any corrupted of data, the backup data will be used to replace the broken section.

- In case of data corruption; the operator check-sheet will be used as source of data.

SECTION D. Data and parameters

D.1. Data and parameters fixed ex ante or at renewal of crediting period

Data/parameter:	**EF_{CH4}**
Unit	kgCH_4/kg COD
Description	Methane emission factor
Source of data	AM0022 ver.04
Value(s) applied)	0.21
Choice of data or measurement methods and procedures	The 2006 IPCC default of 0.25 kg CH_4/kg COD has been corrected to 0.21 kg CH_4/kg COD to account for uncertainties. This is also the value applied in AM0022
Purpose of data	Used for calculated both baseline emission and project emission calculation
Additional comments	N/A

Data/parameter:	**GWP_{CH4}**
Unit	tCO_2/tCH_4
Description	Global Warming Potential for methane
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Value(s) applied)	25
Choice of data or measurement methods and procedures	According to the UNFCCC, EB69, Annex3, the GWP_{CH4} is approved to change from 21 tCO_2/tCH_4 to 25 tCO_2/tCH_4starting from the 2nd commitment period (1st January 2013 onward)
Purpose of data	Calculation of baseline emissions and project emissions
Additional comments	N/A

Data/parameter:	**$M_{lagoon\_aerobic}$**
Unit	Kg COD/ha/day
Description	Amount of organic material degraded aerobically in the lagoon system
Source of data	AM0022 ver.04
Value(s) applied)	254
Choice of data or measurement methods and procedures	As provided by the methodology and tested by the sensitivity analysis
Purpose of data	Used for calculated both baseline emission and project emission calculation
Additional comments	N/A

Data/parameter:	**R_{lagoon}**
Unit	%
Description	Total organic material removal ratio of the lagoon
Source of data	Project developer
Value(s) applied)	96
Choice of data or measurement methods and procedures	Determined in accordance with AM0022 prior to the start of the project activity through on-site biochemical testing in the lagoon system

Purpose of data	Used for calculated both baseline emission and project emission calculation
Additional comments	N/A

Data/parameter:	$\mathbf{R_{deposition}}$
Unit	%
Description	Organic material deposition ratio of the lagoon
Source of data	Project developer
Value(s) applied)	1.78
Choice of data or measurement methods and procedures	In accordance with AM0022, testing was done prior to the start of the project activity which determined the rate of deposition
Purpose of data	Used for calculated both baseline emission and project emission calculation
Additional comments	N/A

Data/parameter:	$\mathbf{NCV_{fuel,oil}}$
Unit	TJ/dm^3
Description	Net calorific value of fuel oil
Source of data	IPCC 2006 and density from Engineer's Edge
Value(s) applied)	39.996×10^{-6}
Choice of data or measurement methods and procedures	IPCC default value from Table 1.2 of Chapter 1 of Vol.2 used for the NCV of fuel oil expressed in TJ/t. This value is multiplied by the density value of 0.99Kg/l from Engineer's Edge (http://www.engineersedge.com/fluid_flow/fluid_data.htm)
Purpose of data	Used for calculated baseline emission; E_{co2_heat}
Additional comments	N/A

Data/parameter:	$\mathbf{EF_{fuel,oil}}$
Unit	tCO_2/TJ
Description	Carbon emission factor of the fuel oil
Source of data	IPCC 2006
Value(s) applied)	77.367
Choice of data or measurement methods and procedures	IPCC default value from Table 1.3 of Chapter 1 of Vol.2 gives an EF for residual fuel oil of 21.1 $kg_{carbon}/GJ_{fueloil}$. Applying the coefficient 44 g of CO_2/12 g of Carbon gives 77.367 tCO_2/TJ
Purpose of data	Used for calculated baseline emission; E_{co2_heat}
Additional comments	N/A

Data/parameter:	**Lagoon surface area**
Unit	Ha
Description	Total lagoon area
Source of data	Project developer
Value(s) applied)	2.09

Choice of data or measurement methods and procedures	N/A
Purpose of data	Used for calculated both baseline and project emission calculation
Additional comments	N/A

Data/parameter:	**Flare efficiency**
Unit	%
Description	Flare efficiency for open flare
Source of data	Tool to determine project emission from flaring gases containing methane
Value(s) applied)	50
Choice of data or measurement methods and procedures	This is calculated according to the “Tool to determine project emissions from flaring gases containing methane” for open flares which consists of using 50% default if a flame is detected for at least 20 min in the hour and ensuring that flare is operated properly
Purpose of data	Used for calculated project emission calculation; PE_{flare}
Additional comments	N/A

Data/parameter:	$\mathbf{R_{SO4}}^{2-}$
Unit	Kg/tonne (kg COD/ tSO_4^{2-})
Description	Reduction factor for SO_4^{2-} oxidative substance
Source of data	AM0022 ver.04
Value(s) applied)	651
Choice of data or measurement methods and procedures	AM0022 ver.04 states in p.32 under the section Determining losses of Chemical Oxygen Demand through chemical oxidation: “where the concentration of sulphate is observed to be 1 kg/m^3 of wastewater, 0.651 kg/m^3 of Chemical Oxygen Demand is removed through chemical reaction with the sulphate” hence the reduction factor is 0.651 kg COD/kgSO_4^{2-} => 651 kg COD/tSO_4^{2-}
Purpose of data	Used for calculated both baseline emission and project emission calculation
Additional comments	N/A

D.2. Data and parameters monitored

Data/parameter:	**WW_{input}**
Unit	m^3
Description	Daily wastewater flows entering system boundary
Measured/calculated/default	Measured
Source of data	Daily reports by SCADA
Value(s) of monitored parameter	see table below
Monitoring equipment	Tag No: FT01 Manufacturer: ABB Type/Model: ProcessMaster Serial No.: 3K672012180487 Calibration frequency: Every 2 years Accuracy class: ±0.40% Date of last calibration and validity: see table below
Measuring/reading/recording frequency:	Measuring continuously with a cumulative flow meter located at the incoming pipe to the CIGAR and reading recorded daily
Calculation method (if applicable):	N/A
QA/QC procedures:	Flow meters should be subject to a regular maintenance and testing regime to ensure accuracy
Purpose of data:	Baseline emission calculation
Additional comments:	N/A

Value(s) of monitored parameter:

Period	Total (m^3)
01/11/2014 – 31/12/2014 (both dates are included)	**129,971**
01/01/2015 – 31/12/2015 (both dates are included)	**798,244**
01/01/2016 – 29/02/2016 (both dates are included)	**149,577**

Date of last calibration and validity:

Certificate Number	Date of Calibration	Validity	Calibrator
L1407-292	18/07/2014	17/07/2016	MIT

Data/parameter:	**WW_{output}**
Unit	m^3
Description	Daily wastewater flow leaving treatment system
Measured/calculated/default	Measured
Source of data	Daily reports by SCADA
Value(s) of monitored parameter	see table below

Period	Total (m^3)
01/11/2014 – 31/12/2014 (both dates are included)	**129,866**
01/01/2015 – 31/12/2015 (both dates are included)	**802,001**
01/01/2016 – 29/02/2016 (both dates are included)	**150,112**

Monitoring equipment	Tag No.: FT05 Manufacturer: ABB Type/Model: ProcessMaster Serial No.: 3K672012180486 Calibration frequency: Every 2 years Accuracy class: ±0.40% Period of Use: 01/11/2014 - 17/02/2015 Date of last calibration and validity: **Certificate Number** | **Date of Calibration** | **Validity** | **Calibrator** L1405-137 | 07/05/2014 | 06/05/2016 | MIT Manufacturer: ABB Type/Model: XEDE43F Serial No.: 6710090063 Calibration Frequency: Every 2 years Accuracy Class: ±0.50% Period of Use: 18/02/2015 - Present Date of last calibration and validity: **Certificate Number** | **Date of Calibration** | **Validity** | **Calibrator** L1502-307 | 12/02/2015 | 11/02/2017 | MIT
Measuring/reading/recording frequency:	Measuring continuously with a cumulative flow meter located at the pipe leaving the CIGAR and reading recorded daily
Calculation method (if applicable):	N/A
QA/QC procedures:	Flow meters should be subject to a regular maintenance and testing regime to ensure accuracy
Purpose of data:	Project emissions calculation
Additional comments:	N/A

Data/parameter:	**COD_{input}**
Unit	$KgCOD/m^3$
Description	Wastewater organic material concentration entering the project boundary
Measured/calculated/default	Measured
Source of data	Daily analysed by Lab-technician
Value(s) of monitored parameter	**Period** | **Avergage ($kgCOD/m^3$)** 01/11/2014 – 31/12/2014 (both dates are included) | **13.613** 01/01/2015 – 31/12/2015 (both dates are included) | **17.814** 01/01/2016 – 29/02/2016 (both dates are included) | **11.780**

<table>
<tr><td>Monitoring equipment</td><td>Tag No.: -
Manufacturer: Hach
Type/Model: Spectrophotometer / DR2800
Serial No.: 1156884
Calibration frequency: once a year
Accuracy class: ±1.5nm
Period of Use: 01/11/2014 - 04/02/2015
Date of last calibration and validity:
<table>
<tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr>
<tr><td>C0140337</td><td>17/09/2014</td><td>16/09/2015</td><td>SPC</td></tr>
</table>
Manufacturer: Merck
Type/Model: Spectrophotometer / Pharo 100
Serial No.: 141410128
Calibration frequency: once a year
Accuracy class: ±1.0nm
Period of Use: 05/02/2015 - Present
Date of last calibration and validity:
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<tr><td>C06160085</td><td>27/01/2016</td><td>26/01/2017</td><td>SPC</td></tr>
<tr><td>S2015/060</td><td>30/01/2015</td><td>29/01/2016</td><td>Bangkok High Lab</td></tr>
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Tag No.: -
Manufacturer: Hach
Type/Model: COD Reactor / DRB200
Serial No.: 10110C0201
Calibration frequency: once a year
Accuracy class: ± 1°C
Date of last calibration and validity:
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<tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr>
<tr><td>C17150124</td><td>16/09/2015</td><td>15/09/2016</td><td>SPC</td></tr>
<tr><td>C17140093</td><td>17/09/2014</td><td>16/09/2015</td><td>SPC</td></tr>
</table>
</td></tr>
<tr><td>Measuring/reading/recording frequency:</td><td>Measuring daily by an internal laboratory and recording result daily</td></tr>
<tr><td>Calculation method (if applicable):</td><td>The test result is reported in mg COD/l. This unit is converted to kg COD/m^3 by simple unit conversion</td></tr>
<tr><td>QA/QC procedures:</td><td>Weekly samples are sent to an accredited analytical laboratory for cross-checking with on-site data to assure accuracy</td></tr>
<tr><td>Purpose of data:</td><td>Baseline emissions calculation</td></tr>
<tr><td>Additional comments:</td><td>N/A</td></tr>
</table>

