

Monitoring Report

Voluntary Carbon Standard 2007.1

Chol Charoen Group Wastewater Treatment with Biogas System I (Cholburi)

Monitoring Period: January 1st, 2009 – September 30th, 2010

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Emission reduction claimed: 46,987 tCO₂e

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1. Project Background

Chol Charoen Group Wastewater Treatment with Biogas System I (Cholburi), hereafter ‘the project activity’, involves biogas recovery and utilisation to an existing open anaerobic effluent treatment system (lagoons). It has been in operation since 7th January 2006 (project start date) at Chol Chareon Co. Ltd., a tapioca starch factory in Cholburi, Thailand.

This starch factory has a design daily production capacity of 240 tonnes of dried starch, generating 2,400 m³ of wastewater per operational day. Under the previous system, wastewater released from the plant was treated in cascading of 13 open anaerobic lagoons. With the depth of these ponds being greater than 2 m from the water surface, and the mean temperature of the area being in the region of 29 °C, there is a suitable anaerobic environment within the ponds, with the anaerobic bacteria, that will result in the breakdown of organic compounds in the wastewater. This consequently leads to biogas generation from the organic content (characterised by chemical oxygen demand or COD) of the wastewater.

The project activity involves modification of the existing open anaerobic lagoon-based process into a closed anaerobic system for treatment of high organic matter wastewater. This is based on Anaerobic Fixed Film Reactor (AFFR) technology; a product from joint research between King Mongkut’s University of Technology Thonburi (KMUTT) and the National Centre for Genetic Engineering and Biotechnology (BIOTEC). In addition, 3 open lagoons at the outlet of the AFFRs were redesigned and converted to covered lagoons in order to increase the gas storage capacity as well as being an emergency wastewater treatment system in the case of malfunction to the AFFR system.

The implementation of AFFR system enables recovery of biogas that would have been released into the atmosphere and utilise it for thermal and electricity generation; the excess biogas (if any) is sent to the enclosed flare system. The hot oil boiler in the existing plant was originally designed to burn fuel oil for heat generation. Under the project activity, the burner is retrofitted with combination fuel burner such that the boiler can be co-fired using both fuel oil and the biogas collected from the reactors. The power produced by the captured biogas facilitates the electricity requirement of the plant; it may in the future be fed to national grid under the pending power purchase agreement with the Provincial Electricity Authority (PEA). With such utilisation of biogas, this project activity does not only achieve GHG emission reduction through avoidance of methane being released into the atmosphere, but also through reduction of fossil fuel consumption with fuel oil and grid electricity being displaced.

By means of this Monitoring Report greenhouse gas emission reductions achieved by the project activity “**Chol Charoen Group Wastewater Treatment with Biogas System I (Cholburi)**” at Chol Charoen Co., Ltd., Thailand are calculated as per the validated PD and as per requirements of the Voluntary Carbon Standard, Version 2007.1.

The project is registered with Markit on 21/05/10. The registration number is 430 ; <https://vcsprojectdatabase1.apx.com/mymodule/ProjectDoc/EditProjectDoc.asp?id1=430>.

Further background information on the project activity can be found in the VCS Project Document (PD) and associated documents, which have been validated as per requirements of the Voluntary Carbon Standard, Version 2007.1. The VCS PD and associated documents have already been made available to the DOE verifying the emission reductions for the period cover by this monitoring report.

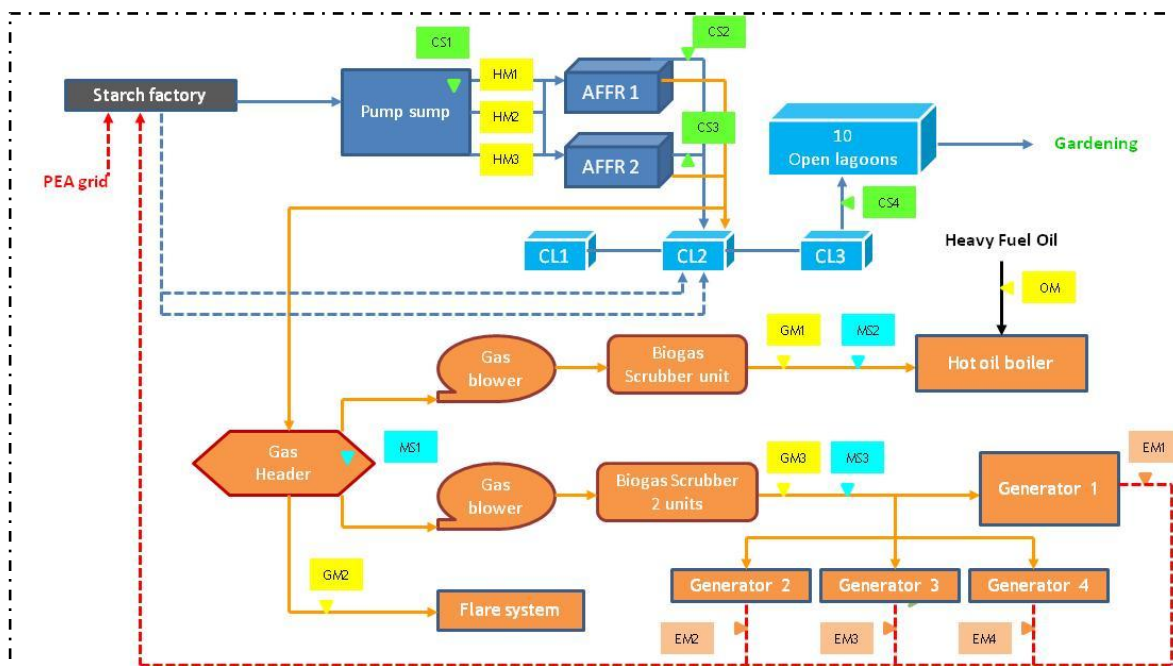


Figure 1: Project activity boundary for monitoring period 01st January 2009 till 08th November 2009

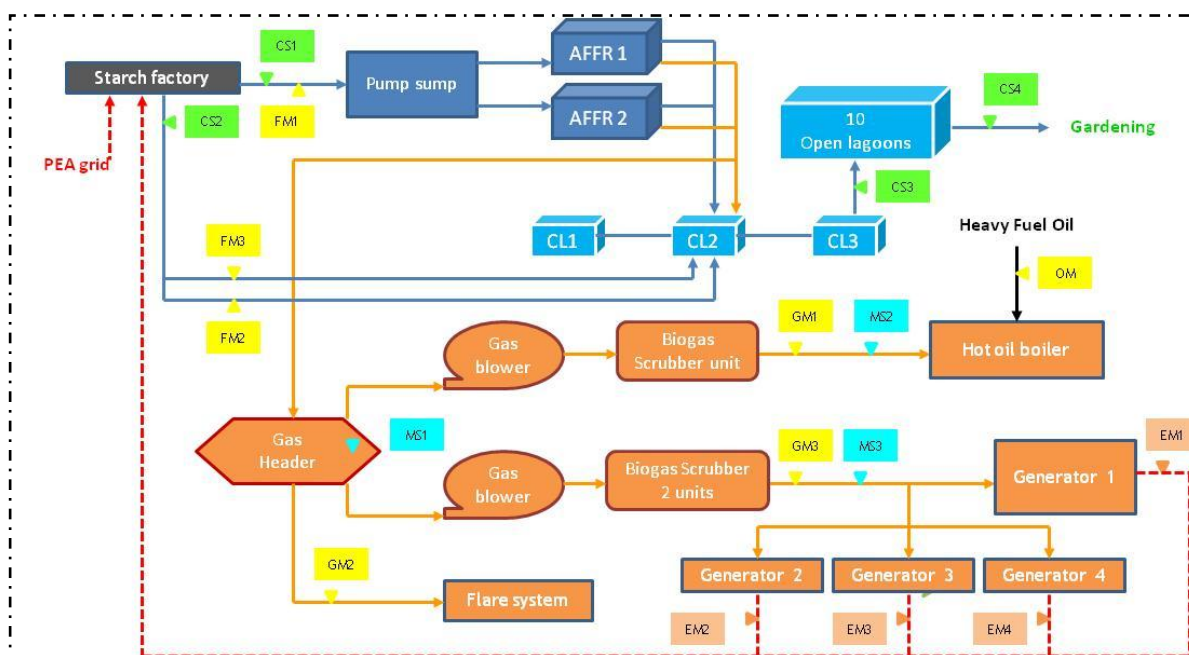


Figure 2: Project activity boundary for monitoring period 09th November 2009 till 30th September 2010

Reference for figure 1 and 2 ;

— wastewater line

— biogas line

- - - electricity line

FM – wastewater flow meter

GM – biogas flow meter

- HM – running hour counter for wastewater pump
- OM – flow meter for heavy fuel oil
- CS – COD sampling point
- MS – Methane sampling point

2. Monitoring Background

Section 3 of the validated VCS PD describes the monitoring plan to be followed by the project activity; section 4 provides all details on the calculation of emission reductions. Both the emission reduction calculations and the monitoring plan were based on the approved CDM methodologies as cited below:

Methane avoidance component:

Type III:	Other project activities
Category III.H:	Methane Recovery in Wastewater Treatment
Reference:	III.H./Version 13, Sectoral Scope 13

Fuel replacement component:

Type I:	Renewable energy projects
Category I.C:	Thermal energy production with or without electricity
Reference:	I.C./Version 15, Sectoral Scope 1

Electricity generation component:

Type I:	Renewable energy projects
Category I.D:	Grid connected renewable electricity generation
Reference:	I.D./Version 14, Sectoral Scope 1

3. Monitoring Results

Monitoring period

This is the second monitoring report (verification) of this project activity. It covers the period from January 1st, 2009 to September 30th, 2010.

Presentation of monitoring results

All monitoring data is available in an Excel spreadsheet. The spreadsheet includes:

- A summary worksheet containing the results of the monitoring for every day of the monitoring period
- Worksheets containing the VER calculations on a yearly basis

Calculation methodology

The project follows the AMS III. H. small scale methodology for Methane Recovery in Wastewater Treatment, Version 13, to estimate the amount of GHG emitted into the atmosphere. The

project also uses AMS I. C. small scale methodology (Version 15) for Thermal energy emissions as well as AMS I. D. (Version 14) for calculating emission from fossil-fuel based grid-connected electricity.

Deviations

All the deviations from the Methodologies or from the Monitoring Plan of the validated VCS PD are clearly explained in the Annex 2 and Annex 3 respectively.

Baseline emissions for the systems affected by the project activity may consist of:

Baseline Emissions for AMS III.H

- (i) Emissions on account of electricity or fossil fuel used ($BE_{power,y}$);
- (ii) Methane emissions from baseline wastewater treatment systems ($BE_{ww,treatment,y}$);
- (iii) Methane emissions from baseline sludge treatment systems ($BE_{s,treatment,y}$);
- (iv) Methane emissions on account of inefficiencies in the baseline wastewater treatment systems and presence of degradable organic carbon in the treated wastewater discharged into river/lake/sea ($BE_{ww,discharge,y}$);
- (v) Methane emissions from the decay of the final sludge generated by the baseline treatment systems ($BE_{s,final,y}$).

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

Where:

Parameter	Details
BE_y	Baseline emissions in year y (tCO ₂ e)
$BE_{power,y}$	Baseline emissions from electricity or fuel consumption in year y (tCO ₂ e)
$BE_{ww,treatment,y}$	Baseline emissions of the wastewater treatment systems affected by the project activity in year y (tCO ₂ e)
$BE_{s,treatment,y}$	Baseline emissions of the sludge treatment systems affected by the project activity in year y (tCO ₂ e)
$BE_{ww,discharge,y}$	Baseline methane emissions from degradable organic carbon in treated wastewater discharged into sea/river/lake in year y (tCO ₂ e).
$BE_{s,final,y}$	Baseline methane emissions from anaerobic decay of the final sludge produced in year y (tCO ₂ e).

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

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

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

Where:

Parameter	Details
$BE_{power,y}$	Baseline emissions from electricity or fuel consumption in year y

BE _{elec, y}	Baseline emissions from electricity consumption in year y
BE _{heat, y}	Baseline emission from fossil fuel consumption in year y

There is no consumption of fossil fuels in waste water treatment system in baseline scenario, thereby BE_{heat, y} = 0.