Data/parameter:	**COD_{output}**
Unit	KgCOD/m^3
Description	Wastewater organic material concentration leaving the treatment facility

Measured/calculated/default	Measured
Source of data	Daily analysed by Lab-technician

Value(s) of monitored parameter

Period	Avergage ($kgCOD/m^3$)
01/11/2014 – 31/12/2014 (both dates are included)	**5.994**
01/01/2015 – 31/12/2015 (both dates are included)	**5.029**
01/01/2016 – 29/02/2016 (both dates are included)	**3.873**

Monitoring equipment

Tag No.: -
Manufacturer: Hach
Type/Model: Spectrophotometer / DR2800
Serial No.: 1156884
Calibration frequency: once a year
Accuracy class: ±1.5nm
Period of Use: 01/11/2014 - 04/02/2015
Date of last calibration and validity:

Certificate Number	Date of Calibration	Validity	Calibrator
C0140337	17/09/2014	16/09/2015	SPC

Manufacturer: Merck
Type/Model: Spectrophotometer / Pharo 100
Serial No.: 141410128
Calibration frequency: once a year
Accuracy class: ±1.0nm
Period of Use: 05/02/2015 - Present
Date of last calibration and validity:

Certificate Number	Date of Calibration	Validity	Calibrator
C06160085	27/01/2016	26/01/2017	SPC
S2015/060	30/01/2015	29/01/2016	Bangkok High Lab

Tag No.: -
Manufacturer: Hach
Type/Model: COD Reactor / DRB200
Serial No.: 10110C0201
Calibration frequency: once a year
Accuracy class: ± 1°C
Date of last calibration and validity:

Certificate Number	Date of Calibration	Validity	Calibrator
C17150124	16/09/2015	15/09/2016	SPC
C17140093	17/09/2014	16/09/2015	SPC

Measuring/reading/recording frequency:	Measuring daily by an internal laboratory and recording result daily
Calculation method (if applicable):	The test result is reported in mg COD/l. This unit is converted to kg COD/m^3 by simple unit conversion.

QA/QC procedures:	Weekly samples are sent to an accredited analytical laboratory for cross-checking with on-site data to assure accuracy.
Purpose of data:	Project emission calculation
Additional comments:	N/A

Data/parameter:	**V_{heat}**
Unit	Nm^3
Description	Volume of biogas sent to facility heaters
Measured/calculated/default	Measured
Source of data	Daily reports by SCADA
Value(s) of monitored parameter	

Period	Total (Nm^3)
01/11/2014 – 31/12/2014 (both dates are included)	**1,022,456**
01/01/2015 – 31/12/2015 (both dates are included)	**5,738,038**
01/01/2016 – 29/02/2016 (both dates are included)	**573,706**

Monitoring equipment:

Tag No.: FT02
Manufacturer: ABB
Type: Sensyflow FMT500 IG
Serial No.: 00000124
Calibration frequency: every 3 years
Accuracy class: ± 0.95%
Date of last calibration and validity:

Certificate Number	Date of Calibration	Validity	Calibrator
L1411-310	17/11/2014	16/11/2017	MIT
0184-D-K-15081-01-00-2011-11	25/11/2011	24/11/2014	ABB

Measuring/reading/recording frequency:	To be measured continuously, reading and recorded daily
Calculation method (if applicable):	N/A
QA/QC procedures:	Biogas meters should be subject to a regular maintenance and testing regime to ensure accuracy
Purpose of data:	Baseline emissions calculation
Additional comments:	N/A

Data/parameter:	**V_{flare}** (also $FV_{FG,h}$)
Unit	Nm^3
Description	Biogas sent to flare
Measured/calculated/default	Measured
Source of data	Daily reports by SCADA
Value(s) of monitored parameter	

Period	Total (Nm^3)
01/11/2014 – 31/12/2014 (both dates are included)	**0**
01/01/2015 – 31/12/2015 (both dates are included)	**0**
01/01/2016 – 29/02/2016 (both dates are included)	**0**

Monitoring equipment	Tag No.: FT04 Manufacturer: ABB Type/Model: Sensyflow FMT500 IG Serial No.: 00000294 Calibration frequency: every 3 years Accuracy class: ± 0.95% Date of last calibration and validity:

Certificate Number	Date of Calibration	Validity	Calibrator
L1412-263	12/12/2014	11/12/2017	MIT
0186-D-K-15081-01-00-2011-12	15/12/2011	14/12/2014	ABB

Measuring/reading/recording frequency:	To be measured continuously, reading and recorded daily
Calculation method (if applicable):	N/A
QA/QC procedures:	Biogas meters should be subject to a regular maintenance and testing regime to ensure accuracy. This parameter is equivalent to the variable $FV_{RG,h}$ (volumetric flow rate of the residual gas in dry basis at normal conditions) as described in the "Tool to determine project emissions from flaring gases containing methane"
Purpose of data:	Project emissions calculation
Additional comments:	N/A

Data/parameter:	$\mathbf{C_{so4^{2-}in}}$
Unit	Tonnes/m^3
Description	Amount of chemical oxidizing agents entering system boundary
Measured/calculated/default	Measured
Source of data	Daily analysed by Lab-technician
Value(s) of monitored parameter	

Period	Total (tonnes/m^3)
01/11/2014 – 31/12/2014 (both dates are included)	**0.000185**
01/01/2015 – 31/12/2015 (both dates are included)	**0.000373**
01/01/2016 – 29/02/2016 (both dates are included)	**0.000520**

Monitoring equipment	Tag No.: - Manufacturer: Hach Type/Model: Spectrophotometer / DR2800 Serial No.: 1156884 Calibration frequency: once a year Accuracy class: ±1.5nm Period of Use: 01/11/2014 - 04/02/2015 Date of last calibration and validity: **Certificate Number** / **Date of Calibration** / **Validity** / **Calibrator** C0140337 / 17/09/2014 / 16/09/2015 / SPC Manufacturer: Merck Type/Model: Spectrophotometer / Pharo 100 Serial No.: 141410128Calibration frequency: once a year Accuracy class: ±1.0nm Period of Use: 05/02/2015 - Present Date of last calibration and validity: **Certificate Number** / **Date of Calibration** / **Validity** / **Calibrator** C06160085 / 27/01/2016 / 26/01/2017 / SPC S2015/060 / 30/01/2015 / 29/01/2016 / Bangkok High Lab Tag No.: - Manufacturer: Hach Type/Model: COD Reactor / DRB200 Serial No.: 10110C0201 Calibration frequency: once a year Accuracy class: ± 1°C Date of last calibration and validity: **Certificate Number** / **Date of Calibration** / **Validity** / **Calibrator** C17150124 / 16/09/2015 / 15/09/2016 / SPC C17140093 / 17/09/2014 / 16/09/2015 / SPC
Measuring/reading/recording frequency:	Samples are collected daily, mixed, and concentration measured weekly. For emission reduction calculations the most recent value from testing is kept until a new test result is received from the lab.
Calculation method (if applicable):	N/A
QA/QC procedures:	N/A
Purpose of data:	Baseline emissions calculation
Additional comments:	N/A

Data/parameter:	$C_{SO4^{2-} out}$
Unit	Tonnes/m^3
Description	Amount of chemical oxidizing agents out of the digester
Measured/calculated/default	Measured

<table>
<tr><td>Source of data</td><td>Daily analysed by Lab-technician</td></tr>
<tr><td>Value(s) of monitored parameter</td><td>
<table>
<tr><th>Period</th><th>Total (tonnes/m³)</th></tr>
<tr><td>01/11/2014 – 31/12/2014 (both dates are included)</td><td>0.000007</td></tr>
<tr><td>01/01/2015 – 31/12/2015 (both dates are included)</td><td>0.000035</td></tr>
<tr><td>01/01/2016 – 29/02/2016 (both dates are included)</td><td>0.000074</td></tr>
</table>
</td></tr>
<tr><td>Monitoring equipment</td><td>
Tag No.: -
Manufacturer: Hach
Type/Model: Spectrophotometer / DR2800
Serial No.: 1156884
Calibration frequency: once a year
Accuracy class: ±1.5nm
Period of Use: 01/11/2014 - 04/02/2015
Date of last calibration and validity:
<table>
<tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr>
<tr><td>C0140337</td><td>17/09/2014</td><td>16/09/2015</td><td>SPC</td></tr>
</table>
Manufacturer: Merck
Type/Model: Spectrophotometer / Pharo 100
Serial No.: 141410128Calibration frequency: once a year
Accuracy class: ±1.0nm
Period of Use: 05/02/2015 - Present
Date of last calibration and validity:
<table>
<tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr>
<tr><td>C06160085</td><td>27/01/2016</td><td>26/01/2017</td><td>SPC</td></tr>
<tr><td>S2015/060</td><td>30/01/2015</td><td>29/01/2016</td><td>Bangkok High Lab</td></tr>
</table>
Tag No.: -
Manufacturer: Hach
Type/Model: COD Reactor / DRB200
Serial No.: 10110C0201
Calibration frequency: once a year
Accuracy class: ± 1°C
Date of last calibration and validity:
<table>
<tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr>
<tr><td>C17150124</td><td>16/09/2015</td><td>15/09/2016</td><td>SPC</td></tr>
<tr><td>C17140093</td><td>17/09/2014</td><td>16/09/2015</td><td>SPC</td></tr>
</table>
</td></tr>
<tr><td>Measuring/reading/recording frequency:</td><td>Samples are collected daily, mixed, and concentration measured weekly. For emission reduction calculations the most recent value from testing is kept until a new test result is received from the lab.</td></tr>
<tr><td>Calculation method (if applicable):</td><td>N/A</td></tr>
<tr><td>QA/QC procedures:</td><td>N/A</td></tr>
<tr><td>Purpose of data:</td><td>Project emissions calculation</td></tr>
<tr><td>Additional comments:</td><td>N/A</td></tr>
</table>