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

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

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

$$BE_{ww,treatment,y} = \sum Q_{ww,i,y} * COD_{removed,i,y} * MCF_{ww,treatment,BL,i} * B_{o,ww} * UF_{BL} * GWP_{CH4}$$

Where:

Parameter	Details
Q _{ww, i, y}	Volume of wastewater treated in baseline wastewater treatment system i in year y (m³). There are 2 sets of monitoring equipment according to Figure 1,2 ; 1. HM1 , HM2 , HM3 2. FM1 , FM2 , FM3 • 01-Jan-09 to 08-Nov-09 : Q_{ww, i, y} is calculated from HM1,HM2,HM3 as per Annex2–Deviation 1 • 09-Nov-09 to 31-Dec-09 : Q_{ww, i, y} is from reading of FM1 as per Annex3-Deviation 1 • 01-Jan-10 to 30-Sep-10 : Q_{ww, i, y} is total volume of FM1,FM2 and FM3.
COD _{re-moved, i, y}	Chemical oxygen demand removed by baseline treatment system i in year y (tonnes/m³) measured as the difference between inflow COD and the outflow COD in system i i.e lagoon system. During 01-Jan-09 to 08-Nov-09, the daily incoming COD is multiplied by the respective daily waste water flow into AFFR system and summed up to estimate the total daily COD entering the project system over a year y. During 09-Nov-09 to 31-Dec-09 , the daily incoming COD from CS1 is multiplied by the respective daily waste water flow from FM1 for then summed up to estimate the total daily COD entering the project system over a year y. During 01-Jan-10 to 30-Sep-10, the daily incoming COD from CS1,and CS2 is multiplied by the respective daily waste water flow from FM1,FM2 and FM3. Since the spectrophotometer for COD measurement is out of order during 11-Jul-10 to 31-Aug-10, the COD results is calculated according to description in Annex 3 – Deviation 3.

	This is multiplied by the baseline COD reduction efficiency i.e. efficiency of the lagoon system ¹ . The COD load thus obtained is used in estimating baseline emissions.
$MCF_{\text{treatment, BL, i}}$	Methane correction factor for the baseline anaerobic wastewater treatment i (MCF values as per table III.H.1)
i	Index for baseline wastewater treatment system
$B_{o, \text{ww}}$	Methane producing capacity of the wastewater (IPCC lower value for domestic wastewater of 0.21 kg CH ₄ /kg COD)
UF_{BL}	Model correction factor to account for model uncertainties (0.94)
GWP_{CH_4}	Global warming potential (value of 21)

In absence of wastewater flow meter for the wastewater going directly to the Cover Lagoons and of COD measurements during the whole year 2009, no emission reductions for the methane avoidance of the cover lagoons are accounted for during this period.

In the absence of wastewater flow meter for the verification period from January 1st 2009 to November 8th 2009, the running hours of the water pumps sending the wastewater into the AFFRs are monitored and used to calculate the wastewater flow as follows:

$$Q_{\text{ww}, i, y} = FR_{\text{ww}} * 65\% * Hr_{y, \text{ww}}$$

Where,

Parameter	Details
FR_{ww}	Total flow rate capacity of wastewater pump for the AFFR system (m ³ /hour) ²
$Hr_{y, \text{ww}}$	Running hours of the wastewater pump (hour)

This is a temporary deviation until the new wastewater flow meters are installed³ during 01st January 2009 till 08th November 2009. Please refer to Annex – 2, Deviation 1. The deviation was accepted during the validation of the project.

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

There is no baseline sludge treatment system. In addition, there is little generated sludge in the baseline scenario in which it is anyway used aerobically for soil application. Therefore baseline methane emissions from sludge treatment and anaerobic decay of the final sludge ($BE_{\text{s, treatment, y}}$ and $BE_{\text{s, final, y}}$) produced is also neglected.

¹ This refers to reduction efficiency of the baseline system, established in the validated PD as 87.37%

² The flow of each wastewater pump is of a capacity of 50 m³/hour. In total, there are three pumps; pump 1 send wastewater into AFFR1, pump3 sends to AFFR2 and pump 2 can send to either one of the AFFR tanks.

³ All 3 new wastewater flow meters are installed in this 2nd verification period

Baseline Emissions for AMS I.D.

Baseline emissions from electricity generation (BE_y)

As per AMS I. D., paragraph 9, the baseline is the MWh produced by the renewable generating unit multiplied by an emission coefficient as follows:

$$BE_y = BE_{gen,y} = EF_y * EG_y$$

Where:

Parameter	Details
BE_y	Baseline emissions from electricity generation referred as $BE_{gen,y}$ hereafter
EG_y	The quantity of electricity supplied by the project activity during the year “y” (MWh)
EF_y	Thailand National Grid emission factor (tCO_2e/MWh) = 0.5057 tCO_2/MWh (As per the validated PD)

Baseline Emissions for AMS IC

Emissions from steam/heat displacement by the project activity ($BE_{thermal,CO_2,y}$)

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

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

Where:

Parameter	Details
$EG_{thermal}$	The net quantity of steam/heat supplied by the project activity during the year y (TJ)
$\eta_{BL,thermal}$	The efficiency of the plant using fossil fuel that would have been used in the absence of the project activity.
EF_{CO_2}	The CO_2 emission factor per unit of energy of the fuel that would have been used in the baseline plant in (tCO_2 / TJ), obtained from reliable local or national data if available, otherwise, IPCC default emission factors are used.

Since the monitoring mechanism is not available for the measurement of baseline input/output thermal energy, a conservative approach for calculation of $BE_{thermal, CO_2, y}$ has been adopted by the project proponent. Please refer to Deviation -2 of Annex – 2 of the Monitoring report for detailed approach on this deviation, which accepted during the validation of the project.

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

$$BE_{thermalCO_2,y} = ER_{heat,y} = (Q_{starch,y} * Q_{FO,starch} - q_{FO,y}) * D_{FO} * NCV_{FO} * EF_{CO_2} / 10^6$$

Where:

Parameter	Details
$Q_{starch,y}$	Quantity of dry starch produced in year “y” (tonnes)
$Q_{FO,starch}$	Quantity of fossil fuel per unit of dry starch (liter/tonne)
$q_{FO,y}$	Quantity of fossil fuel consumed at the project site in year “y” (litres)
D_{FO}	Density of fossil fuel (kg/litre)
NCV_{FO}	Net Calorific value of the fuel oil (TJ/ton)

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

As per paragraph 18 of AMS I.D. Version 14, “for projects consuming biomass a specific fuel consumption of each type of fuel to be used should be specified ex ante”.

Refer to the service report of Generator maintenance service supplier on 26th -27th July 2009 , the specific biogas consumption for each generator is shown below.

1. Generator no. 1
Guascor : SFGLD 560/55
Technical specification : 433.44⁴ Nm³ biogas at 952 kW or 0.455 Nm³/kW
Actual consumption : 479 Nm³ at 943 kW or 0.508 Nm³/kW
2. Generator no. 2,3
Shengli : 500GF1-1RZ (same model for generator no.2 and 3)
Technical specification : 234.11⁵ Nm³ biogas at 500 kW or 0.468 Nm³/kW
Actual consumption : 272 Nm³ at 450 kW or 0.604 Nm³/kW

Project activity emissions from the systems affected by the project activity are:

- (i) CO₂ emissions on account of power and fuel used by the project activity facilities (PE_{power, y});
- (ii) Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery in the project situation (PE_{ww, treatment, y});
- (iii) Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery in the project situation (PE_{s, treatment, y});
- (iv) Methane emissions on account of inefficiency of the project activity wastewater treatment systems and presence of degradable organic carbon in treated wastewater (PE_{ww, discharge, y});
- (v) Methane emissions from the decay of the final sludge generated by the project activity treatment systems (PE_{s, final, y});
- (vi) Methane fugitive emissions on account of inefficiencies in capture systems (PE_{fugitive, y});

⁴ The biogas consumption specification is 2,520 kW , the unit conversion is based on 1 watt = 1 J/s , 1 kW/h = 3.60*10⁶ J/h while the LHV of biogas is 20.93 MJ/Nm³

⁵ The technical specification identifies 9.80 MJ/kWh

- (vii) Methane emissions due to incomplete flaring ($PE_{\text{flaring}, y}$);
- (viii) Methane emissions from biomass stored under anaerobic conditions which does not take place in the baseline situation ($PE_{\text{biomass}, y}$).

$$PE_y = \begin{cases} PE_{\text{power}, y} + PE_{\text{ww}, \text{treatment}, y} + PE_{\text{s}, \text{treatment}, y} + PE_{\text{ww}, \text{discharge}} + PE_{\text{s}, \text{final}} + \\ PE_{\text{fugitive}, y} + PE_{\text{biomass}, y} + PE_{\text{flaring}, y} \end{cases}$$

Where:

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

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

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

$$PE_{\text{power}, y} = EF_y * EC_y$$

Where:

Parameter	Details
EC_y	Electricity consumption by the project activity (MWh)
EF_y	Thailand National Grid emission factor (tCO ₂ e/MWh) = 0.5057 tCO ₂ /MWh (As per the validated PD)

In the absence of electric meter for the electricity consumption of project activity, maximum rated consumption shall be used to calculate the emissions from $PE_{\text{power}, y}$ as per prescribed method in paragraph 35 of AMS III.H., as follows:

$$PE_{\text{power}, y} = \frac{\sum P_{el} * 110\% * 8,760 * EF_y}{1000}$$

Where:

Parameter	Details
P_{el}	Total electrical capacity of the equipments installed in the project activity (kW) – for reference, 116 kW will be used for this project activity
EF_y	Thailand National Grid emission factor (tCO ₂ e/MWh)

Taking into account the distribution losses, 10% has been added to the total electricity consumption. As well, the calculated electricity consumption is based on an assumption that the electrical appliances will be running at full capacity for the entire year.

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

Methane emissions from wastewater treatment systems affected by the project activity are calculated as per the paragraph 20, AMS III.H. The following equation is used.

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

Where:

Parameter	Details
$Q_{ww,k,y}$	Volume of wastewater treated in project wastewater treatment system k is monitored on daily basis in a year y (m^3). As there is no waste water lost during the treatment process in project system, as per hydrological balance, the waste water coming out of a particular system is same as waste water going in. There are 2 sets of monitoring equipment according to Figure 1,2 ; HM1 , HM2 , HM3 FM1 , FM2 , FM3 • 01-Jan-09 to 08-Nov-09 : $Q_{ww,i,y}$ is calculated from HM1,HM2,HM3 as per Annex2–Deviation 1 • 09-Nov-09 to 31-Dec-09 : $Q_{ww,i,y}$ is from reading of FM1 as per Annex3-Deviation 1 • 01-Jan-10 to 30-Sep-10: $Q_{ww,i,y}$ is total volume of FM1, FM2 and FM3.
$COD_{y, removed, PJ, k}$	Chemical oxygen demand removed by project wastewater treatment system k on daily basis (tonnes/ m^3), measured as the difference between inflow COD and the outflow COD in system k. For the calculation of $PE_{ww,treatment,y}$, system k refers to the post project treatment of waste water in open lagoons.
$B_{o,ww}$	Methane producing capacity of the wastewater (IPCC default value of 0.21 kg CH_4 /kg COD)
$MCF_{ww,treatment,PJ,k}$	Methane correction factor for project wastewater treatment system k
UF_{PJ}	Model correction factor to account for model uncertainties (1.06)
GWP_{CH4}	Global Warming Potential for methane (value of 21 is used)

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

The project activity does not include sludge treatment system, therefore the emission from sludge treatment system are omitted.

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

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

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

If the sludge is controlled combusted, disposed in a landfill with methane recovery, or used for soil application, this term can be neglected, and the final disposal of the sludge shall be monitored during the crediting period.

In this project activity, the final sludge produced is sold to local farmers for soil application. Sale receipts of sludge are kept for monitoring purpose. With this term being neglected, $PE_{s,final,y} = 0$.

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

Project activity emissions from methane release in capture systems are determined as per paragraph 27 of AMS III.H., as given below.

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

Where:

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

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

These emissions are calculated as follows:

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

Where:

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

Note that:

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

Where:

Parameter	Details
$COD_{y, removed, PJ, k, y}$	The chemical oxygen demand removed ⁶ by the treatment system k of the project activity equipped with biogas recovery in the year y (tonnes/m ³). System k in this case refer to the AFFR and Covered Lagoon (CL) system, thus there are three components corresponding to AFFR1, AFFR2 and CL. The total load going in and coming out of each AFFR and CL is calculated based on COD readings and waste water flow readings on daily basis. Since the COD reactor for COD measurement is out of order during 11-Jul-10 to 31-Aug-10, the COD results are calculated according to description in Annex 3 – Deviation 3. Conservative COD values of COD are assumed based on the lower limit of the 95% confidence interval from available set of readings.
$MCF_{ww, treatment, PJ, k}$	Methane correction factor for the project wastewater treatment system k equipped with biogas recovery equipment (MCF values as per table III.H.1)
UF_{PJ}	Model correction factor to account for model uncertainties (1.06)
$B_{o, ww}$	Methane producing capacity of the wastewater (IPCC default value of 0.21 kg CH ₄ /kg COD)

b. Fugitive emissions through capture and utilisation/combustion/flare inefficiencies in the anaerobic sludge treatment systems in the year y ($PE_{fugitive, s, y}$):

Sludge will be used only for land application, therefore no sludge treatment envisaged in the project activity. Therefore emission from sludge treatment is omitted.