Data/parameter:	$WW_{bypassing}$
Unit	m^3
Description	Flow of wastewater directly to the current water treatment system, and bypassing the new wastewater treatment facility
Measured/calculated/default	Measured
Source of data	Daily analysed by SCADA
Value(s) of monitored parameter	<table><tr><th>Period</th><th>Total (m³)</th></tr><tr><td>01/11/2014 – 31/12/2014 (both dates are included)</td><td>**0**</td></tr><tr><td>01/01/2015 – 31/12/2015 (both dates are included)</td><td>**0**</td></tr><tr><td>01/01/2016 – 29/02/2016 (both dates are included)</td><td>**0**</td></tr></table>
Monitoring equipment	Tag No.: FT06 Manufacturer: ABB Type/Model: ProcessMaster Serial No.: 3K672011450101 Calibration frequency: every 2 years Accuracy class: ±0.40% Date of last calibration and validity: <table><tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr><tr><td>L1511-318</td><td>12/11/2015</td><td>11/11/2017</td><td>MIT</td></tr><tr><td>LC1311-326</td><td>14/11/2013</td><td>13/11/2015</td><td>MIT</td></tr></table>
Measuring/reading/recording frequency:	Measuring continuously and data recorded hourly
Calculation method (if applicable):	N/A
QA/QC procedures:	Regular maintenance and calibration of the flow meter
Purpose of data:	N/A
Additional comments:	N/A

Data/parameter:	**Biogas loss from pipeline**
Unit	%
Description	Loss of biogas from pipeline
Measured/calculated/default	Measured
Source of data	Hydrostatic test report by Accredited Laboratory <table><tr><th>Report Number</th><th>Testing date</th><th>Validity</th><th>Tester</th></tr><tr><td>RP-P51-160112</td><td>25/12/2015</td><td>24/12/2016</td><td>STIC</td></tr><tr><td>RP-P51-140932</td><td>04/08/2014</td><td>03/08/2015</td><td>STIC</td></tr></table>
Value(s) of monitored parameter	<table><tr><th>Period</th><th>Biogas loss from pipeline</th></tr><tr><td>01/11/2014 – 31/12/2014 (both dates are included)</td><td>**0**</td></tr><tr><td>01/01/2015 – 31/12/2015 (both dates are included)</td><td>**0**</td></tr><tr><td>01/01/2016 – 29/02/2016 (both dates are included)</td><td>**0**</td></tr></table>

Monitoring equipment	N/A
Measuring/reading/recording frequency:	Integrity of biogas pipeline for losses of biogas methane is tested annually through pressurizing the system and establishing pressure drops through leakage.
Calculation method (if applicable):	N/A
QA/QC procedures:	The standard method for testing has followed by Department of Energy's liquefied petroleum gas piping and equipped with storage tanks and gas.
Purpose of data:	Project emissions calculation
Additional comments:	N/A

Data/parameter:	**NCV_{biogas}**
Unit	J/Nm^3
Description	Biogas calorific value
Measured/calculated/default	Measured
Source of data	NCV test report by Accredited Laboratory **Report Number** / **Testing date** / **Validity** / **Tester** COA-EX-1309-00143 / 29/08/2013 / 28/08/2014 / PTTGC COA-EX-1412-01640 / 15/12/2014 / 14/12/2015 / PTTGC LAR-EX-1601-00992 / 08/01/2016 / 07/01/2017 / PTTGC
Value(s) of monitored parameter	**Period** / **NCV_{biogas} (J/Nm^3)** 01/11/2014 – 31/12/2014 (both dates are included) / **21,125,796** 01/01/2015 – 31/12/2015 (both dates are included) / **19,672,728** 01/01/2016 – 29/02/2016 (both dates are included) / **19,896,253**
Monitoring equipment	N/A
Measuring/reading/recording frequency:	To be measured annually
Calculation method (if applicable):	The value in the test report of the accredited laboratory is show in btu/ft^3 unit. Thus, the unit has been converted to J/Nm^3 by simple unit conversion. (1 btu = 1,055.056 J[1]; $1Nm^3$ = 35.31467 ft^3[2]). The conversion factor of btu/ft^3 to J/Nm^3 is 1 btu/ft^3 equal to 37,258.9 J/Nm^3.
QA/QC procedures:	N/A
Purpose of data:	Baseline emissions calculation
Additional comments:	N/A

Data/parameter:	**PE_{flare}**
Unit	tCO_2
Description	Project emissions from flaring of the residual gas stream
Measured/calculated/default	Calculated
Source of data	Emission reduction calculation sheet

[1] Geankoplis, C. (1993). *Transport processes and unit operations*. 3rd ed. Engelwood Cliffs, N.J.: PTR Prentice Hall, p.852

[2] Brown, J. (1999). *Foseco non-ferrous foundryman's handbook*. 11th ed. Oxford [England]: Butterworth-Heinemann, p.2.

Value(s) of monitored parameter	<table><tr><th>Period</th><th>PE_{flare} (tCO_2e)</th></tr><tr><td>01/11/2014 – 31/12/2014 (both dates are included)</td><td>**0**</td></tr><tr><td>01/01/2015 – 31/12/2015 (both dates are included)</td><td>**0**</td></tr><tr><td>01/01/2016 – 29/02/2016 (both dates are included)</td><td>**0**</td></tr></table>
Monitoring equipment	N/A
Measuring/reading/recording frequency:	N/A
Calculation method (if applicable):	Following the “Tool to determine project emissions from flaring gases containing methane”
QA/QC procedures:	N/A
Purpose of data:	Project emissions calculation
Additional comments:	N/A

Data/parameter:	**F**
Unit	dm^3
Description	Fossil fuel volume equivalent to generate the same amount of heat generated from the biogas collected in anaerobic treatment facility
Measured/calculated/default	Calculated
Source of data	Emissions reduction calculation sheet
Value(s) of monitored parameter	<table><tr><th>Period</th><th>F (dm^3)</th></tr><tr><td>01/11/2014 – 31/12/2014 (both dates are included)</td><td>**540,059**</td></tr><tr><td>01/01/2015 – 31/12/2015 (both dates are included)</td><td>**2,822,354**</td></tr><tr><td>01/01/2016 – 29/02/2016 (both dates are included)</td><td>**285,394**</td></tr></table>
Monitoring equipment	N/A
Measuring/reading/recording frequency:	N/A
Calculation method (if applicable):	Calculated from the monitored V_{heat} multiplied by monitored NCV_{biogas} and divided by fixed parameter NCV_{fuel}
QA/QC procedures:	N/A
Purpose of data:	Baseline emissions calculation
Additional comments:	N/A

Data/parameter:	C_{CH4} (also $FV_{CH4,y}$)
Unit	% of Nm^3/Nm^3
Description	Biogas methane concentration
Measured/calculated/default	Measured
Source of data	SCADA midnight report
Value(s) of monitored parameter	<table><tr><th>Period</th><th>Average (% of Nm^3/Nm^3)</th></tr><tr><td>01/11/2014 – 31/12/2014 (both dates are included)</td><td>**58.19**</td></tr><tr><td>01/01/2015 – 31/12/2015 (both dates are included)</td><td>**58.04**</td></tr><tr><td>01/01/2016 – 29/02/2016 (both dates are included)</td><td>**58.09**</td></tr></table>

<table>
<tr><td>Monitoring equipment</td><td><u>Tag No.: XT01</u>
Manufacturer: ANRI
Type: CAM-3L
Serial No.: LFB-028
Calibration frequency: once a year
Accuracy class: ±2%
Period of Use: 01/11/2014 - 09/04/2015
Date of last calibration and validity:

<table><tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr><tr><td>G570127-1</td><td>17/04/2014</td><td>16/04/2015</td><td>Entech</td></tr></table>
Manufacturer: JE
Type: Gas Analyzer
Serial No.: 35286
Calibration frequency: once a year
Accuracy class: ±2%
Period of Use: 10/04/2015 – 27/11/2015
Date of last calibration and validity:

<table><tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr><tr><td>G580136</td><td>08/04/2015</td><td>07/04/2016</td><td>Entech</td></tr></table>
Manufacturer: Edinburgh
Type: Guardian NG
Serial No.: 8008
Calibration frequency: once a year
Accuracy class: ±2%
Period of Use: 28/11/2015 - Present
Date of last calibration and validity:

<table><tr><th>Certificate Number</th><th>Date of Calibration</th><th>Validity</th><th>Calibrator</th></tr><tr><td>G580523</td><td>27/11/2015</td><td>26/11/2016</td><td>Entech</td></tr></table></td></tr>
<tr><td>Measuring/reading/recording frequency:</td><td>Measured continuously, reading and recorded daily</td></tr>
<tr><td>Calculation method
(if applicable):</td><td>N/A</td></tr>
<tr><td>QA/QC procedures:</td><td>N/A</td></tr>
<tr><td>Purpose of data:</td><td>Project emissions calculation</td></tr>
<tr><td>Additional comments:</td><td>Also, referred as $FV_{CH4,h}$ (Volumetric fraction of component i in the biogas in the hour h, where i = CH_4) in the “Tool to determine project emissions from flaring gases containing methane”. Only CH_4 will be monitored, the remaining part will be considered as N_2 (simplified approach to Tool). The monitored value will actually have to be multiplied by the CH_4 density of 0.0007168 tCH_4/m^3CH_4 from ACM0001 at normal conditions to obtain the value of CCH_4 in tCH_4/Nm^3.</td></tr>
</table>

Data/parameter:	**f_{heat}**
Unit	%

Description	Heating system combustion efficiency
Measured/calculated/default	Measured
Source of data	Combustion efficiency test report by External laboratory **Report Number** / **Testing date** / **Validity** / **Tester** TM 1919 / 30/04/2015 / 29/04/2016 / Thai Burner TM 1073 / 20/05/2014 / 19/05/2015 / Thai Burner
Value(s) of monitored parameter	**Period** / **f_{heat} (%)** 01/11/2014 – 31/12/2014 (both dates are included) / **91.41** 01/01/2015 – 31/12/2015 (both dates are included) / **90.87** 01/01/2016 – 29/02/2016 (both dates are included) / **90.87**
Monitoring equipment	N/A
Measuring/reading/recording frequency:	Measuring and recording at least annually
Calculation method (if applicable):	N/A
QA/QC procedures:	Boiler is maintained regularly by Weishaupt in order to ensure optimal performance.
Purpose of data:	Project emissions calculation
Additional comments:	N/A

Data/parameter:	**$M_{removed}$**
Unit	tCOD
Description	Organic material removed from wastewater facility
Measured/calculated/default	Calculated
Source of data	Calculated based on monitored parameters COD_{input} and COD_{output}
Value(s) of monitored parameter	**Period** / **$M_{removed}$ (tCOD)** 01/11/2014 – 31/12/2014 (both dates are included) / **991** 01/01/2015 – 31/12/2015 (both dates are included) / **10,187** 01/01/2016 – 29/02/2016 (both dates are included) / **1,181**
Monitoring equipment	N/A
Measuring/reading/recording frequency:	N/A
Calculation method (if applicable):	The parameter is calculated from COD_{input} and COD_{output}. $M_{removed} = [(WW_{input} \times COD_{in}) - (WW_{output} \times COD_{out})] \div 1000$
QA/QC procedures:	N/A
Purpose of data:	N/A
Additional comments:	N/A

D.3. Implementation of sampling plan

>>

There is no data and parameter monitored described in section D.2 are determined by a sampling approach. Therefore, this section is not applicable for this project activity.