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

Methane emissions due to incomplete flaring in year y are calculated as per the “Tool to determine project emissions from flaring gases containing methane” (tCO₂e). The project proponent has installed an enclosed flare system. For the determination of the flare efficiency, the default value of 90% (for enclosed flare) will be used for the calculation of project emissions from flaring gases. Steps 1 to 7 of the “Tool to determine project emissions from flaring gases containing methane” (hereafter the flaring tool) are used to determine the project emissions from flaring of the residual gas stream.

As per the Step 6 of the flaring tool for determination of the hourly flare efficiency, a default value of 90% is to be used provided that it can be demonstrated that the flare is operational. If the flare is not operational, the default value to be adopted for flare efficiency is 0%. For the current verification period, the calculation of this parameter is not necessary with there being no excess biogas available. To elaborate further, the biogas has not been sent to flare for more than 2 years (since 3rd June 2006). This was also presented to DOE during validation/verification site visit and an interview with project owner as well as the provision of documentary evidence in the form of log sheet to substantiate the same. Reason for the stoppage in flare operation is due to the insufficient amount of biogas to be utilised in the boiler of ≈3.78MWth capacity and gas engine sets with capacity of ≈2MWe. This is in fact confirmed by ex-post data in which total electricity generated in both 2007 (3,429 MWh) and 2008 (2,684 MWh) is much lower than its potential as per total installed capacity of ≈2MW (i.e. around 15 to 20% PLF). As well, the fact that 3 open lagoons have been converted into covered lagoons has increased the gas storage capacity of the project activity, thus in the case that the biogas utilisation devices are not under operation, the biogas can still be stored for a considerable period.

⁶ Difference between COD of influent and effluent from the system

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

Biomass storage is not envisaged in the project activity. Therefore methane emissions from biomass stored under anaerobic conditions which does not take place in the baseline situation are omitted.

Leakage (LE_y):

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

Emission Reduction (ER_y):

According to the paragraph 31 AMS III.H., emission reduction achieved by the project activity is limited to the ex-post calculated baseline emissions minus project emissions using the actual monitored data for the project activity. Emission reductions achieved on any year are the lowest value of the following;

$$ER_{y, \text{ex post}} = \min((BE_{y, \text{ex post}} - PE_{y, \text{ex post}} - LE_{y, \text{ex post}}), (MD_y - PE_{\text{power}, y} - PE_{\text{biomass}, y} - LE_{y, \text{ex post}}))$$

Where:

Parameter	Details
$ER_{y, \text{ex post}}$	Emission reductions achieved by the project activity based on monitored values for year y (tCO ₂ e)
$BE_{y, \text{ex post}}$	Baseline emissions calculated as per paragraph ex post monitored values
$PE_{y, \text{ex post}}$	Project emissions calculated as per paragraph ex post monitored values
MD_y	Methane captured and destroyed/gainfully used by the project activity in the year y

As per paragraph 32 in AMS III.H., in case of flaring/combustion MD_y will be measured using the conditions of the flaring process:

$$MD_y = BG_{\text{burnt}, y} * w_{CH_4, y} * D_{CH_4} * FE * GWP_{CH_4}$$

Where:

Parameter	Details
$BG_{\text{burnt}, y}$	Biogas flared/combusted in year y (m ³)
w_{CH_4}	Methane content in the biogas in the year y (mass fraction)
D_{CH_4}	Density of methane at the temperature and pressure of the biogas in the year y (tonnes/m ³)
FE	Flare efficiency in year y (fraction)

As per answers to authors of query by the SSC WG “in the case that the biogas is combusted for a gainful use of the released energy as in an engine or a power plant, a destruction efficiency of 100% can be used for the portion of biogas that is combusted when applying AMS III.H., i.e. use a value of 100% for FE in equation 16 in paragraph 32 for the portion of biogas that is combusted for a gainful use”⁷. Based on this, the alternative MD_y value is deviated from the approved methodology and can be calculated as follows:

$$MD_y = W_{CH_4} * D_{CH_4} * GWP_{CH_4} * [(BG_{TOFlare} * FE) + (BG_{combusted} * DE)]$$

Where:

Parameter	Details
BG _{TOFlare}	Biogas sent to flare in year y (Nm ³ /year)
FE	Flare efficiency (fraction)
BG _{combusted, y}	Biogas combusted for gainful use in year y (Nm ³ /year)
DE	Destruction efficiency of biogas combusted for a gainful use (fraction)

With reference to the clarification made by the SSC WG, this approach can be considered as not impact negatively on the conservativeness of the applied methodology’s criteria and procedures to quantify data leading to GHG emission reductions or removals. The clarification from EB, as referenced above, can be used to substantiate this statement.

The approach is explained in the deviation 3 of Annex 2.

For the current monitoring period the biogas is converted from m³ to Nm³ using a conservative factor, adjusting the temperature of normal conditions and project site conditions. The approach is explained in detail in the deviation 4 of Annex 2.

Monitoring and default parameters used

Please refer to Section 3.3 of the VCS PD for an elaboration of parameters relevant to this project activity. A summary of the same is tables below. In the case of monitoring parameters which are not being monitored, they are either not applicable or the project proponents have deviated from the methodologies using conservative approaches.

⁷ <http://cdm.unfccc.int/UserManagement/FileStorage/VNWAGY8MS92ZXDKUHEF5LB07QICT1P>

Data and parameters determined at registration and not monitored during the monitoring period, including default values and factors

Data / Parameter:	GWP_{CH4}
Data unit:	-
Description:	Global warning potential of methane gas
Source of data used:	Default value from AMS III.H.
Value(s) :	21
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline and project emission calculation
Additional comment:	

Data / Parameter:	B_{0, ww}
Data unit:	kg CH ₄ /kg COD
Description:	Methane producing capacity of the COD in wastewater
Source of data used:	IPCC default value, corrected as per methodology AMS III.H., is used for estimation
Value(s) :	0.21 kg CH ₄ /kg COD
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation
Additional comment:	

Data / Parameter:	UF_{BL}
Data unit:	Factor
Description:	Model correction factor to account for model uncertainties
Source of data used:	AMS III.H., Version 13
Value(s) :	0.94
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation
Additional comment:	

Data / Parameter:	UF_{PJ}
Data unit:	Factor
Description:	Model correction factor to account for model uncertainties
Source of data used:	AMS III.H., Version 13
Value(s) :	1.06
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation
Additional comment:	

Data / Parameter:	$MCF_{ww, treatment, BL, i}$
Data unit:	Fraction
Description:	Methane correction factor for the baseline anaerobic wastewater treatment systems
Source of data used:	Table III.H.1. of AMS III.H., Version 13 page no 6
Value(s) :	0.8
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation
Additional comment:	IPCC Default values from chapter 6 of volume 5 page no 6.21. Waste in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Data / Parameter:	$MCF_{ww, treatment, PJ, k}$
Data unit:	Fraction
Description:	Methane correction factor for project wastewater treatment system k
Source of data used:	Table III.H.1. of AMS III.H., Version 13 page no 6
Value(s) :	0.8
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation
Additional comment:	IPCC Default values from chapter 6 of volume 5 page no 6.21. Waste in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Data / Parameter:	COD removal efficiency
Data unit:	%
Description:	COD removal efficiency of baseline wastewater treatment system
Source of data used:	Measured – Colorimetric analysis
Value(s) :	87%
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation
Additional comment:	

Data / Parameter:	CFE_{ww}
Data unit:	Fraction
Description:	Capture efficiency of the biogas recovery equipment in the wastewater treatment systems.
Source of data used:	Equation 10 in AMS III.H, Version 13 methodology (page 11)
Value(s) :	0.9
Indicate what the data	Project emission calculation

are used for (Baseline/ Project/ Leakage emis- sion calculations)	
Additional comment:	

Data / Parameter:	EF_y
Data unit:	t CO ₂ /MWh
Description:	CO ₂ emission factor for grid power
Source of data used:	“The calculation of emission factor for an electricity system in Thailand 2007”, DEDE
Value(s) :	0.5057
Indicate what the data are used for (Baseline/ Project/ Leakage emis- sion calculations)	Baseline emission calculation
Additional comment:	Conservative choice and publically available data.

Data / Parameter:	EF_{CO2}
Data unit:	tCO ₂ /TJ
Description:	Emission factor of fossil fuel replaced – Residual Fuel oil
Source of data used:	IPCC 2006 default value for residual fuel oil, Volume 2, Chapter 1, 1.23
Value(s) :	77.4 tCO ₂ /TJ
Indicate what the data are used for (Baseline/ Project/ Leakage emis- sion calculations)	Baseline emission calculation
Additional comment:	

Data / Parameter:	NCV_{FO}
Data unit:	GJ/tonne
Description:	NCV of fuel oil i.e. fossil fuel displaced by biogas
Source of data used:	‘Thailand Energy Situation 2009’ , pg.32 http://www.dede.go.th/dede/images/stories/stat_dede/ThailEnSituation2009.pdf
Value(s) :	42.244
Indicate what the data are used for (Baseline/ Project/ Leakage emis- sion calculations)	Baseline emission calculation
Additional comment:	

Data / Parameter:	NCV_{biogas}
Data unit:	MJ/Nm ³
Description:	NCV of biogas
Source of data used:	‘Thailand Energy Situation 2009’ , pg.32 http://www.dede.go.th/dede/images/stories/stat_dede/ThailEnSituation2009.pdf
Value(s) :	20.93
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation
Additional comment:	

Data / Parameter:	q_{FO, starch}
Data unit:	l/tonne
Description:	Liters of fossil fuel required per tonne of dry starch historically
Source of data used:	Historic data
Value(s) :	34.3 litres/tonne
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation
Additional comment:	

Data / Parameter:	D_{CH4}
Data unit:	Kg/m ³
Description:	Density of methane at normal conditions
Source of data used:	Tool to determine project emissions from flaring gases containing methane.
Value(s) :	0.716
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation
Additional comment:	<u>CDM EB as per EB28 Meeting report (Annex 13)</u>

Data / Parameter:	D_{FO}
Data unit:	Kg/liter
Description:	Density of fuel oil
Source of data used:	http://www.engineeringtoolbox.com/fuels-densities-specific-volumes-d_166.html
Value(s) :	0.93
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation
Additional comment:	

Data / Parameter:	FE
Data unit:	%
Description:	Flare efficiency
Source of data used:	Tool to determine project emissions from flaring gases containing methane.
Value(s) :	90%
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation
Additional comment:	Default value for enclosed as per Tool to determine project emissions from flaring gases containing methane has been applied

Data / Parameter:	DE
Data unit:	%
Description:	Destruction efficiency of the electricity generator
Source of data used:	SSC WG
Value(s) :	100%
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation
Additional comment:	According to clarification from SSC WG “ <i>in the case that the biogas is combusted for a gainful use of the released energy as in an engine or a power plant, a destruction efficiency of 100% can be used for the portion of biogas that is combusted when applying AMS III.H., i.e. use a value of 100% for FE in equation 16 in paragraph 32 for the portion of biogas that is combusted for a gainful use</i> ” ⁸

Data / Parameter:	FR_{ww}
Data unit:	m ³ /hour
Description:	Total flow rate capacity of wastewater pumps
Source of data used:	Nameplates of equipments
Value(s) :	50 m ³ /hour
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline and project emission calculation

⁸ <http://cdm.unfccc.int/UserManagement/FileStorage/VNWAGY8MS92ZXDKUHEF5LB07QICT1P>

Additional comment:	
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Data / Parameter:	P_{el}
Data unit:	kW
Description:	Total electrical capacity of the equipments installed in the project activity
Source of data used:	Plant data
Value(s) :	139.25 kW
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation
Additional comment:	

Monitored and calculated parameters:

Data / Parameter:	Q _{ww, y}																	
Data unit:	m ³																	
Description:	Volume of wastewater treated in the year y																	
Measured /Calculated /Default:	Measured																	
Source of data:	01-Jan-09 to 08-Nov-09: Q_{ww, i, y} is calculated from HM1,HM2,HM3 as per Annex2–Deviation 1 09-Nov-09 to 31-Dec-09: Q_{ww, i, y} is from reading of FM1 as per Annex3-Deviation 1 01-Jan-10 to 30-Sep-10: Q_{ww, i, y} is total volume of FM1,FM2 and FM3																	
Value(s) of monitored parameter:	<table><tr><th>Parameter</th><th>Jan’09 – Dec’09</th><th>Jan’10 – Sep’10</th></tr><tr><td>Q_{ww, y}</td><td>299,041</td><td>540,411</td></tr></table>			Parameter	Jan’09 – Dec’09	Jan’10 – Sep’10	Q _{ww, y}	299,041	540,411									
Parameter	Jan’09 – Dec’09	Jan’10 – Sep’10																
Q _{ww, y}	299,041	540,411																
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline and project emission calculation																	
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	<table><tr><th>Meter</th><th>FM1</th><th>FM2</th></tr><tr><td>Type of meter</td><td>Liquid flow meter</td><td>Liquid flow meter</td></tr><tr><td>Serial number</td><td>YAL1263</td><td>YAL1624</td></tr><tr><td>Accuracy</td><td>± 0.2%⁹</td><td>± 0.2%</td></tr><tr><td>Calibration frequency</td><td>once every 3 years</td><td>Once 3 every years</td></tr></table>			Meter	FM1	FM2	Type of meter	Liquid flow meter	Liquid flow meter	Serial number	YAL1263	YAL1624	Accuracy	± 0.2% ⁹	± 0.2%	Calibration frequency	once every 3 years	Once 3 every years
Meter	FM1	FM2																
Type of meter	Liquid flow meter	Liquid flow meter																
Serial number	YAL1263	YAL1624																
Accuracy	± 0.2% ⁹	± 0.2%																
Calibration frequency	once every 3 years	Once 3 every years																

⁹ Reference : Technical specification from Euromag for sensor wafer MUT 1000EL

	Initial calibration	07/09/09	07/09/09
	Last calibration	21/10/10	21/10/10
	Meter	FM3	
	Type of meter	Liquid flow meter	
	Serial number	YAL1265	
	Accuracy	± 0.2%	
	Initial calibration	07/09/09	
	Calibration frequency	once every year	
Last calibration	21/10/10		
Measuring/ Reading/ Recording frequency:	Continuous measuring / Daily recording		
Calculation method (if applicable):	Annex 2 – Deviation 1 Annex 3 – Deviation 1		
QA/QC procedures applied:	The flow meter is calibrated at least once every 3 years.		

Data / Parameter:	HR _{ww, y}																	
Data unit:	Hour																	
Description:	Running hours of the wastewater pumps																	
Measured /Calculated /Default:	Measured																	
Source of data:	Running hour counter of wastewater pump																	
Value(s) of monitored parameter:	<table><tr><td>Parameter</td><td>Jan'09 – Dec'09</td><td>Jan'10 – Sep'10</td></tr><tr><td>HR_{ww, y}</td><td>8,630</td><td>Not monitored</td></tr></table>			Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10	HR _{ww, y}	8,630	Not monitored									
Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10																
HR _{ww, y}	8,630	Not monitored																
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline and project emission calculation																	
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	<table><tr><td>Meter</td><td colspan="2">HM1 , HM2 , HM3</td></tr><tr><td>Type of meter</td><td colspan="2">Electromechanical counter</td></tr><tr><td>Serial number</td><td colspan="2">-</td></tr><tr><td>Calibration frequency</td><td colspan="2">-</td></tr><tr><td>Last calibration</td><td colspan="2">13-Sep-09</td></tr></table>			Meter	HM1 , HM2 , HM3		Type of meter	Electromechanical counter		Serial number	-		Calibration frequency	-		Last calibration	13-Sep-09	
Meter	HM1 , HM2 , HM3																	
Type of meter	Electromechanical counter																	
Serial number	-																	
Calibration frequency	-																	
Last calibration	13-Sep-09																	
Measuring/ Reading/ Recording frequency:	Continuous measuring / daily recording																	
Calculation method (if applicable):																		
QA/QC procedures applied:	The discount factor is used to multiply the parameter HR _{ww, y} , This in turn will discount our emission reductions for the first verification period.																	

Data / Parameter:	COD_{ww, untreated, y}
Data unit:	mg/l

Description:	COD of wastewater entering the treatment plant																
Measured /Calculated /Default:	Measured																
Source of data:	Colorimetric analysis																
Value(s) of monitored parameter:	<table><tr><th>Parameter</th><th>Jan'09 – Dec'09</th><th>Jan'10 – Sep'10</th></tr><tr><td>COD_{ww, untreated, y}</td><td>27,130</td><td>26,406</td></tr></table>			Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10	COD _{ww, untreated, y}	27,130	26,406								
Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10															
COD _{ww, untreated, y}	27,130	26,406															
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline and project emission calculation																
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	<table><tr><th>Meter</th><th>Spectrophotometer</th></tr><tr><td>Type of meter</td><td>Photometer</td></tr><tr><td>Serial number</td><td>050100006010</td></tr><tr><td>Accuracy</td><td>± 1 nm of wave length¹⁰ or ± 0.13%¹¹</td></tr><tr><td>Calibration frequency</td><td>once a year</td></tr><tr><td>Previous calibration</td><td>03-Oct-07 04-Jun-09</td></tr><tr><td>Last calibration</td><td>14-May-10</td></tr></table>			Meter	Spectrophotometer	Type of meter	Photometer	Serial number	050100006010	Accuracy	± 1 nm of wave length ¹⁰ or ± 0.13% ¹¹	Calibration frequency	once a year	Previous calibration	03-Oct-07 04-Jun-09	Last calibration	14-May-10
Meter	Spectrophotometer																
Type of meter	Photometer																
Serial number	050100006010																
Accuracy	± 1 nm of wave length ¹⁰ or ± 0.13% ¹¹																
Calibration frequency	once a year																
Previous calibration	03-Oct-07 04-Jun-09																
Last calibration	14-May-10																
Measuring/ Reading/ Recording frequency:	Measurement in every operational day																
Calculation method (if applicable):																	
QA/QC procedures applied:	Calibration at least once a year																
Any comment	Because of the delayed calibration, the correction factor is applied for COD result on 01-Jan-09 to 04-Jun-09 as per guidelines EB 52 , annex 60. - Applied -0.13% for BE calculation - Applied +0.13% for PE emission calculation According to HACH instruction manual, the accuracy of the measurement is ±0.1 nm or Δ 0.010 Abs. The procedure for COD testing method program 435 says that the sensitivity of the Δ 0.010 Abs is equal to 20 mg/l of COD. The maximum COD reading for this program is 15,000 mg/l. So the accuracy for COD measurement will be 20/15,000 or 0.13%.																

Data / Parameter:	COD _{removed, PJ, k, y}
Data unit:	tonnes/m ³
Description:	COD of water exiting the AFFR treatment process
Measured /Calculated	Measured

¹⁰ Reference : Technical specification of HACH spectrophotometer DR/2400

¹¹ Reference : Procedure manual for HACH spectrophotometer DR/2400 – COD program 235

/Default:																	
Source of data:	Colorimetric analysis																
Value(s) of monitored parameter:	<table><tr><td>Parameter</td><td>Jan'09 – Dec'09</td><td>Jan'10 – Sep'10</td></tr><tr><td>COD removed, PJ, k, y</td><td>0.0243</td><td>0.0192</td></tr></table>			Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10	COD removed, PJ, k, y	0.0243	0.0192								
Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10															
COD removed, PJ, k, y	0.0243	0.0192															
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation																
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	<table><tr><td>Meter</td><td>Spectrophotometer</td></tr><tr><td>Type of meter</td><td>Photometer</td></tr><tr><td>Serial number</td><td>050100006010</td></tr><tr><td>Accuracy</td><td>± 1 nm of wave length or ± 0.13%</td></tr><tr><td>Calibration frequency</td><td>once a year</td></tr><tr><td>Previous calibration</td><td>03-Oct-07 04-Jun-09</td></tr><tr><td>Last calibration</td><td>14-May-10</td></tr></table>			Meter	Spectrophotometer	Type of meter	Photometer	Serial number	050100006010	Accuracy	± 1 nm of wave length or ± 0.13%	Calibration frequency	once a year	Previous calibration	03-Oct-07 04-Jun-09	Last calibration	14-May-10
Meter	Spectrophotometer																
Type of meter	Photometer																
Serial number	050100006010																
Accuracy	± 1 nm of wave length or ± 0.13%																
Calibration frequency	once a year																
Previous calibration	03-Oct-07 04-Jun-09																
Last calibration	14-May-10																
Measuring/ Reading/ Recording frequency:	Measurement in every operational day																
Calculation method (if applicable):	Measured as the difference between inflow COD and the outflow COD of the AFFR system																
QA/QC procedures applied:	Calibration at least once a year																

Data / Parameter:	BG _{combusted, y}		
Data unit:	Nm ³		
Description:	Amount of biogas combusted for gainful use		
Measured /Calculated /Default:	Measured		
Source of data:	Calculated from a summation of total biogas utilized in boiler and generation sets		
Value(s) of monitored parameter:			
	Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10
	BG _{combusted, y}	3,432,932	3,045,292
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation		
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)			
	Meter	GM1	GM3
	Type of meter	Differential Pressure transmitter	Thermal mass
	Serial number	FE-102	7565

	Accuracy	$\pm 1\%^{12}$	$\pm 1\%^{13}$
	Calibration frequency	once every 3 years	once every 2 years
	Last calibration	12/01/10	27/10/10
Measuring/ Reading/ Recording frequency:	Continuous measuring / daily recording		
Calculation method (if applicable):	The correction factor applied to adjust temperature difference between Nm ³ conditions and m3 is done conservatively as explained in Annex 2 – Deviation 4		
QA/QC procedures applied:	The flow meter is calibrated at least once every 3 years.		

Data / Parameter:	BG _{TOFlare, y}														
Data unit:	Nm ³														
Description:	Amount of biogas flared														
Measured /Calculated /Default:	Measured														
Source of data:	Biogas flow meter														
Value(s) of monitored parameter:	<table><tr><th>Parameter</th><th>Jan’09 – Dec’09</th><th>Jan’10 – Sep’10</th></tr><tr><td>BG_{TOFlare, y}</td><td>0</td><td>0</td></tr></table>			Parameter	Jan’09 – Dec’09	Jan’10 – Sep’10	BG _{TOFlare, y}	0	0						
Parameter	Jan’09 – Dec’09	Jan’10 – Sep’10													
BG _{TOFlare, y}	0	0													
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation														
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	<table><tr><th>Meter</th><th>GM2</th></tr><tr><td>Type of meter</td><td>Differential Pres- sure transmitter</td></tr><tr><td>Serial number</td><td>FE-01</td></tr><tr><td>Accuracy</td><td>± 1%¹⁴</td></tr><tr><td>Calibration frequency</td><td>once every 3 years</td></tr><tr><td>Last calibration</td><td>12/01/10</td></tr></table>			Meter	GM2	Type of meter	Differential Pres- sure transmitter	Serial number	FE-01	Accuracy	± 1% ¹⁴	Calibration frequency	once every 3 years	Last calibration	12/01/10
Meter	GM2														
Type of meter	Differential Pres- sure transmitter														
Serial number	FE-01														
Accuracy	± 1% ¹⁴														
Calibration frequency	once every 3 years														
Last calibration	12/01/10														
Measuring/ Reading/ Recording frequency:	Continuous measuring / daily recording														
Calculation method (if applicable):	The correction factor applied to adjust temperature difference between Nm ³ conditions and m3 is done conservatively as explained in Annex 2 – Deviation 4														

¹² Reference : instruction manual for flow meter

¹³ <http://www.foxthermalinstruments.com/pdfs/ft2/ft2.pdf>

¹⁴ Reference : instruction manual for flow meter

QA/QC procedures applied:	The flow meter is calibrated at least once every 3 years.
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Data / Parameter:	W_{CH4}														
Data unit:	%														
Description:	Methane content in biogas														
Measured /Calculated /Default:	Measured														
Source of data:	Gas analyzer system to monitor % of methane in biogas														
Value(s) of monitored parameter:	<table><tr><td>Parameter</td><td>Jan’09 – Dec’09</td><td>Jan’10 – Sep’10</td></tr><tr><td>W_{CH4}</td><td>53.50</td><td>52.52</td></tr></table>			Parameter	Jan’09 – Dec’09	Jan’10 – Sep’10	W_{CH4}	53.50	52.52						
Parameter	Jan’09 – Dec’09	Jan’10 – Sep’10													
W_{CH4}	53.50	52.52													
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation														
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	<table><tr><td>Meter</td><td>Gas analyzer</td></tr><tr><td>Type of meter</td><td>Portable gas analyzer</td></tr><tr><td>Serial number</td><td>VI3-3005</td></tr><tr><td>Accuracy</td><td>± 2%¹⁵</td></tr><tr><td>Calibration frequency</td><td>once every 3 years</td></tr><tr><td>Last calibration</td><td>01/09/10</td></tr></table>			Meter	Gas analyzer	Type of meter	Portable gas analyzer	Serial number	VI3-3005	Accuracy	± 2% ¹⁵	Calibration frequency	once every 3 years	Last calibration	01/09/10
Meter	Gas analyzer														
Type of meter	Portable gas analyzer														
Serial number	VI3-3005														
Accuracy	± 2% ¹⁵														
Calibration frequency	once every 3 years														
Last calibration	01/09/10														
Measuring/ Reading/ Recording frequency:	Daily measuring / daily recording														
Calculation method (if applicable):	Annex 3 – Deviation 2														
QA/QC procedures applied:	The gas analyzer is calibrated at least once every 3 years.														