SECTION E. Calculation of emission reductions or GHG removals by sinks

E.1. Calculation of baseline emissions or baseline net GHG removals by sinks

>>

As per the equation set out in AM0022 version04 which applied for registered project activity, the following equations are applied to calculate the baseline emissions.

Total Baseline emissions:

$$\boldsymbol{E}_{BL} = \boldsymbol{E}_{CH4\_lagoon\_BL} + \boldsymbol{E}_{CO2\_heat\_BL} + \boldsymbol{E}_{CO2\_power\_BL}$$

Where;

E_{BL}	= total baseline emissions (tCO_2e)
$E_{CH4\_lagoons\_BL}$	= the fugitive methane emissions from lagoons in the baseline case (tCO_2e)
$E_{CO2\_heat\_BL}$	= CO_2 emissions from on-site fossil heat in the baseline case (tCO_2e) that are displaced by generation based on biogas collected in the anaerobic treatment facility.
$E_{CO2\_power\_BL}$	= CO_2 emissions from on-site power generation in the baseline case (tCO_2e) that are displaced by generation based on biogas collected in the anaerobic treatment facility.

Since in this registered project activity there are no any electricity generation that are displaced base on biogas collected in the anaerobic treatment facility, the $E_{CO2\_power\_BL}$ = 0.

Then the follow equation has been applied for this case:

$$\boldsymbol{E}_{BL} = \boldsymbol{E}_{CH4\_lagoon\_BL} + \boldsymbol{E}_{CO2\_heat\_BL}$$

Period of 01/11/2014 – 31/12/2014 (both dates are included)

E_{BL}	$E_{CH4\_lagoon\_BL}$	$E_{CO2\_heat\_BL}$	$E_{CO2\_power\_BL}$
tCO_2e	tCO_2e	tCO_2e	tCO_2e
10,187	8,516	1,671	0

Period of 01/01/2015 – 31/12/2015 (both dates are included)

E_{BL}	$E_{CH4\_lagoon\_BL}$	$E_{CO2\_heat\_BL}$	$E_{CO2\_power\_BL}$
tCO_2e	tCO_2e	tCO_2e	tCO_2e
77,086	68,353	8,733	0

Period of 01/01/2016 – 29/02/2016 (both dates are included)

E_{BL}	$E_{CH4\_lagoon\_BL}$	$E_{CO2\_heat\_BL}$	$E_{CO2\_power\_BL}$
tCO_2e	tCO_2e	tCO_2e	tCO_2e
9,174	8,291	883	0

Total baseline emissions before the conservativeness calculation check during period 01/11/2014 – 29/02/2016 (both dates are included) is **96,447** tCO_2e

a) On-site heat generation emission displaced by generation based on biogas collected in the anaerobic treatment facility.

In the calculation of CO_2 emission from on-site heat displaced by biogas collected in the anaerobic treatment, the use of fossil fuels is considered:

$$E_{CO2\_heat} = F \times NCV \times EF$$

Where:

F	= the corresponding amount of fossil fuel displaced by the use of biogas for the generation of on-site heat (dm^3). This is estimated as product of: (1) Average specific fuel consumption for the output of the facility and (2) The annual production.
NCV	= the net calorific value of the fossil fuel consider (TJ/unit).
EF	= the carbon emission factor of the fossil fuel considers (tCO_2/TJ).

According to heat balance equation, the corresponding amount of fossil fuel displaced by the use of biogas for the generation of on-site heat can be calculated as equation below:

$$F_{fueloil} \times NCV_{fueloil} = F_{biogas} \times NCV_{biogas}$$

$$F_{fueloil} = F_{biogas} \times \frac{NCV_{biogas}}{NCV_{fueloil}}$$ then;

$$E_{CO2\_heat} = \left(F_{biogas} \times \frac{NCV_{biogas}}{NCV_{fueloil}}\right) \times NCV_{fueloil} \times EF$$

As equation above, the CO_2 emissions from on-site heat displaced by biogas collected in the anaerobic treatment, the use of fossil fuels is considered as:

$$E_{CO2\_heat} = F_{biogas} \times NCV_{biogas} \times EF$$

Period of 01/11/2014 – 31/12/2014 (both dates are included)

E_{CO2_heat}	F	NCV_{biogas}	EF
tCO_2e	Nm^3	TJ/ Nm^3	tCO_2/TJ
1,671	1,022,456	2.11258×10^{-5}	77.367

Period of 01/01/2015 – 31/12/2015 (both dates are included)

E_{CO2_heat}	F	NCV_{biogas}	EF
tCO_2e	Nm^3	TJ/ Nm^3	tCO_2/TJ
8,733	5,738,038	1.96727×10^{-5}	77.367

Period of 01/01/2016 – 29/12/2016 (both dates are included)

E_{CO2_heat}	F	NCV_{biogas}	EF
tCO_2e	Nm^3	TJ/ Nm^3	tCO_2/TJ
883	573,706	1.98963×10^{-5}	77.367

Noted: 77.367 tCO_2/TJ has been applied for the carbon emission factor of the fuel oil referred to IPCC default value from Table 3.1, Chapter 1 vol.2

Therefore, the total CO_2 emission from the on-site heat displaced by biogas collected in the anaerobic treatment from 01/11/2014 – 29/02/2016 (both dates are included) is **11,287** tCO_2e.

b) On-site and/or off-site Grid Power Generation Emission displaced by generation based on biogas collected in the anaerobic treatment facility

No electricity was generated. Therefore, $E_{CO2\_power\_BL}$ = **0** tCO_2e.

c) Baseline organic material entering lagoon system from new anaerobic wastewater treatment system:

$$\boldsymbol{M}_{lagoon\_input\_BL} = \boldsymbol{M}_{input\_total}$$

Where;

$M_{lagoon\_input\_BL}$	= the value used to specify the amount of organic material flowing into the lagoon system from the CIGAR in the project scenario equation (kg COD).
M_{input_total}	= the total amount of organic material fed into the baseline wastewater treatment facility (kg COD). It is same amount as fed into the project water treatment facility.

In the baseline, organic material from the facility enters directly into the lagoon system with no degradation of the wastewater before entering the lagoon system and all organic material to be treated enters the lagoon system. The pond based fugitive methane emissions are quantified by determining;

- How much material enters the lagoon system;
- How much is lost through aerobic and oxidative processes;
- How much is lost through sedimentation in the lagoon system; and
- How much is removed through anaerobic process.

All emission factors, surface aerobic losses of organic material, aerobic degradation, deposition or removal as well as chemical oxidation are determined in the same way as described for the project scenario in the section on project emission above.

Hence, the equation to determine the fugitive methane emission from lagoons for project emissions has been applied for baseline scenario according to the methodology.

Fugitive methane emission from lagoons in baseline scenario

$$\boldsymbol{E}_{CH4\_lagoon\_BL} = \boldsymbol{M}_{lagoon\_anaerobic} \times \boldsymbol{EF}_{CH4} \times \boldsymbol{GWP}_{CH4} \div \mathbf{1000}$$

Where;

$E_{CH4\_lagoon\_BL}$	= the methane emission from the lagoons (tCO_2)
$M_{lagoon\_anaerobic}$	= the amount of organic material removed by anaerobic processes in the lagoon system (kg COD).
EF_{CH4}	= the methane emission factor (kg CH_4 / kg COD)
GWP_{CH4}	= the Global Warming Potential of methane (GWP_{CH4} = 25 tCO_2/tCH_4)

Note: A default COD to methane conversion factor of 0.21 kg CH_4/kg COD is used referred to IPCC, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, page 5.16 and/or methodology AM0022 Version 04, page 3.

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$E_{CH4\_lagoon\_BL}$	$M_{lagoon\_anaerobic}$	EF_{CH4}	GWP_{CH4}
tCO_2e	kg COD	kg CH_4 / kg COD	tCO_2/tCH_4
8,516	1,622,172.14	0.21	25

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$E_{CH4\_lagoon\_BL}$	$M_{lagoon\_anaerobic}$	EF_{CH4}	GWP_{CH4}
tCO_2e	kg COD	kg CH_4 / kg COD	tCO_2/tCH_4
68,353	13,019,679.00	0.21	25

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$E_{CH4\_lagoon\_BL}$	$M_{lagoon\_anaerobic}$	EF_{CH4}	GWP_{CH4}
tCO_2e	kg COD	kg CH_4 / kg COD	tCO_2/tCH_4
8,291	1,579,301.61	0.21	25

Total fugitive methane emission from lagoons in baseline scenario in this monitoring period from 01/11/2014 – 29/02/2016 (both date are included) is **85,160** tCO_2e.