Data / Parameter:	Q _{FO, y}								
Data unit:	Litres								
Description:	Quantity of fossil fuel used in boiler in year y.								
Measured /Calculated /Default:	Measured								
Source of data:	Usage data (monitored from boiler panel). Value is used for conservative estimation of biogas / methane used in replacement of fossil fuel during an year y.								
Value(s) of monitored parameter:	<table><tr><td>Parameter</td><td>Jan'09 – Dec'09</td><td>Jan'10 – Sep'10</td></tr><tr><td>Q_{FO, y}</td><td>1,356</td><td>7,563</td></tr></table>			Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10	Q _{FO, y}	1,356	7,563
Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10							
Q _{FO, y}	1,356	7,563							
Indicate what the data are used for (Baseline/ Project/ Leakage emis-	Baseline emission calculation								

¹⁵ Reference : Calibration report for gas analyzer for Thai Steam Service & Supply

sion calculations)													
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	<table border="1"> <thead> <tr> <th>Meter</th><th>HFO meter</th></tr> </thead> <tbody> <tr> <td>Type of meter</td><td>Liquid flow meter</td></tr> <tr> <td>Serial number</td><td>92049</td></tr> <tr> <td>Accuracy</td><td>$\pm 1\%^{16}$</td></tr> <tr> <td>Calibration frequency</td><td>once every 3 years</td></tr> <tr> <td>Last calibration</td><td>01/07/10</td></tr> </tbody> </table>	Meter	HFO meter	Type of meter	Liquid flow meter	Serial number	92049	Accuracy	$\pm 1\%^{16}$	Calibration frequency	once every 3 years	Last calibration	01/07/10
Meter	HFO meter												
Type of meter	Liquid flow meter												
Serial number	92049												
Accuracy	$\pm 1\%^{16}$												
Calibration frequency	once every 3 years												
Last calibration	01/07/10												
Measuring/ Reading/ Recording frequency:	Continuous measuring / daily recording												
Calculation method (if applicable):													
QA/QC procedures applied:	The flow meter is calibrated at least once every 3 years.												

Data / Parameter:	$Q_{\text{starch}, y}$								
Data unit:	Tonnes								
Description:	Quantity of dry starch produced								
Measured /Calculated /Default:	Measured								
Source of data:	Based on operational log sheet at the plant (daily)								
Value(s) of monitored parameter:	<table><tr><th>Parameter</th><th>Jan'09 – Dec'09</th><th>Jan'10 – Sep'10</th></tr><tr><td>$Q_{\text{starch}, y}$</td><td>52,319</td><td>33,131</td></tr></table>			Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10	$Q_{\text{starch}, y}$	52,319	33,131
Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10							
$Q_{\text{starch}, y}$	52,319	33,131							
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation								
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)									
Measuring/ Reading/ Recording frequency:	Daily recording								
Calculation method (if applicable):									
QA/QC procedures applied:	Production data can cross-checked with sales record if necessary.								

Data / Parameter:	EG_y
Data unit:	MWh/y
Description:	Net electricity production by the generators during year y.

¹⁶ Reference : Specification document of CONTOIL flow meter

Measured /Calculated /Default:	Measured														
Source of data:	Electricity meter built into the generator sets ¹⁷														
Value(s) of monitored parameter:	<table><tr><td>Parameter</td><td>Jan'09 – Dec'09</td><td>Jan'10 – Sep'10</td></tr><tr><td>EG_y</td><td>3,905</td><td>2,204</td></tr></table>			Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10	EG _y	3,905	2,204						
Parameter	Jan'09 – Dec'09	Jan'10 – Sep'10													
EG _y	3,905	2,204													
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Baseline emission calculation														
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	<table><tr><td>Meter</td><td>EM1</td></tr><tr><td>Type of meter</td><td>3-phase power meter</td></tr><tr><td>Serial number</td><td>61580000N0050</td></tr><tr><td>Accuracy</td><td>± 0.2%¹⁸</td></tr><tr><td>Calibration frequency</td><td>once every 3 years</td></tr><tr><td>Last calibration</td><td>06/11/10</td></tr></table>			Meter	EM1	Type of meter	3-phase power meter	Serial number	61580000N0050	Accuracy	± 0.2% ¹⁸	Calibration frequency	once every 3 years	Last calibration	06/11/10
	Meter	EM1													
	Type of meter	3-phase power meter													
	Serial number	61580000N0050													
	Accuracy	± 0.2% ¹⁸													
	Calibration frequency	once every 3 years													
	Last calibration	06/11/10													
	<table><tr><td>Meter</td><td>EM2</td></tr><tr><td>Type of meter</td><td>Multi-function power monitor</td></tr><tr><td>Serial number</td><td>HT08051884</td></tr><tr><td>Accuracy</td><td>± 0.2% of current/voltage</td></tr><tr><td>Calibration frequency</td><td>-</td></tr><tr><td>Last calibration</td><td>03/03/06¹⁹</td></tr></table>			Meter	EM2	Type of meter	Multi-function power monitor	Serial number	HT08051884	Accuracy	± 0.2% of current/voltage	Calibration frequency	-	Last calibration	03/03/06 ¹⁹
	Meter	EM2													
	Type of meter	Multi-function power monitor													
	Serial number	HT08051884													
	Accuracy	± 0.2% of current/voltage													
	Calibration frequency	-													
	Last calibration	03/03/06 ¹⁹													
	<table><tr><td>Meter</td><td>EM3</td></tr><tr><td>Type of meter</td><td>Multi-function power monitor</td></tr><tr><td>Serial number</td><td>HT09050004</td></tr><tr><td>Accuracy</td><td>± 0.2% of current/voltage</td></tr><tr><td>Calibration frequency</td><td>-</td></tr><tr><td>Last calibration</td><td>03/03/06²⁰</td></tr></table>			Meter	EM3	Type of meter	Multi-function power monitor	Serial number	HT09050004	Accuracy	± 0.2% of current/voltage	Calibration frequency	-	Last calibration	03/03/06 ²⁰
	Meter	EM3													
	Type of meter	Multi-function power monitor													
	Serial number	HT09050004													
	Accuracy	± 0.2% of current/voltage													
	Calibration frequency	-													
Last calibration	03/03/06 ²⁰														
Measuring/ Reading/ Recording frequency:	Continuous measuring / daily recording														
Calculation method (if applicable):															
QA/QC procedures applied:	The power meter is calibrated at least once every 3 years.														

¹⁷ The electricity supplied from 4th generator is not included in this calculation since it is the additional equipment after project implementation which is not indicated in registered PD

¹⁸ <http://www.gavazzionline.com/pdf/WM396.pdf>

¹⁹ Calibration certificate is valid for 10 years.

²⁰ Calibration certificate is valid for 10 years.

Any comment	Since the calibration gap of electricity meter at generator no.1 is over 3 years. So the correction of accuracy -0.2% for baseline calculation is applied for conservativeness approach for the whole monitoring period as per guidelines EB 52 , annex 60.
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Data / Parameter:	EC _y					
Data unit:	MWh					
Description:	Electricity consumption by wastewater treatment plant in year y					
Measured /Calculated /Default:	Calculated					
Source of data:	Maximum rated consumption based on total electrical capacity of the entire waste water treatment plant and operation period.					
	Item	Equipment	rated power (kW)	Number	Total power	Unit
	1	Pump	7.5	2	15	kW
	2	Pump - covered lagoon	11	1	11	kW
	3	Submersible pump	7.5	1	7.5	kW
	4	Blower to burner	22	1	22	kW
	5	Blower to generator	22	1	22	kW
		Blower to generator	7.5	2	15	kW
	6	pump-Scrubber for burner	4	1	4	kW
	7	pump-Bio scrubber	4	4	16	kW
		pump-Bio scrubber	5.5	1	5.5	kW
	8	pump-Scrubber for generator	4	1	4	kW
	9	Chiller	0.375	2	0.75	kW
	10	feed pump	5.5	3	16.5	kW
					139.25	kW
Value(s) of monitored parameter:						
	Parameter	Jan'09 – Dec'09		Jan'10 – Sep'10		
	EC _y	1,342		1,004		
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation					
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	N/A					
Measuring/ Reading/ Recording frequency:	N/A					
Calculation method (if applicable):	Calculation based on maximum rated consumption is conducted in a conservative manner (as per paragraph 35 in AMS III. H., version 13).					
QA/QC procedures applied:						
Comments	The rated power consumption of the equipments is updated according to the nameplate of the existing equipments. The total power consumption is higher than identified value in PDD. This is the conservativeness approach for higher project emission					

	which can reduce the emission reduction.
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Data / Parameter:	Sludge removed and its application
Data unit:	Tonnes / and type of application
Description:	The quantity of organic material / sludge removed from treatment plant and its application.
Measured /Calculated /Default:	Measured
Source of data:	Weighing equipment available at site is used. Plant record every time sludge is removed from the system.
Value(s) of monitored parameter:	0
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	N/A
Measuring/ Reading/ Recording frequency:	N/A
Calculation method (if applicable):	
QA/QC procedures applied:	Plant manager's signature is required on the record

Data / Parameter:	T_{flare}, h
Data unit:	Deg C
Description:	Temperature at the flame of flare
Measured /Calculated /Default:	Measured
Source of data:	Flame detection shall be logged from measurements by a Type N (or its equivalent) thermocouple
Value(s) of monitored parameter:	500°C
Indicate what the data are used for (Baseline/ Project/ Leakage emission calculations)	Project emission calculation
Monitoring equipment (type, accuracy class, serial number, calibration frequency, date of last calibration, validity)	
Measuring/ Reading/ Recording frequency:	Continuous Measuring

Calculation method (if applicable):	
QA/QC procedures applied:	.

QA/QC procedure and Calibration for monitored parameters

1. Monitoring Management

The project hires people to operate the biogas generation and utilisation plants. The required monitoring equipment is installed in consultation with the equipment supplier under supervision of the QC officer as well as the Managing Director.

Data acquisition for the gas and wastewater flow meters is executed through the manual process control unit of the biogas plant and then insert into the plant operation software. Lab data is fed into the operations software through a manual data entry user interface. The plant is operated by trained operators who also collect data under the supervision of the QC officer who is in charge of filing and processing data.

2. Quality Assurance and Quality Control

Together with the Managing Director, the QC officer monitors overall performance of the plant, ensures proper and timely calibration, data acquisition and storage.

3. On-site Procedures

The operations software creates daily logs of plant performance which are printed out and recorded electronically for periodic download onsite or remote transfer for further processing. Procedures for Calibration of Equipment are included in GHG performance protocol. The plant in-charge/operators are responsible to execute timely calibration as per the specification from equipment supplier or at least once in three years.

4. Data Storage and Filing – Electric Workbook

All relevant data is first stored manually in operational log sheets, then electronically with the process control computer unit, external storage media and transferred. A daily log is printed. All parameters monitored under the monitoring plan will be kept for a period of two years following the end of the crediting period or the last issuance of VERs for the project activity, whichever occurs later.

5. Emergency preparedness

The project activity does not result in any unidentified activity that can result in substantial emissions from the project activity.

However, the leakages, if any, in the piping or digester shall come under notice of plant operator either instantly on the control screens else at the time of data logging, due to mismatch between expected biogas generation from wastewater quantities processed or other way around.

4. Summary of all data used in emission reduction calculation

Parameter	Description	Unit	2009	2010
$Q_{ww,y}$	Total volume of wastewater treated in a year.	m ³	299,041	540,411
$COD_{ww, untreated,y}$	Average level of COD concentration of Influent	mg/L	27,130	26,355
$COD_{out, CL}$	Average level of COD concentration of effluent from last covered lagoon	mg/L	2,329	996
$COD_{out, lagoon, PJ}$	Average level of COD concentration of effluent from final open lagoon	mg/L	922	537
$COD_{load, untreated, y}$	COD load of untreated wastewater going into AFFR and CL	Tonnes	7,907.79	10,907.60
$COD_{load, out, AFFR+CL, y}$	COD load of treated wastewater leaving CL 3	Tonnes	644.19	552.30
$COD_{load, out, lagoon, y}$	COD load of wastewater leaving post-treatment open lagoons	Tonnes	249.97	291.23
$COD_{removed, i, y}$	COD that would have been removed by the baseline treatment system	Tonnes	6,899	9,523
$COD_{y, removed, PJ, AFFR+CL, y}$	COD of wastewater removed by AFFR & covered lagoon.	Tonnes	7,264	10,355
		Tonnes/m3	0.0243	0.0192
$COD_{y, removed, PJ, Lagoon, y}$	COD of wastewater removed by the post-treatment open lagoons	Tonnes	394	261
		Tonnes/m3	0.00132	0.00048
$MEP_{ww, treatment, y}$	Methane emission potential of the AFFR system.	tonnes	1,293.50	1,844.07
$BG_{combusted, y}$	Amount of biogas combusted at boiler and generator	Nm ³	3,432,932	3,045,292
$BG_{TOFlare, y}$	Amount of biogas sent to flare at normal conditions (see deviation 4).	Nm ³	-	-
W_{CH4}	Methane content in biogas - monitored	%	53.99%	52.97%
W_{CH4}	Methane content in biogas - adjusted	%	53.50%	52.52%
$q_{fo, y}$	Quantity of fuel oil used in boiler in a year.	Liters	1,356	7,563
$Q_{starch, y}$	Quantity of dry starch produced	Tonnes	52,319	33,131
EG_y	Net electricity production by the generators in a year.	MWh	3,905	2,204
EC_y	Electricity consumption by the wastewater treatment plant in a year	MWh	1,342	1,004
Sludge removed	The quantity of sludge removed from treatment plant	Tonnes	0	0
$Q_{biogas, flare, h}$	Biogas sent to flare during a particular hour.	Nm ³ /hour	-	-
$T_{flare, h}$	Temperature at the flame of flare.	Deg C	-	-

5. Summary of Results

Baseline emissions

The calculation of relevant baseline emissions are elaborated here below; for further details, please find the corresponding excel sheet:

Methodology: AMS III. H. (Methane avoidance component)			
Emissions from baseline wastewater treatment systems ($BE_{ww, treatment, y}$)			
Formula: $BE_{ww, treatment, y} = \sum Q_{ww, i, y} * COD_{removed, i, y} * MCF_{ww, treatment, BL, i} * B_{o, ww} * UF_{BL} * GWP_{CH4}$			
Parameter	2009	2010	Explanation
$Q_{ww, y} =$	299,041 m ³	540,411 m ³	Volume of wastewater being treated by AFFR and Covered Lagoon • 01-Jan-09 to 08-Nov-09 : $Q_{ww, i, y}$ is calculated from HM1, HM2, HM3 as per Annex2–Deviation 1 • 09-Nov-09 to 31-Dec-09 : $Q_{ww, i, y}$ is from reading of FM1 as per Annex3-Deviation 1 • 01-Jan-10 to 30-Sep-10 : $Q_{ww, i, y}$ is total volume of FM1, FM2 and FM3.
$COD_{removed, i,}$	6,899 tonnes	9,523 tonnes	The daily incoming COD is multiplied by the respective waste water flow for each treatment units and summed up to estimate the total COD entering the project system. This is multiplied by fixed value of baseline COD removal efficiency of 87.37% i.e. efficiency of the lagoon system. The COD load thus obtained is used in estimating baseline emissions. Since the COD reactor for COD measurement is out of order during 11-Jul-10 to 31-Aug-10, the COD results is calculated according to description in Annex 3 – Deviation 3.
$B_{o, ww} =$	0.21kg CH ₄ /kg COD		Default value
$MCF_{ww, treatment, BL, i} =$	0.8		Default value for anaerobic deep lagoons
UF_{BL}	0.94		Model correction factor from AMS III. H.
$GWP_{CH4} =$	21		Default value
$BE_{ww, treatment, y}$	22,878	31,582	tCO₂e
Methodology: AMS III. H. (Methane avoidance component)			
Emissions from methane captured and destroyed/gainfully used by the project activity			
Formula: $MD_y = W_{CH4} * D_{CH4} * GWP_{CH4} * [(BG_{TOFlare} * FE) + (BG_{combustion} * DE)]$ (as per deviation 3 in the validated VCS PD)			
Parameter	2009	2010	Explanation
$W_{CH4} =$	53.50 %	52.52 %	The monitored methane content in biogas ,

			use average value from 3 sampling points. The deviation applied is according to Annex 3 – Deviation 2.
$D_{CH_4} =$	0.716 kg/m ³		Default value
GWP_{CH_4}	21		Default value
$BG_{toFlare, y}$	0 Nm ³	0 Nm ³	No biogas vented or sent to flare. All biogas is used in boiler, engines or store in a storage that consists of 2 AFFRs and 3 covered lagoons
FE	0		Not applicable due to no excess biogas.
$BG_{combusted, y}$	3,432,932 Nm ³	3,045,292 Nm ³	At normal conditions as per deviation 4 of the VCS PD. For period 01-Jan-09 to 14-Jun-09, the BG sent to Boiler (GM1) is adjusted with 0.5% of meter accuracy due to calibration delay in accordance with EB52 Annex 60.
DE	100%		As per deviation 4 of the Annex 1.
MD_y	27,613	24,050	tCO ₂ e
Methodology: AMS I. C. (Fuel replacement component)			
Emissions from heat displacement by the project activity			
Formula: $BE_{thermal, CO_2, y} = (EG_{thermal, y} / \eta_{BL, thermal}) * EF_{CO_2}$ $BE_{thermal, CO_2, y} = ER_{heat, y} = (Q_{starch, y} * Q_{FO, starch} - q_{FO, y}) * D_{FO} * NCV_{FO} * EF_{CO_2} / 10^6$ (as per deviation 2 in the validated VCS PD)			
Parameter	2009	2010	Explanation
$Q_{starch, y}$	52,319 tonne	33,131 tonne	Monitored
$Q_{FO, starch}$	34.3 liters/tonne		Default value
$q_{FO, y}$	1,356 liters	7,563 liters	Monitored
D_{FO}	0.93 kg/liter		Default value
NCV_{FO}	42.244 GJ/tonne		Default value
EF_{CO_2}	77.4 tCO ₂ /TJ		Default value
$BE_{thermal, CO_2, y} = ER_{heat, y}$	5,453	3,433	tCO ₂ e
Methodology: AMS I. D. (Power generation component)			
Emissions from electricity generation			
Formula: $BE_{gen, y} = EF_y * EG_y$			
Parameter	2009	2010	Explanation
$EG_y =$	3,905 MWh	2,204 MWh	Monitored, as the performance of the biogas production is very good. The the 4 th generator is installed. The electricity generated from this new generator is not included in this calculation.
$EF_y =$	0.5057 tCO ₂ /MWh		Default value
$BE_{gen, y}$	1,975	1,115	tCO ₂ e

²¹ Please refer to Annex 1 deviation 2.

In short, all components of baseline emissions are summarised here below:

AMS III. H. : Baseline emissions			
Parameter	2009	2010	Unit
BE _{ww, treatment, y}	22,878	31,582	tCO ₂ e
BE _{power, y}	0	0	tCO ₂ e
BE _{s, treatment, y}	0	0	tCO ₂ e
BE _{ww, discharge, y}	0	0	tCO ₂ e
BE _{s, final, y}	0	0	tCO ₂ e
BE _{y, ex post}	22,877	31,582	tCO ₂ e
MD _y	27,613	24,050	tCO ₂ e

AMS I. C.			
Parameter	2009	2010	Unit
BE _{thermal, CO₂, y}	5,453	3,433	tCO ₂ e

AMS I. D.			
Parameter	2009	2010	Unit
BE _{gen, y = ER_{pow}}	1,975	1,115	tCO ₂ e

Project emissions

The calculation of relevant project emissions are elaborated here below; for further details, please find the corresponding excel sheet:

Methodology: AMS III H (Methane avoidance component)			
Formula: $PE_{power, y} = EF_y * EC_y$			
Parameter	2009	2010	Explanation
EC _y	1,342 MWh	1,004 MWh	Based on power capacity installed (116 kW) and the operating hour in a year
EF _y	0.5057 tCO ₂ /MWh		Default value
PE _{power, y}	679	508	tCO ₂ e
Emissions in wastewater treatment system without biogas recovery			
Formula:			
$PE_{ww, treatment, y} = Q_{ww, k, y} * COD_{removed, PJ, k, y} * MCF_{ww, treatment, PJ, k} * B_{o, ww} * UF_{PJ} * GWP_{CH4}$			
Parameter	2009	2010	Explanation
Q _{ww, k, y}	299,041 m ³	540,411 m ³	Volume of wastewater being treated by AFFR and Covered Lagoon. As there is no waste water lost during the treatment process in project system, as per hydrological balance, the waste water coming out of a particular system is same as waste water going in. 01-Jan-09 to 08-Nov-09 : Q_{ww, k, y} is calculated from HM1, HM2, HM3 as per Annex2–

			Deviation 1 • 09-Nov-09 to 31-Dec-09: $Q_{ww, k, y}$ is from reading of FM1 as per Annex3-Deviation 1 • 01-Jan-10 to 30-Sep-10 : $Q_{ww, k, y}$ is total volume of FM1, FM2 and FM3.
$COD_{removed, PJ, k, y} =$	394 tonnes	261 tonnes	The COD concentration out of CL is multiplied by respective daily wastewater flow to get COD load in tonnes entering the lagoon system. This COD loading is then multiplied by the baseline COD removal efficiency of 98.1% ²² , to estimate the COD load removed by treatment system k i.e. lagoon system. Since the spectrophotometer for COD measurement is out of order during 11-Jul-10 to 31-Aug-10, the COD results are calculated according to description in Annex 3 – Deviation 3.
$MCF_{ww, treatment, PJ, k} =$	0.8		Default value
$B_{o, ww} =$	0.21kg CH ₄ /kg COD		Default value
UF_{PJ}	1.06		Default value
$GWP_{CH_4} =$	21		Default value
$PE_{ww, treatment, y}$	7,020	4,649	tCO ₂ e
Fugitive emissions in wastewater treatment system with biogas recovery			
Formula: $PE_{fugitive, ww, y} = (1 - CFE_{ww}) * MEP_{ww, treatment, y} * GWP_{CH_4}$ $MEP_{ww, treatment, y} = \sum_k (COD_{removed, PJ, k, y} * Q_{ww, y}) * B_{o, ww} * UF_{PJ} * MCF_{ww, treatment, PJ, k}$			
Parameter	2009	2010	Explanation
$CFE_{ww} =$	0.9		Default value
$MEP_{ww, treatment, y} =$	1,293.50 tonnes	1,844.07 tonnes	Methane emission potential of wastewater treatment systems equipped with biogas recovery.
$GWP_{CH_4} =$	21		Default value
$PE_{fugitive, ww, y}$	2,716	3,873	tCO ₂ e

²² Unlike the case of estimating $BE_{ww, treatment, y}$, the COD removal efficiency of baseline lagoon system used here has not been multiplied by a factor of 0.89. This in turn increases project emissions and thus can be considered as a conservative approach as per VCS 2007.1. Please refer to Annex 3, Deviation 1.

In short, all components of project emissions are also summarised here below:

Project emissions			
Parameter	2009	2010	Unit
PE _{power, y}	679	508	tCO ₂ e
PE _{ww, treatment, y}	7,020	4,649	tCO ₂ e
PE _{s, treatment, y}	0	0	tCO ₂ e
PE _{ww, discharge, y}	0	0	tCO ₂ e
PE _{s, final, y}	0	0	tCO ₂ e
PE _{fugitive, y}	2,716	3,873	tCO ₂ e
PE _{fugitive, s, y}	0	0	tCO ₂ e
PE _{fugitive, ww, y}	2,716	3,873	tCO ₂ e
PE _{flaring, y}	0	0	tCO ₂ e
PE _{biomass, y}	0	0	tCO ₂ e
PE _{y, ex post}	10,415	9,029	tCO ₂ e
LE _y	0	0	tCO ₂ e

Emissions Reductions

This table below summarises the total emission reduction from this project. The project proponents hereby conclude the VERs to be verified for the monitoring period between January 1st, 2009 and September 30th, 2010, as follows.

	Parameter	2009	2010	Unit
AMS III. H.	ER - approach 1 (COD)	12,461	22,552	tCO ₂ e
	ER - approach 1 (MD _y)	26,934	23,542	tCO ₂ e
	ER _{ww, y}	12,461	22,552	tCO ₂ e
AMS I. C.	ER _{heat, y}	5,453	3,433	tCO ₂ e
AMS I. D.	ER _{power, y}	1,975	1,115	tCO ₂ e
Total ER for the	46,987	19,888	27,099	tCO₂e

As per the validated PD, the project activity is expected to achieve GHG emission reductions in the amount of 28,881 tCO₂e per year. Such discrepancy between the ex-ante and ex-post value can be explained by the variation in starch production over the years as well as the conservative approaches taken to calculate emission reductions for the second verification.

- In the year 2009, there are several factors which lead to lowering of the emission reductions such as
 - a Waste water flow meters are not available for waste water entering the covered lagoon directly from starch plant.
 - b The waste water entering the AFFR digester is also estimated using the conservative approach using hour meter readings till November 8th 2009.
 - c There are missing COD readings on some days, which are estimated using the statistical conservative approach. These conservative deviations are explained in Annex – 3.
- In the year 2010, the results cannot be compared to the figures of 2009 because all the waste water meters were installed including the direct line from starch plant to covered

lagoon 2. These meters were not installed till 9th November 2009 and the COD coming through this inlet into waste water system was not included in the Emission Reduction calculation. After the improvement of monitoring system, the entire COD load generated from starch factory has been included into the emission reduction estimation formulae. It is also noticed that the COD in waste water is a bit higher than designed value. This usually is dependent on the raw material and has no relation to waste water project design. The quality of raw material processed determines the COD of outgoing waste water. The higher COD values are sited as another possible reason for increase in emission reductions in 2010 as compared 2009.