The total removal of COD from individual lagoons is a function of:

- Aerobic surface oxidation of COD
- Chemical oxidation in lagoons (where oxidative species such as sulphate present)
- Sedimentation of material that microbes are unable to degrade before they form a bottom sediment
- COD degradation as a result of anaerobic micro bacterial activity

The mass balance in the considered lagoon system provides the amount of organic material by anaerobic process:

$$\boldsymbol{M}_{lagoon_{anaerobic}} = \boldsymbol{M}_{lagoon_{total}} - \boldsymbol{M}_{lagoon_{aerobic}} - \boldsymbol{M}_{lagoon_{chemical_{ox}}} - \boldsymbol{M}_{lagoon_{deposition}}$$

Where;

$M_{lagoon\_anaerobic}$ = the amount of organic material removed by anaerobic processes in the lagoon system (kg COD).

M_{lagoon_total} = the total amount of organic material removed in the lagoon system (kg COD)

$M_{lagoon\_aerobic}$ = the amount of organic material degraded aerobically in the lagoon system (kg COD)

$M_{lagoon\_che,mical\_ox}$ = the amount of organic material lost through chemical oxidation in the lagoon system (kg COD)

$M_{lagoon\_deposition}$ = the amount of organic material lost through deposition in the lagoon system (kg COD)

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$M_{lagoon\_anaerobic}$	M_{lagoon_total}	$M_{lagoon\_aerobic}$	$M_{lagoon\_che,mical\_ox}$	$M_{lagoon\_deposition}$
Kg COD	kg COD	Kg COD	Kg COD	Kg COD
1,622,172.41	1,698,492.58	29,197.30	15,629.98	31,492.88

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$M_{lagoon\_anaerobic}$	M_{lagoon_total}	$M_{lagoon\_aerobic}$	$M_{lagoon\_che,mical\_ox}$	$M_{lagoon\_deposition}$
Kg COD	kg COD	Kg COD	Kg COD	Kg COD
13,019,697.00	13,651,477.53	184,739.28	193,920.11	253,121.15

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$M_{lagoon\_anaerobic}$	M_{lagoon_total}	$M_{lagoon\_aerobic}$	$M_{lagoon\_che,mical\_ox}$	$M_{lagoon\_deposition}$
Kg COD	kg COD	Kg COD	Kg COD	Kg COD
1,579,301.61	1,691,544.11	30,259.02	50,619.43	31,364.05

In order to assess the amount of COD actually entering the anaerobic system (the lagoons) the amount of COD removed as a result of the new wastewater treatment facility must be determined. This is set out in equation below.

Project organic material entering lagoon system from new anaerobic water treatment system is:

$$\boldsymbol{M}_{lagoon\_input} = \boldsymbol{M}_{input\_total} \times (\mathbf{1} - \boldsymbol{R}_{NAWTF})$$

Where;

M_{lagoon_input} = the input of organic material from the new project anaerobic wastewater treatment facility into the lagoon system (kg COD).

M_{input_total} = the total amount of organic material fed into the baseline water treatment facility (kg COD). It is the same amount as fed into the project water treatment facility

R_{NAWTF} = the total organic material removed efficiency of the new project water treatment facility

Note: In case of baseline calculation, the R_{NAWTF} = 0 is applied because the new project water treatment was not implemented yet.

Period of 01/11/2014 – 31/12/2014 (both dates are included)

M_{lagoon_input}	M_{input_total}	R_{NAWTF}
Kg COD	kg COD	-
1,769,263.10	1,769,263.10	0

Period of 01/01/2015 – 31/12/2015 (both dates are included)

M_{lagoon_input}	M_{input_total}	R_{NAWTF}
Kg COD	kg COD	-
14,220,289.09	14,220,289.09	0

Period of 01/01/2016 – 29/02/2016 (both dates are included)

M_{lagoon_input}	M_{input_total}	R_{NAWTF}
Kg COD	kg COD	-
1,762,025.11	1,762,025.11	0

Total material removal in lagoon system is:

$$\boldsymbol{M}_{lagoon\_total} = \boldsymbol{M}_{lagoon\_input} \times \boldsymbol{R}_{lagoon}$$

Where;

M_{lagoon_total} = the total amount of organic material removed in the lagoon system through various routes (kg COD).

M_{lagoon_input} = the input of organic material from the new project anaerobic wastewater treatment facility into the lagoon system (kg COD)

R_{lagoon} = the total organic material removal ratio of the lagoon

Note: the total organic material removal ratio of the lagoon is equal to the proportion of organic material removed within the boundaries of the lagoon system under consideration. This factor should be determined by carrying out a series of biochemical tests period to project implementation. This test will determine the COD flows into the system, and the COD flows out of the system boundary. The relative difference of COD flowing in and out of the system over a period of time will allow determination of the Total Organic Material Removed Ratio which already tested during validation process. Refer to registered PDD-page 22, the R_{lagoon} is 96%

Period of 01/11/2014 – 31/12/2014 (both dates are included)

M_{lagoon_total}	M_{lagoon_input}	R_{lagoon}
Kg COD	kg COD	%
1,698,492.58	1,769,263.10	96

Period of 01/01/2015 – 31/12/2015 (both dates are included)

M_{lagoon_total}	M_{lagoon_input}	R_{lagoon}
Kg COD	kg COD	%
13,561,477.53	14,220,289.09	96

Period of 01/01/2016 – 29/02/2016 (both dates are included)

M_{lagoon_total}	M_{lagoon_input}	R_{lagoon}
Kg COD	kg COD	%
1,691,544.11	1,762,025.11	96

Material degraded aerobically in the lagoon system

$$\boldsymbol{M_{lagoon\_aerobic} = 254 \times Pond\ Surface\ Area \times Operating\ Time}$$

Note: Surface aerobic losses of organic material in pond based system equal to 254 kg COD per hectare of pond surface area and per day is assumed to be lost through aerobic processes.

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$M_{lagoon\_aerobic}$	Constant Value	Pond Surface Area	Operation Day
Kg COD	kg COD/ha/day	ha	day
29,197.30	254	2.09	55

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$M_{lagoon\_aerobic}$	Constant Value	Pond Surface Area	Operation Day
Kg COD	kg COD/ha/day	ha	day
184,739.28	254	2.09	348

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$M_{lagoon\_aerobic}$	Constant Value	Pond Surface Area	Operation Day
Kg COD	kg COD/ha/day	ha	day
30,259.02	254	2.09	57

Material lost through chemical oxidation in lagoon system

$$\boldsymbol{M_{lagoon\_chemical\_ox} = C_{SO_{4in}^{2-}} \times R_{SO_4^{2-}}}$$

Where;

$M_{lagoon\_chemical\_ox}$ = the total amount of organic material lost through chemical oxidation in lagoon system (kg COD).

$C_{SO4^{2-}in}$ = the concentration of sulphate is absorbed (t SO_4^{2-})

$R_{SO4^{2-}}$ = reduction factor for SO_4^{2-} oxidative substance

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$M_{lagoon\_chemical\_ox}$	$C_{SO4^{2-}in}$	$R_{SO4^{2-}}$
Kg COD	$t_{SO4^{2-}}$	kgCOD/ $t_{SO4^{2-}}$
15,629.98	24.01	651

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$M_{lagoon\_chemical\_ox}$	$C_{SO4^{2-}in}$	$R_{SO4^{2-}}$
Kg COD	$t_{SO4^{2-}}$	kgCOD/ $t_{SO4^{2-}}$
193,920.11	297.88	651

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$M_{lagoon\_chemical\_ox}$	$C_{SO4}{}^{2-}{}_{in}$	$R_{SO4}{}^{2-}$
Kg COD	$t_{SO4}{}^{2-}$	kgCOD/ $t_{SO4}{}^{2-}$
50,619.43	77.76	651

Material deposition in lagoon system is:

$$\boldsymbol{M}_{lagoon\_deposition} = \boldsymbol{M}_{lagoon\_input} \times \boldsymbol{R}_{deposition}$$

Where;

$M_{lagoon\_deposition}$ = the total amount of organic material lost through deposition in the lagoon system (kg COD).

M_{lagoon_input} = the input of organic material from the new project anaerobic wastewater treatment facility into the lagoon system (kg COD)

$R_{deposition}$ = the organic material deposition ratio of the lagoon

Note: The organic material deposition ration of the lagoon is equal to the proportion of organic material physically sediment in lagoons within the project boundaries. For the baseline, $R_{deposition}$ is 1.78% mentioned in registered PDD, page 23

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$M_{lagoon\_deposition}$	M_{lagoon_input}	$R_{deposition}$
Kg COD	kg COD	%
31,492.88	1,769,263.10	1.78

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$M_{lagoon\_deposition}$	M_{lagoon_input}	$R_{deposition}$
Kg COD	kg COD	%
253,121.15	14,220,289.09	1.78

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$M_{lagoon\_deposition}$	M_{lagoon_input}	$R_{deposition}$
Kg COD	kg COD	%
31,364.05	1,762,025.11	1.78

According to the calculation above, the conclusion of baseline emission (before the conservativeness check) during this monitoring period; 01/11/2014 – 29/02/2016 (both date are included) can be presented in the table below.

Period	**Baseline emissions or baseline net GHG removals by sinks; before the conservativeness check (tCO_2e)**
01/11/2014 – 31/12/2014 (both dates are included)	10,187
01/01/2015 – 31/12/2015 (both dates are included)	77,086
01/01/2016 – 29/02/2016 (both dates are included)	9,174
Total	**96,447**

Nevertheless, to verify that the equation delivers a conservative estimate of emission reductions, the equation below is taken into account;

$$E_{CH4\_lagoon\_BL} - \left(E_{CH4\_lagoon} + E_{CH4\_NAWTF} + E_{CH4\_coll}\right)$$

Where;

E_{CH4_coll} = the amount of methane expressed in (tCO_2e) contained in the biogas collected from the anaerobic treatment facility

Period of 01/11/2014 – 31/12/2014 (both dates are included)

Result	$E_{CH4\_lagoon\_BL}$	E_{CH4_lagoon}	E_{CH4_NAWTF}	E_{CH4_coll}
-	tCO_2e	tCO_2e	tCO_2e	tCO_2e
-3,054	8,516	908	0	10,662

Period of 01/01/2015 – 31/12/2015 (both dates are included)

Result	$E_{CH4\_lagoon\_BL}$	E_{CH4_lagoon}	E_{CH4_NAWTF}	E_{CH4_coll}
-	tCO_2e	tCO_2e	tCO_2e	tCO_2e
4,834	68,353	3,839	0	59,680

Period of 01/01/2016 – 29/02/2016 (both dates are included)

Result	$E_{CH4\_lagoon\_BL}$	E_{CH4_lagoon}	E_{CH4_NAWTF}	E_{CH4_coll}
-	tCO_2e	tCO_2e	tCO_2e	tCO_2e
1,627	8,291	692	0	5,972

E_{CH4_coll} is obtained from the equation;

$$E_{CH4\_coll} = \left(\left(V_{heat} + V_{elec} + V_{flare}\right) \times C_{CH4} \times \rho_{CH4} \times GWP_{CH4}\right)$$

Period of 01/11/2014 – 31/12/2014 (both dates are included)

E_{CH4_coll}	V_{heat}	V_{power}	V_{flare}	C_{CH4}	ρ_{CH4}	GWP_{CH4}
tCO_2e	Nm^3	Nm^3	Nm^3	%	t_{CH4}/ Nm^3_{CH4}	tCO_2/tCH_4
10,662	1,022,456	0	0	58.19	0.0007168	25

Period of 01/01/2015 – 31/12/2015 (both dates are included)

E_{CH4_coll}	V_{heat}	V_{power}	V_{flare}	C_{CH4}	ρ_{CH4}	GWP_{CH4}
tCO_2e	Nm^3	Nm^3	Nm^3	%	t_{CH4}/ Nm^3_{CH4}	tCO_2/tCH_4
59,680	5,738,038	0	0	58.04	0.0007168	25

Period of 01/01/2016 – 29/02/2016 (both dates are included)

E_{CH4_coll}	V_{heat}	V_{power}	V_{flare}	C_{CH4}	ρ_{CH4}	GWP_{CH4}
tCO_2e	Nm^3	Nm^3	Nm^3	%	t_{CH4}/ Nm^3_{CH4}	tCO_2/tCH_4
5,972	573,706	0	0	58.09	0.0007168	25

As stated in AM0022, Version 04, Page 13, if the difference of the conservativeness verification is '**POSITIVE**', it has to be deducted from emission reduction in order to obtain the final estimation of the emission reduction. Therefore, period from 01/01/2015 to 31/12/2015 and 01/01/2016 to 29/02/2016 have to be deducted from the total baseline emission (as shown in table below).

Therefore, total baseline emissions during this monitoring period; 01/11/2014 – 29/02/2016 (both date are included) is **89,985** tCO_2e

Period	Baseline emissions or baseline net GHG removals by sinks (tCO_2e)
01/11/2014 – 31/12/2014 (both dates are included)	10,187
01/01/2015 – 31/12/2015 (both dates are included)	72,252
01/01/2016 – 29/02/2016 (both dates are included)	7,546
Total	**89,985**

E.2. Calculation of project emissions or actual net GHG removals by sinks

>>

Total project emissions are the sum of fugitive methane emissions from the existing based water treatment system, from possible methane emission from the new anaerobic wastewater treatment facility, from incomplete biogas combustion, biogas leaks.

Total project emissions:

$$\boldsymbol{E}_{project} = \boldsymbol{E}_{CH4\_lagoons} + \boldsymbol{E}_{CH4\_NAWTF} + \boldsymbol{E}_{CH4_{IC}+Leaks}$$

Where;

$E_{project}$	= total project emissions (tCO_2e)
$E_{CH4\_lagoons}$	= the fugitive methane emissions from lagoons (tCO_2e)
E_{CH4_NAWTF}	= the fugitive methane emissions from the new anaerobic wastewater treatment facility (tCO_2e)
$E_{CH4\_IC+Leaks}$	= the methane emissions from inefficient combustion and leaks (tCO_2e)

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$E_{project}$	E_{CH4_lagoon}	E_{CH4_NAWTF}	$E_{CH4\_IC+Leaks}$
tCO_2e	tCO_2e	tCO_2e	tCO_2e
1,824	908	0	916

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$E_{project}$	E_{CH4_lagoon}	E_{CH4_NAWTF}	$E_{CH4\_IC+Leaks}$
tCO_2e	tCO_2e	tCO_2e	tCO_2e
9,288	3,839	0	5,449

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$E_{project}$	E_{CH4_lagoon}	E_{CH4_NAWTF}	$E_{CH4\_IC+Leaks}$
tCO_2e	tCO_2e	tCO_2e	tCO_2e
1,238	692	0	546

Total project emissions during this monitoring period 01/11/2014 – 29/02/2016 (both date are included) is **12,350** tCO_2e

(a) Fugitive methane emission from lagoons

$$\boldsymbol{E}_{CH4\_lagoons} = \boldsymbol{M}_{lagoon\_anaerobic} \times \boldsymbol{EF}_{CH4} \times \boldsymbol{GWP}_{CH4} \div \mathbf{1000}$$

Where;

E_{CH4_lagoon}	= the methane emission from the lagoons (tCO_2e)
$M_{lagoon\_anaerobic}$	= the amount of organic material removed by anaerobic processes in the lagoon system (kg COD)
EF_{CH4}	= the methane emission factor (kg CH_4 / kg COD)
GWP_{CH4}	= the Global Warming Potential of methane (GWP_{CH4} = 25 tCO_2/tCH_4)

Note: A default COD to methane conversion factor of 0.21 kg CH_4 / kg COD is used referred to IPCC, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, page 5.16 and/or methodology AM0022 Version 04, page 3

Period of 01/11/2014 – 31/12/2014 (both dates are included)

E_{CH4_lagoon}	$M_{lagoon\_anaerobic}$	EF_{CH4}	GWP_{CH4}
tCO_2e	kg COD	kg CH_4 / kg COD	tCO_2/tCH_4
908	172,800.66	0.21	25

Period of 01/01/2015 – 31/12/2015 (both dates are included)

E_{CH4_lagoon}	$M_{lagoon\_anaerobic}$	EF_{CH4}	GWP_{CH4}
tCO_2e	kg COD	kg CH_4 / kg COD	tCO_2/tCH_4
3,839	731,071.24	0.21	25

Period of 01/01/2016 – 29/02/2016 (both dates are included)

E_{CH4_lagoon}	$M_{lagoon\_anaerobic}$	EF_{CH4}	GWP_{CH4}
tCO_2e	kg COD	kg CH_4 / kg COD	tCO_2/tCH_4
692	131,774.02	0.21	25

The total fugitive methane emission from lagoons during this monitoring period 01/11/2014 – 29/02/2016 (both date are included) is **5,439** tCO_2e

The total removal of COD from individual lagoons is a function of:

- Aerobic surface oxidation of COD;
- Chemical oxidation in lagoons (where oxidative species such as sulphate are present);
- Sedimentation of material that microbes are unable to degrade before they form a bottom sediment; and
- COD degradation as a result of anaerobic micro bacterial activity.

The mass balance in the considered lagoon system provides the amount of organic material by anaerobic process:

$$\boldsymbol{M}_{lagoon_{anaerobic}} = \boldsymbol{M}_{lagoon_{total}} - \boldsymbol{M}_{lagoon_{aerobic}} - \boldsymbol{M}_{lagoon_{chemical_{ox}}} - \boldsymbol{M}_{lagoon_{deposition}}$$

Where;

$M_{lagoon\_anaerobic}$	= the amount of organic material removed by anaerobic processes in the lagoon system (kg COD).
M_{lagoon_total}	= the total amount of organic material removed in the lagoon system
$M_{lagoon\_aerobic}$	= the amount of organic material degraded aerobically in the lagoon system (kg COD)

$M_{lagoon\_che,mical\_ox}$ = the amount of organic material lost through chemical oxidation in the lagoon system (kg COD)

$M_{lagoon\_deposition}$ = the amount of organic material lost through deposition in the lagoon system (kg COD)

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$M_{lagoon\_anaerobic}$	M_{lagoon_total}	$M_{lagoon\_aerobic}$	$M_{lagoon\_che,mical\_ox}$	$M_{lagoon\_deposition}$
Kg COD	kg COD	Kg COD	Kg COD	Kg COD
172,800.66	206,424.91	29,197.30	599.49	3,827.46

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$M_{lagoon\_anaerobic}$	M_{lagoon_total}	$M_{lagoon\_aerobic}$	$M_{lagoon\_che,mical\_ox}$	$M_{lagoon\_deposition}$
Kg COD	kg COD	Kg COD	Kg COD	Kg COD
731,071.24	951,819.45	184,739.28	18,360.61	17,648.32

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$M_{lagoon\_anaerobic}$	M_{lagoon_total}	$M_{lagoon\_aerobic}$	$M_{lagoon\_che,mical\_ox}$	$M_{lagoon\_deposition}$
Kg COD	kg COD	Kg COD	Kg COD	Kg COD
131,774.02	172,472.56	30,259.02	7,241.60	3,197.93

In order to assess the amount of COD actually entering the anaerobic system (the lagoons) the amount of COD removed as a result of the new wastewater treatment facility must be determined. This is set out in the next equation.

Project organic material entering lagoon system from new anaerobic water treatment system is:

$$\boldsymbol{M_{lagoon\_input} = M_{input\_total} \times (1 - R_{NAWTF})}$$

Where;

M_{lagoon_input} = the input of organic material from the new project anaerobic wastewater treatment facility into the lagoon system (kg COD).

M_{input_total} = the total amount of organic material fed into the new project water treatment facility (kg COD)

R_{NAWTF} = the total organic material removal efficiency of the new project water treatment facility (-).

Note: For the project emission calculation, the R_{NAWTF} is determined according to methodology AM0022; Version 04, page 31

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$\mathbf{M_{lagoon\_input}}$	$\mathbf{M_{input\_total}}$	$\mathbf{R_{NAWTF}}$
Kg COD	kg COD	-
215,025.95	778,423.43	0.724

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$\mathbf{M_{lagoon\_input}}$	$\mathbf{M_{input\_total}}$	$\mathbf{R_{NAWTF}}$
Kg COD	kg COD	-
991,478.60	4,033,621.82	0.754

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$\mathbf{M_{lagoon\_input}}$	$\mathbf{M_{input\_total}}$	$\mathbf{R_{NAWTF}}$
Kg COD	kg COD	-
179,658.92	581,367.97	0.691

Total material removal in lagoon system is:

$$\boldsymbol{M}_{lagoon\_total} = \boldsymbol{M}_{lagoon\_input} \times \boldsymbol{R}_{lagoon}$$

Where;

M_{lagoon_total}	= the total amount of organic material removed in the lagoon system through various routes (kg COD).
M_{lagoon_input}	= the input of organic material from the new project anaerobic wastewater treatment facility into the lagoon system (kg COD)
R_{lagoon}	= the total organic material removal ratio of the lagoon

Note: the total organic material removal ratio of the lagoon is equal to the proportion of organic material removed within the boundaries of the lagoon system under consideration. This factor should be determined by carrying out a series of biochemical tests period to project implementation. This test will determine the COD flows into the system, and the COD flows out of the system boundary. The relative difference of COD flowing in and out of the system over a period of time will allow determination of the Total Organic Material Removed Ratio which already tested during validation process. Refer to registered PDD-page 22, the R_{lagoon} is 96%

Period of 01/11/2014 – 31/12/2014 (both dates are included)

M_{lagoon_total}	M_{lagoon_input}	R_{lagoon}
Kg COD	kg COD	%
206,424.91	215,025.95	96

Period of 01/01/2015 – 31/12/2015 (both dates are included)

M_{lagoon_total}	M_{lagoon_input}	R_{lagoon}
Kg COD	kg COD	%
951,819.45	991,478.60	96

Period of 01/01/2016 – 29/02/2016 (both dates are included)

M_{lagoon_total}	M_{lagoon_input}	R_{lagoon}
Kg COD	kg COD	%
172,472.56	179,658.92	96

Material degraded aerobically in the lagoon system

$$\boldsymbol{M}_{lagoon\_aerobic} = \boldsymbol{254} \times \boldsymbol{Pond\ Surface\ Area} \times \boldsymbol{Operating\ Time}$$

Note: Surface aerobic losses of organic material in pond based system equal to 254 kg COD per hectare of pond surface area and per day is assumed to be lost through aerobic processes.

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$M_{lagoon\_aerobic}$	**Constant Value**	**Pond Surface Area**	**Operation Day**
Kg COD	kg COD/ha/day	ha	day
29,197.30	254	2.09	55

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$M_{lagoon\_aerobic}$	**Constant Value**	**Pond Surface Area**	**Operation Day**
Kg COD	kg COD/ha/day	ha	day
184,739.28	254	2.09	348

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$M_{lagoon\_aerobic}$	Constant Value	Pond Surface Area	Operation Day
Kg COD	kg COD/ha/day	ha	day
30,259.02	254	2.09	57

Material lost through chemical oxidation in lagoon system

$$\boldsymbol{M}_{lagoon\_chemical\_ox} = \boldsymbol{C}_{SO_{4out}^{2-}} \times \boldsymbol{R}_{SO_4^{2-}}$$

Where;

$M_{lagoon\_chemical\_ox}$ = the total amount of organic material lost through chemical oxidation in lagoon system (kg COD).

$C_{SO4^{2-}out}$ = concentrate of oxidative substance SO_4^{2-} at the effluent of the digester (tSO_4^{2})

$R_{SO4^{2-}}$ = reduction factor for SO_4^{2-} oxidative substance

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$M_{lagoon\_chemical\_ox}$	$C_{SO4^{2-}out}$	$R_{SO4^{2-}}$
Kg COD	t/m^3	$kgCOD/t_{SO4^{2-}}$
599.49	0.92	651

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$M_{lagoon\_chemical\_ox}$	$C_{SO4^{2-}out}$	$R_{SO4^{2-}}$
Kg COD	t/m^3	$kgCOD/t_{SO4^{2-}}$
18,360.61	28.20	651

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$M_{lagoon\_chemical\_ox}$	$C_{SO4^{2-}out}$	$R_{SO4^{2-}}$
Kg COD	t/m^3	$kgCOD/t_{SO4^{2-}}$
7,241.60	11.12	651

Material deposition in lagoon system is:

$$\boldsymbol{M}_{lagoon\_deposition} = \boldsymbol{M}_{lagoon\_input} \times \boldsymbol{R}_{deposition}$$

Where;

$M_{lagoon\_deposition}$ = the total amount of organic material lost through deposition in the lagoon system (kg COD).

M_{lagoon_input} = the input of organic material from the new project anaerobic wastewater treatment facility into the lagoon system (kg COD)

$R_{deposition}$ = the organic material deposition ratio of the lagoon

Note: The organic material deposition ration of the lagoon is equal to the proportion of organic material physically sediment in lagoons within the project boundaries. For the baseline, $R_{deposition}$ is 1.78% mentioned in registered PDD, page 23

Period of 01/11/2014 – 31/12/2014 (both dates are included)

$M_{lagoon\_deposition}$	M_{lagoon_input}	$R_{deposition}$
Kg COD	kg COD	%
3,827.46	215,025.95	1.78

Period of 01/01/2015 – 31/12/2015 (both dates are included)

$M_{lagoon\_deposition}$	M_{lagoon_input}	$R_{deposition}$
Kg COD	kg COD	%
17,648.32	991,478.60	1.78

Period of 01/01/2016 – 29/02/2016 (both dates are included)

$M_{lagoon\_deposition}$	M_{lagoon_input}	$R_{deposition}$
Kg COD	kg COD	%
3,197.93	179,658.92	1.78

(b) Methane emissions from new anaerobic wastewater treatment facility

Methane emission from the specific anaerobic wastewater treatment facility that is implemented with the project should be assessed and estimated based on measurements, technology supplier data and expert estimates. They may be neglected if documented evidence for their insignificance is given.

In this case, the leakage of wastewater treatment facility has been inspected everyday internally and inspecting and checking by other party annually. The result during this monitoring period 01/11/2014 – 31/10/2015 (both date are included) founded that there were no leakages. Therefore, the methane emission from new anaerobic wastewater treatment facility is neglected in the project during this monitoring period.

(c) Methane emissions from Inefficient Combustion Emissions

The combustion of biogas methane may give rise to significant methane emission as a result of incomplete or inefficient combustion. The three predominant potential routes for the destruction of methane are:

- Biogas flaring
- Biogas use in heating system
- Biogas use for on-site electricity generation

However, in this project activity there is no electricity generated from biogas; so, the methane emissions from biogas use for on-site electricity generation are not applicable and can be avoided.

$$\boldsymbol{E}_{CH4\_IC+Leak} = \boldsymbol{E}_{CH4\_heat} + \boldsymbol{E}_{CH4\_power} + \boldsymbol{PE}_{flare}$$

Since there is no electricity generated and flaring from biogas in this project, E_{CH4_power} and PE_{flare} = 0
Therefore;

$$\boldsymbol{E}_{CH4\_IC+Leaks} = \left(\sum_{r} \boldsymbol{V}_{heat} \cdot \boldsymbol{C}_{CH4_{heat}} \cdot (1 - f_{heat}) \cdot \boldsymbol{GWP}_{CH4} \right)$$

For this project activity, r = heat only, then

$$\boldsymbol{E}_{CH4\_heat} = \boldsymbol{V}_{heat} \times \boldsymbol{C}_{CH4\_heat} \times (\mathbf{1} - f_{heat}) \times \boldsymbol{GWP}_{CH4}$$

Period of 01/11/2014 – 31/12/2014 (both dates are included)

E_{CH4_heat}	V_{heat}	C_{CH4_heat}	f_{heat}	GWP_{CH4}
tCO_2e	Nm^3	tCH_4/Nm^3	%	tCO_2/tCH_4
915.58	1,022,456	0.000417	91.41	25

Period of 01/01/2015 – 31/12/2015 (both dates are included)

E_{CH4_heat}	V_{heat}	C_{CH4_heat}	f_{heat}	GWP_{CH4}
tCO_2e	Nm^3	tCH_4/Nm^3	%	tCO_2/tCH_4
5,448.82	5,738,038	0.000416	90.87	25

Period of 01/01/2016 – 29/02/2016 (both dates are included)

E_{CH4_heat}	V_{heat}	C_{CH4_heat}	f_{heat}	GWP_{CH4}
tCO_2e	Nm^3	tCH_4/Nm^3	%	tCO_2/tCH_4
545.21	573,706	0.000416	90.87	25

PE_{flare} is the project emission from flaring of the residual gas stream calculated following the procedure described in the “Tool to determine project emission from flaring gases containing Methane”. Since, there were no continuous monitoring takes place; the default flare efficiency prescribed by the tool is utilized. The calculation steps for the project emission are as follows:

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Step 1: Determination of the mass flow rate of the residual gas that is flared

This step calculates the residual gas mass flow rate in each hour h, based on the volumetric flow rate and the density of the residual gas. The density of the residual gas is determined based on the volumetric fraction of all components in the gas

$$\boldsymbol{FM}_{RG,h} = \boldsymbol{\rho}_{RGn,h} \times \boldsymbol{FV}_{RG.h}$$

As stated in the “Tool to determine project emission from flaring gases containing Methane”, a simplified approach may be taken, in which only the volumetric fraction of methane is measured and the difference to 100% is considered as nitrogen (N_2). Hence, step 2 is not applicable to chosen methodological application of the tool and it is not included here for clarity purposes. As the methane combustion efficiency of the flare will not continuously monitored as a default value for open flares will be used, step 3 and 4 are also not applicable and will not be included.

Step 5: Determination of methane mass flow rate in the residual gas on a dry basis

The quantity of methane in the residual gas flowing into the flare is the product of the volumetric flow rate of the residual gas ($FV_{RG,h}$), the volumetric fraction of methane in the residual gas ($fv_{CH4,RG,h}$) and the density of methane ($\rho_{CH4,n,h}$) in the same reference conditions.

$$\boldsymbol{TM}_{RG,h} = \boldsymbol{FV}_{\boldsymbol{RG,h}} \times \mathfrak{f}\boldsymbol{v}_{CH4,RG,h} \times \boldsymbol{\rho}_{CH4,n}$$

Step 6: Determination of the hourly flare efficiency and

Step 7: Calculation of annual project emissions from flaring

Project emission from flaring are calculated as the sum of emission from each hour h, based on the methane flow rate in the residual gas ($TM_{RG,h}$) and the falre efficiency during each hour h, as follows:

$$\boldsymbol{PE}_{flare,y} = \sum_{h=1}^{8760} \boldsymbol{TM}_{RG,h} \cdot (1 - \eta_{flare,h}) \cdot \frac{\boldsymbol{GWP}_{CH4}}{\boldsymbol{1000}}$$

Since, the value is calculated on hourly basis then only one day sample is taken in the monitoring report. However, the detail for calculation is provided in the calculation sheet.

Date where flaring occurred	Time	Gas flow to flare ($FV_{RG,h}$)	Methane Content ($fv_{CH4,RG,h}$)	Minute Flaring	Temp	$TM_{RG,h}$	Hourly flare efficiency	$PE_{flare,h}$	$PE_{flare,y}$	
Unit	hh:mm	Nm^3/h	%	Minute	°C	kg/h	%	tCO_2e/h	tCO_2e	
	1:00	0	0	0		0	0	0		0
	2:00	0	0	0		0	0	0		
	3:00	0	0	0		0	0	0		
	4:00	0	0	0		0	0	0		
	5:00	0	0	0		0	0	0		
	6:00	0	0	0		0	0	0		
	7:00	0	0	0		0	0	0		
	8:00	0	0	0		0	0	0		
	9:00	0	0	0		0	0	0		
	10:00	0	0	0		0	0	0		
	11:00	0	0	0		0	0	0		
01/01/15	12:00	0	0	0		0	0	0		
	13:00	0	0	0		0	0	0		
	14:00	0	0	0		0	0	0		
	15:00	0	0	0		0	0	0		
	16:00	0	0	0		0	0	0		
	17:00	0	0	0		0	0	0		
	18:00	0	0	0		0	0	0		
	19:00	0	0	0		0	0	0		
	20:00	0	0	0		0	0	0		
	21:00	0	0	0		0	0	0		
	22:00	0	0	0		0	0	0		
	23:00	0	0	0		0	0	0		
	0:00	0	0	0		0	0	0	0	

Since, there is no flaring from biogas in this monitoring period 01/11/2014 – 29/02/2016 (both date are included) then PE_{flare} = 0

Period	PE_{flare} (tCO_2e)
01/11/2014 – 31/12/2014 (both date are included)	0
01/01/2015 – 31/12/2015 (both date are included)	0
01/01/2016 – 29/02/2016 (both date are included)	0
Total	**0**

Therefore, total project emissions during this monitoring period; 01/11/2014 – 29/02/2016 (both date are included) is **12,350** tCO_2e

Period	Project emissions or actual net GHG removals by sinks (tCO_2e)
01/11/2014 – 31/12/2014 (both dates are included)	1,824
01/01/2015 – 31/12/2015 (both dates are included)	9,288
01/01/2016 – 29/02/2016 (both dates are included)	1,238
Total	**12,350**

E.3. Calculation of leakage

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Leaks in the biogas system include leaks from any anaerobic digester and leaks from the biogas pipeline delivery system. Leaks monitored on a daily basis and the pipeline pressurized testing annually, as required by AM0022. A conservative value of 1% was included in the ex-ante emissions reductions calculation. However, as the annual test report for pressure test at pipelines could be confirmed that 0% or no leakage can be account for this project.

Methane emissions from the CIGAR are zero in this project. Because the CIGAR is being operated effectively under sub atmospheric pressure, it is reasonable to expect that air will actually be sucked in as opposed to biogas leaking out. The biogas delivery pipe to the off-taker site is also less than 2kms, and thus there is no expectation that there will be leaks of biogas.

E.4. Summary of calculation of emission reductions or net GHG removals by sinks

Item	Baseline emissions or baseline net GHG removals by sinks (tCO_2e)	Project emissions or actual net GHG removals by sinks (tCO_2e)	Leakage (tCO_2e)	GHG emission reductions or net GHG removals by sinks (tCO_2e) achieved in the monitoring period		
				Up to 31/12/2012	From 01/01/2013	Total amount
01/11/14 – 31/12/14 (Both dates are included)	10,187	1,824	0	N/A	8,363	8,363
01/01/15 – 31/12/15 (Both dates are included)	72,252	9,288	0	N/A	62,964	62,964
01/01/16 – 29/02/16 (Both dates are included)	7,546	1,238	0	N/A	6,308	6,308
Total	**89,985**	**12,350**	**0**	**N/A**	**77,635**	**77,635**

E.5. Comparison of actual emission reductions or net GHG removals by sinks with estimates in registered PDD

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The estimated amount of ex-ante emission reductions in the registered PDD is **48,167** tCO_2e (see the UNFCCC project's webpage; http://cdm.unfccc.int/Projects/DB/DNV-CUK1218616482.16/view). This amount was calculated as an annual estimation; however, this monitoring period is from 01/11/2014 – 29/02/2016, which is **486** days.

Therefore, the interpolation to calculate the amount of ex-ante emission reductions during this monitoring period is ER = 48,167tCO_2e × 486days ÷ 365days = **64,134** tCO_2e.

Item	Values estimated in ex ante calculation of registered PDD	Actual values achieved during this monitoring period
Emission reductions or GHG removals by sinks (tCO_2e)	**64,134**	**77,635**

E.6. Remarks on difference from estimated value in registered PDD

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The emission reduction achieved in this monitoring period is **77,635** tCO_2e, which is higher than the ex-ante emission reduction estimated in the registered PDD.

The main reasons for this difference are as follows:

- The assumption of baseline emissions in ex-ant on the total amount of organic material fed into the digester (COD Loading) or the M_{input_total} is one of the factors that led to the significant difference between emission reduction and ex-ante estimation. The COD loading in this monitoring period is equal **17,751,577** kgCOD, while in this ex-ante is equal to **15,013,233** kgCOD. The increasing in COD loading for this monitoring period comparing to the ex-ante is accounted for **18.23%**.
- One of the reasons behind the increasing of COD loading is the increasing in amount of wastewater influent from the host factory. From the ex-ante, the amount of WW_{input} equal to **1,692** m^3/day (registered PDD, page 52), while in this monitoring period the average is **2,427** m^3/day. The increase is accounted for **43.44%**.
- The new amount of Global Warming Potential of Methane (GWP_{CH4}) referred to the UNFCCC; EB69, Annex 3 is also another factor that causes emission reduction to be higher than estimated. The GWP_{CH4} was increased from **21** tCO_2/tCH_4 to be **25** tCO_2/tCH_4. Thus, this led to the increasing in emission reduction from **67,018** tCO_2e (in case of GWP_{CH4} equal to 21 tCO_2e/tCH_4) to **77,635** tCO_2e, which is accounted for **15.84%** increasing.

Annex 1

The downtimes of the project during 01/11/2014 – 29/02/2016 (both dates are included)

Month	Date	Event	Reason
Dec-14	26/12/2014	Host factory shutdown, no influent to the biogas system	Holiday
	27/12/2014	Host factory shutdown, no influent to the biogas system	Holiday
	28/12/2014	Host factory shutdown, no influent to the biogas system	Holiday
	29/12/2014	Host factory shutdown, no influent to the biogas system	Holiday
	30/12/2014	Host factory shutdown, no influent to the biogas system	Holiday
	31/12/2014	Host factory shutdown, no influent to the biogas system	Holiday
Jan-15	1-Jan-2015	Host factory shutdown, no influent to the biogas system	Holiday
	2-Jan-2015	Host factory shutdown, no influent to the biogas system	Holiday
	3-Jan-2015	Host factory shutdown, no influent to the biogas system	Holiday
	4-Jan-2015	Host factory shutdown, no influent to the biogas system	Holiday
Mar-15	25-Mar-2015	Host factory shutdown, no influent to the biogas system	Factory Maintenance
	26-Mar-2015	Host factory shutdown, no influent to the biogas system	Factory Maintenance
	27-Mar-2015	Host factory shutdown, no influent to the biogas system	Factory Maintenance
	28-Mar-2015	Host factory shutdown, no influent to the biogas system	Factory Maintenance
	29-Mar-2015	Host factory shutdown, no influent to the biogas system	Factory Maintenance
	30-Mar-2015	Host factory shutdown, no influent to the biogas system	Factory Maintenance
Apr-15	10-Apr-2015	Host factory shutdown, no influent to the biogas system	Holiday
	11-Apr-2015	Host factory shutdown, no influent to the biogas system	Holiday
	12-Apr-2015	Host factory shutdown, no influent to the biogas system	Holiday
	13-Apr-2015	Host factory shutdown, no influent to the biogas system	Holiday
	14-Apr-2015	Host factory shutdown, no influent to the biogas system	Holiday
	15-Apr-2015	Host factory shutdown, no influent to the biogas system	Holiday
	16-Apr-2015	Host factory shutdown, no influent to the biogas system	Holiday
	17-Apr-2015	Host factory shutdown, no influent to the biogas system	Holiday
Jan-16	2-Jan-2016	Host factory shutdown, no influent to the biogas system	Holiday
	3-Jan-2016	Host factory shutdown, no influent to the biogas system	Holiday
	4-Jan-2016	Host factory shutdown, no influent to the biogas system	Holiday

Appendix 1. Contact information of project participants and responsible persons/entities

Project participant and/or responsible person/ entity	☒ Project participant ☐ Person/entity responsible for completing the CDM-MR-FORM
Organization name	Thai Biogas Energy Company Limited
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Document information

Version	Date	Description
05.1	4 May 2015	Editorial revision to correct version numbering.
05.0	1 April 2015	Revisions to: • Include provisions related to delayed submission of a monitoring plan; • Provisions related to the Host Party; • Remove reference to programme of activities; • Overall editorial improvement.
04.0	25 June 2014	Revisions to: • Include the Attachment: Instructions for filling out the monitoring report form (these instructions supersede the "Guideline: Completing the monitoring report form" (Version 04.0)); • Include provisions related to standardized baselines; • Add contact information on a responsible person(s)/ entity(ies) for completing the CDM-MR-FORM in A.6 and Appendix 1; • Change the reference number from *F-CDM-MR* to *CDM-MR-FORM*; • Editorial improvement.
03.2	5 November 2013	Editorial revision to correct table in page 1.
03.1	2 January 2013	Editorial revision to correct table in section E.5.
03.0	3 December 2012	Revision required to introduce a provision on reporting actual emission reductions or net GHG removals by sinks for the period up to 31 December 2012 and the period from 1 January 2013 onwards (EB70, Annex 11).
02.0	13 March 2012	Revision required ensuring consistency with the "Guidelines for completing the monitoring report form" (EB 66, Annex 20).
01	28 May 2010	EB 54, Annex 34. Initial adoption.

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