In conclusion, total emission reduction to be verified in the 2nd monitoring period is 46,987 tCO₂e.

Annex 1

CONTACT INFORMATION ON PARTICIPANTS IN THE PROJECT ACTIVITY

Role	Project owner (responsible for implementation and operation of the project activity)
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Annex 2

COMPLIANCE TO ALL DEVIATIONS STATED IN THE VALIDATED PD

Explanation of the deviation	Compliance with the deviation
1. In the absence of wastewater flow meter for the first verification period, the running hours of the water pumps sending the wastewater into the AFFRs are monitored and used to calculate the wastewater flow as per conservative approach exhibited in the validated PD.	A factor of 0.65 is applied to account for the fact that the water pumps are not operating at full capacity. As per industry practice and experience, the discharge of wastewater pumps is generally close to the rated capacity based on the head of the pump. With reference to site visit observations, head of the pump and the related performance curves, it can be concluded that the assumed 65% discharge factor with regards to rated capacity is conservative. To give further confidence, it shall be ensured that the wastewater volume estimated using this approach is lower than the default wastewater volume expected from the starch production process during a particular year. Considering wastewater generation rate at 10 m³ per tonne of dry starch production (design value) in a year, and compared this with the value obtain from the deviated approach, it is clear that the deviated approach results in a lower volume of wastewater generation²³. In addition, it should be mentioned that the emission reductions estimate the wastewater approach will anyway have to be compared with the ‘methane destruction’ or ‘MD’ approach. This ensures that the GHG emission reductions are not overestimated and therefore acts as a confirmation that the deviation is in compliance with paragraph 5.3, page 13 of VCS 2007.1. The deviation has been applied from 01st January 2009, till the wastewater flow meters were installed on 08th November 2009.
2. Since complete monitoring mechanism is not available for the measurement of baseline input/output thermal energy, a conservative approach has been adopted as explained in the validated PD.	For verification, with a quantity of dry starch that is produced during a particular year, a minimum required quantity of fossil fuel (fuel oil) can be estimated from quantity of fossil fuel used per unit of dry starch historically. For the same year, if the data for fossil fuel consumed is available, then the remaining energy must be supplied by biogas. This is a conservative approach to estimate the fuel oil that, in the absence of project activity, would be used in the starch drying process. The deviation takes into account the baseline efficiencies and a simplified approach is explained here to estimate the baseline emissions, the approach is based on historical consumption of fuel oil per tonne of starch generation. The deviation addresses the coherence with §15, &

²³ Based on the comparison approach as described above, theoretical wastewater generation is 373,970 and 438,470 m³ for the years 2007 and 2008 respectively. This is much higher than the applied values at 214,024 and 154,030 m³ for the same years. This justified again the conservative approach adopted for this project,

	10 of the methodology. It must be noted that the efficiency of the boiler when used in dual-fuel mode is lower than at regular single-fuel conditions (HFO only). This drop in efficiency leads to a lower biogas to HFO displacement rate. Based on the arguments listed below (provided by technical experts on the subject) and energy balance comparisons based on data available before and after implementation of the dual-fuel mode in such boiler systems, an efficiency drop resulting in 10% less HFO displacement (than under theoretical conditions) is a conservative approximation. This can be substantiated based on following arguments: - Higher hydro/moisture loss makes boiler efficiency lower with biogas - The efficiency of a heating equipment depends on several factors; one of the important ones being the C:H ratio in the fuel; which is higher for the fuel oil and lower for biogas. Lower C:H ratio leads to higher quantity of H₂O as combustion product, which decreases the thermal efficiency of the boiler. This is typically called "hydrogen loss". In addition, the biogas has much higher moisture percentage as compared to fuel oil, thus increasing the moisture losses from the equipment, making it less efficient fuel for burning. The hydrogen sulfide content in the biogas adds to the hydrogen loss. - Higher dry flue gas loss reduces boiler efficiency in dual fuel firing mode - Air in excess of the theoretical calculations (called excess air) is always added for proper and complete combustion. In case of dual fuel firing, due to the different mixing properties of the fuel with the air, this quantity of excess air added is always higher due to the reduced probability of achieving proper air-fuel mixing due to varying fuel properties. At the end of the combustion process, the quantity of unused air is exhausted through the flue gases thus removing away unusable heat in the boiler, such a loss being partly accounted in the dry flue gas loss (the rest is the unusable heat from the high temperature flue gas itself). This can be understood by the fact that the air enters the furnace at ambient temperature but the flue gases are typically at a much higher temperature, 200-300 deg.C for most low-pressure boiler systems. Thus if the quantity of excess air pumped into the furnace is higher, which is the case for most such dual fuel fired systems, the dry flue gas loss is also higher, bringing down the effi-
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	ciency of the boiler. The excess air quantity adjustment is a matter of experience and over a period of time boiler operators do understand how to do this and achieve better efficiencies than what they start with. Thus it is expected that during the initial stages of operation, this loss is higher. - Variation in biogas quality and quantity influences the air regulation mechanism, thus lowering the efficiency of the system - The varying quantity and quality of biogas influences the air regulation mechanism continuously, never allowing it to achieve a steady state operation, thus lowering the efficiency of the system. The statements above can be confirmed through interview with technical expert and details of same can be provided. In addition, the energy balance for a particular year, considering amount of biogas and fossil fuel used, would easily justify the assumption that energy input required in dual fuel system is higher than in baseline system. From this, the deviation can be considered as justifiable as it the requirements as per paragraph 5.3, page 13 of VCS 2007.1 that it does not impact negatively on the conservativeness of the emission reduction calculation or the additionality of the project. Starch production in year 2007 and 2008 are multiplied by this default factor (34.3 litres per tonne) to get minimum fuel oil consumption for each year. For the same year, subtracting actual amount of fuel oil used, we estimate the amount of thermal energy supplied by biogas and consequently amount of GHG emission reductions made from the project as per AMS I. C., version 15, component.
3. As per answers to authors of query by the SSC WG “<i>in the case that the biogas is combusted for a gainful use of the released energy as in an engine or a power plant, a destruction efficiency of 100% can be used for the portion of biogas that is combusted when applying AMS III. H., i.e. use a value of 100% for FE in equation 16 in paragraph 32 for the portion of biogas that is combusted for a gainful use</i>”. Based on this, the calculation approach of MD_y has been deviated from the methodology as justified and accepted in the validation report.	A destruction efficiency of 100% is used for the portion of biogas that is combusted for gainful use i.e. in boiler and gas engines. For the portion of biogas that is sent to flare, a flare efficiency of 0% has been adopted for the current monitoring period to account for non-operation of the flare system due to unavailability of excess biogas.
4. Based on paragraph 36 of AMS	The deviated approach has been adopted for the first

III.H., version 13, volume of gas has to be estimated in Nm³ from the volume of gas available in m³. However, due to the unavailability of regular measurement of pressure and temperature values, a conversion of biogas from measured conditions (m³) to normal conditions (Nm³) has been done using a conservative factor as elaborated in the validated PD.	monitoring period. The approach assumes that no pressure measurement is done in the supply pipe and thereby pressure difference is assumed to be zero, estimating the volume in Nm³ to be on a lower side. Temperature for ambient conditions around the year as per validated PD is used to calculate a conservative factor in the estimation of biogas volume at normal conditions. Note that the calculated volume of biogas at normal conditions is found to be at an approximate of 90.4% of the measured conditions (m³), resulting in a lower estimation of methane destructed through combustion of biogas. The approach is explained in detail below this table.
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Deviation -4

As per the gas equation: $P_1 \times V_1 / T_1 = P_2 \times V_2 / T_2$; where 1 represents parameters at measured conditions and 2 refers to parameters at normal conditions. Now for each of these parameters, an explanation of range is as shown below.

P1 would always be higher than 1 atm pressure so that there is a positive gauge pressure and gas can flow from gas storage to boiler and gas engines. Let's assume the same to be (1+x) atm where x is a positive number.

P2 = 1 atm as per normal conditions of temperature and pressure.

Since the gas is generated, stored and sent to boiler and gas engines at ambient conditions T1 (average temperature of 29 C as per meteorological data) and normal conditions as 0 C.

So if V1 represents volume in m³ and V2 represents volume in Nm³, we have the following situation.

$$V_2 (Nm^3) = (1+x) \times V_1 (m^3) \times \frac{273}{273+29}$$

If we assume x = 0, we get a conservative factor of 0.904 to be multiplied by gas volume in m³ to get biogas volume in Nm³ on a conservative basis.

The approach assumes that no pressure measurement is done in the supply pipe and thereby pressure difference is assumed to be zero, estimating the volume in Nm³ to be on a lower side. The ambient temperature conditions around the year are available and a conservative value is used to calculate a factor used in estimation of volume at normal conditions. The approach is thus considered as conservative and it meets the deviation requirements as per paragraph 5.3, page 13 of VCS 2007.1.

Annex 3

ADDITIONAL DEVIATION MADE FOR THIS MONITORING PERIOD

Deviation	Compliance with the deviation	Justification for deviation
1. Missing the COD result of sampling point CS2 during 09-Nov -2009 till 31-Dec-2009.	As only the COD from sampling point CS1 is available. The wastewater volume, $Q_{ww,i,y}$ and $Q_{ww,k,y}$ is based on the reading of FM1. The reading from FM2 and FM3 is not taken into account.	This approach is considered conservative as it discards the wastewater flow from FM2 and FM3. This will reduce the emission reduction and thus can be assured that such deviated approach does not result in a negative impact on the conservativeness in calculating emission reductions. The approach meets the deviation requirements as per paragraph 5.3, page 13 of VCS 2007.1.
2. The Methane content in biogas is not daily measured for 3 sampling points.	As described below	As described below
3. COD readings are not monitored as per the monitoring plan in validated PD during 11-Jul-10 to 31-Aug-10. COD measurements are required to be made on a daily basis, whereas during the monitoring period, the project proponent has not done regular daily monitoring of the COD sample data.	As described below	As described below

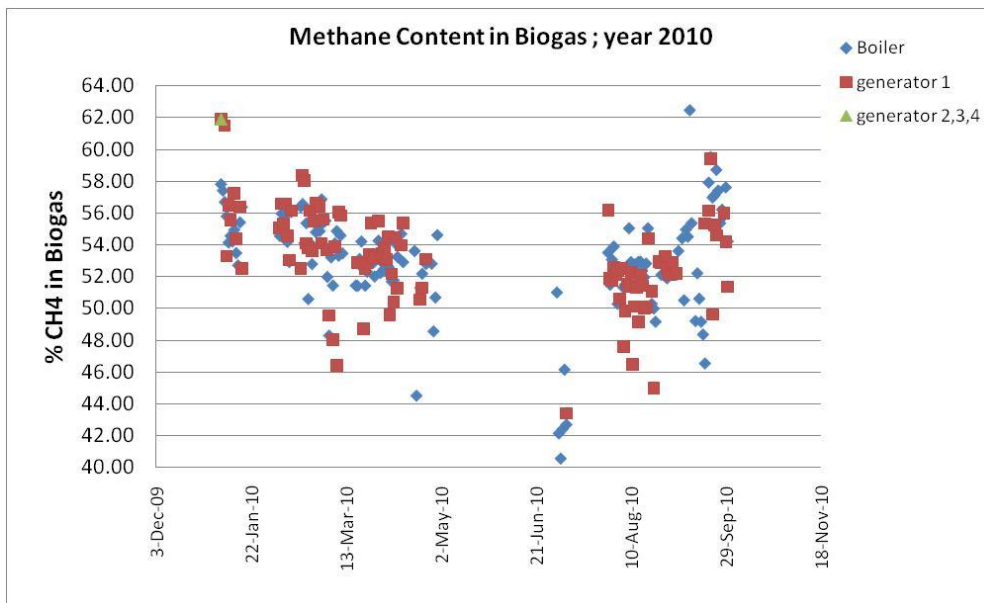
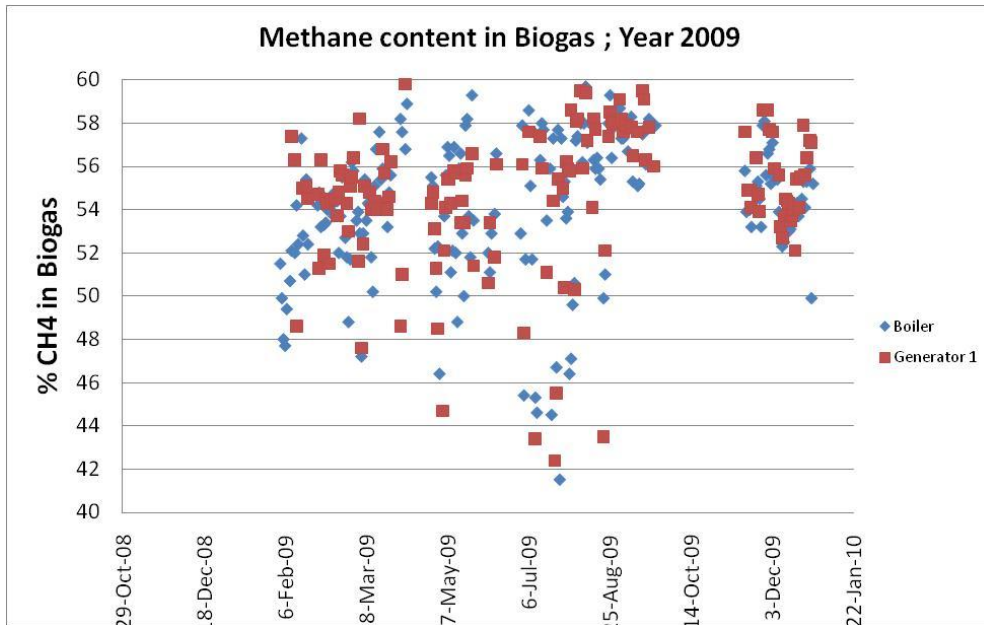
Deviation 2:

Status in the monitoring / monitoring period: For Project 283: Chol Charoen Group Wastewater Treatment with Biogas System; the Methane content in biogas is required daily measurement, whereas during the monitoring period, the project proponent has not done regular daily monitoring of the Methane content in biogas. The data is scattered over days and 2 sampling points in 2009 and 3 sampling points in 2010. This due to the readiness of gas analyzer equipment and the operation of Boiler and Generator. The operator will measure the biogas only when the biogas is supplied to machine, which is not continuous operation.

Deviation applied for period : 01-Jan-09 to 30-Sep-10

Followed approach: The measured values of W_{CH_4} parameter when plotted against time of year show no clear change or dependency of W_{CH_4} on time of year. It should be acceptable to

assume that w_{CH_4} readings represent a normal distribution over a year, which means that for most days, the value of w_{CH_4} is close to the mean, while for fewer days, the w_{CH_4} value is higher or smaller than the average. This is well represented on the following graph.



The approach is aimed to estimate the 95% confidence interval for the W_{CH_4} values for year 2009 and 2010. The lowest bound of the interval shall be used for the baseline emissions and highest bound is used for project emissions as a conservative approach.

Conservativeness of Used approach and conjunction with the EB Guidance:

As per EB Guidance EB 50-Annex 30 the referred approach in case of sampling data is 90% confidence and 10% precision for the collected data. In simpler terms, "Precision is an as-

assessment of the error margin of the final estimate. Confidence is the likelihood that the sampling has resulted in the true value within a certain range of values²⁴.”

In the approach followed in the case under consideration, 95% confidence interval is in line with the guidance as per the methodology. The methodology recommends using 95% confidence level for the methane percentage values.

As per EB guidance, the sample size for a given parameter should be chosen to achieve 90% confidence and 10% precision of data. In case of the sampling for the project under consideration, the precision (i.e. error margin) is calculated for the established 95% confidence interval (the approach of establishing the confidence interval is explained later).

Theory of used approach: In case there are infinite number of data samples available, true mean and true standard deviation can be established for the normally distributed data. On the other hand when number of samples is low, Student-t distribution approach is used. The approach of student-t distribution is explained below.

$\bar{X}$ = Average of the n number of sample readings available.

μ = is the mean of normally distributed data if large number of readings are available.

s = standard deviation of the sample readings.

n = number of sample readings.

n-1 = degrees of freedom, the scores which are free to vary.

A = Factor applied to the calculation term based on standard tables, The value of A is inversely proportional to the value of n. If more number of samples is available, the value of A is lower, whereby the range of confidence interval is low making the estimate more precise. For the reference check the Reference box below.

In such cases the confidence intervals is defined, in which the value μ would lie with a probability of (100- α)%. So in this case we select $\alpha=0.05$ (for both sides of the curve contributing 0.025 on each end of the curve is curtailed), the interval is defined as $[\bar{X} - (A * s / \sqrt{n}), \bar{X} + (A * s / \sqrt{n})]$. Here A is dependent on the number of sample readings available. The value is available in standard tables on many sources.

More specifically, probability $(\bar{X} - (A * s / \sqrt{n}) \leq \mu \leq \bar{X} + (A * s / \sqrt{n})) = 0.95$

So the lower limit of established intervals is used for baseline emissions and upper limit is used for project emissions.

References: The above approach is available on various sources and cannot be understood in totally from just one source. However, PP believes that certain pages on www.wikipedia.org provide a very good summary of statistical approach and its application under practical condition. The sources of data consulted for the above approach are as follows:

Student-t distribution theory: http://www.wikidoc.org/index.php/Student's_t-distribution

Confidence Interval theory: http://www.wikidoc.org/index.php/Confidence_interval

‘A’ values for variable probabilities:

<http://www.staff.brad.ac.uk/yysentur/course/dp1008m/Student-t-table.pdf>

²⁴ http://cdm.unfccc.int/EB/050/eb50_repan30.pdf

Distribution Tables: <http://www.statsoft.com/textbook/distribution-tables/>
 Statistic Tutorials: <http://stattrek.com/Lesson3/TDistribution.aspx?Tutorial=AP>

Approach applied to the project activity:

Common terms used:

$\bar{X}$ = average of the parameter, COD in this case

s= standard deviation of the data set

n= number of sample readings

$s/\sqrt{n}$ = standard error of the data

The 95% confidence interval is represented as $\bar{X} - \left(A * s/\sqrt{n} \right)$ and $\bar{X} + \left(A * s/\sqrt{n} \right)$. The value of A depends on degrees of freedom i.e. n-1. Higher the value of n, lower the value of A. For the range between 250 and infinity of n, the value of A is 1.969; which refers to the normal distribution.

W _{CH4}	2009	2010
$\bar{X}$	54.0	52.98
s	4.33	4.24
n	350	338
A	1.969	1.969
X	53.50	52.52

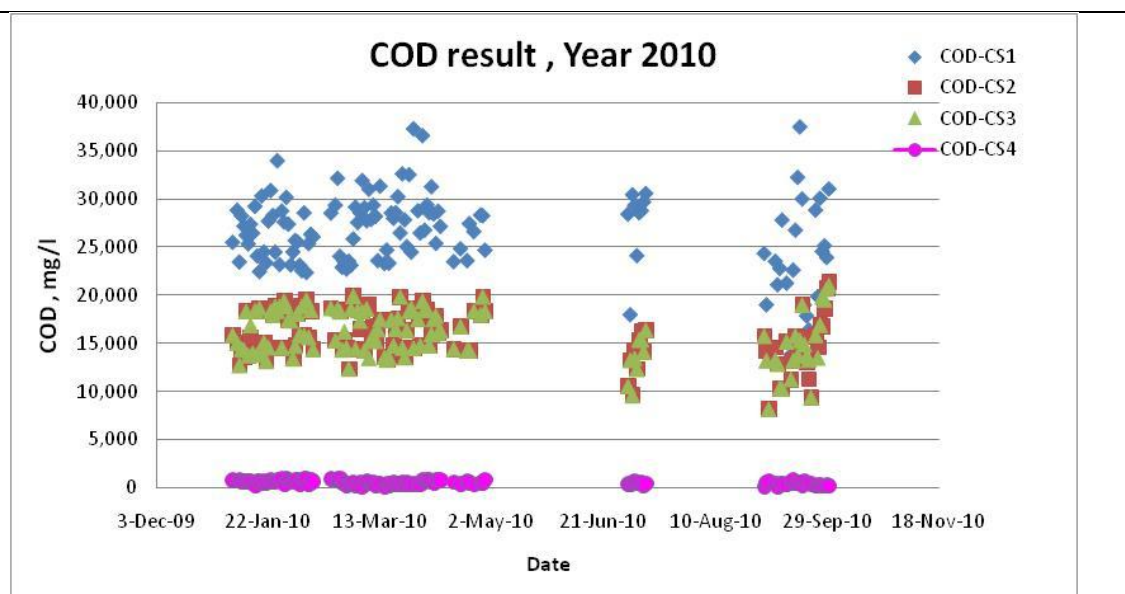
The above values of lower of intervals are used for W_{CH4} respectively, for conservative estimation of Emission Reductions.

Deviation 3:

Status in the monitoring / monitoring period: For Project 283: Chol Charoen Group Wastewater Treatment with Biogas System I; the COD measurements are required to be made on a daily basis, whereas during the monitoring period, the project proponent has not done regular daily monitoring of the COD sample data. The data is scattered over days in each month. The data is not available during 11-Jul-10 to 31-Aug-10 because the COD reactor for COD measuring was sent to repair.

Deviation applied for period : 11-Jul-10 to 31-Aug-10

Introduction to followed approach: The measured values of COD parameter when plotted against time of year show no clear change or dependency of COD on time of year. Since each sample is collected from same location CS1, CS2, CS3 and CS4, at approximately same time of the day and from waste water generated from the same process, whole year around, it should be acceptable to assume that COD readings represent a normal distribution over a year, which means that for most days, the value of COD is close to the mean, while for fewer days, the COD value is higher or smaller than the average. This is well represented on the following graph.



The approach is aimed to estimate the 95% confidence interval for the COD values for period of 11-Jul-10 to 31-Aug-10. The lower bound of the interval of the incoming COD values, the lower confidence limit, would then be used for the days when COD in values are not monitored. Additionally, the higher bound of the interval of outgoing COD values, the higher confidence limit, would be used for the days when no COD out values are monitored.

Conservativeness of Used approach and conjunction with the EB Guidance:

As per EB Guidance EB 50-Annex 30 the referred approach in case of sampling data is 90% confidence and 10% precision for the collected data. In simpler terms, "*Precision is an assessment of the error margin of the final estimate. Confidence is the likelihood that the sampling has resulted in the true value within a certain range of values*"²⁵."

In the approach followed in the case under consideration, 95% confidence interval ensures a higher conservativeness as compared to the EB guidance. It is remarked that the tool guidance would be valid as there is no guidance available in the applied version of the methodology specific to COD sampling.

As per EB guidance, the sample size for a given parameter should be chosen to achieve 90% confidence and 10% precision of data. In case of the sampling for the project under consideration, the precision (i.e. error margin) is calculated for the established 95% confidence interval (the approach of establishing the confidence interval is explained later) and found out to be +/- 8% (for 2007) OR +/- 6 (for 2008)²⁶. The mentioned precision level is under a confidence level of 95%, and is thereby more conservative than the referred guidance of 90% confidence and 10% precision.

Theory of used approach: In case there are infinite number of data samples available, true mean and true standard deviation can be established for the normally distributed data. On the

²⁵ http://cdm.unfccc.int/EB/050/eb50_repan30.pdf

²⁶ The error margin is estimated as difference between the extreme values and mean value of the 95% confidence interval, represented in percentage terms.

other hand when number of samples is low, Student-t distribution approach is used. The information from the starch factory²⁷, confirms that the production process is normal during this period and no variation is expected in the waste water characteristic.

The approach of student-t distribution is explained below.

$\bar{X}$ = Average of the n number of sample readings available.

μ = is the mean of normally distributed data if large number of readings are available.

s = standard deviation of the sample readings.

n = number of sample readings.

n-1 = degrees of freedom, the scores which are free to vary.

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In such cases the confidence intervals is defined, in which the value μ would lie with a probability of (100- α)%. So in this case we select $\alpha = 0.05$ (for both sides of the curve contributing 0.025 on each end of the curve is curtailed), the interval is defined as $[\bar{X} - (A * s / \sqrt{n}), \bar{X} + (A * s / \sqrt{n})]$. Here A is dependent on the number of sample readings available. The value is available in standard tables on many sources.

More specifically, probability $(\bar{X} - (A * s / \sqrt{n}) \leq \mu \leq \bar{X} + (A * s / \sqrt{n})) = 0.95$

So the lower limit of established intervals is used for baseline emissions (for incoming COD) and upper limit (for outgoing COD) is used for project emissions.

References: The above approach is available on various sources and cannot be understood in totality from just one source. However, PP believes that certain pages on www.wikipedia.org provide a very good summary of statistical approach and its application under practical condition. The sources of data consulted for the above approach are as follows:

Student-t distribution theory: [http://www.wikidoc.org/index.php/Student's t-distribution](http://www.wikidoc.org/index.php/Student's_t-distribution)

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'A' values for variable probabilities:

<http://www.staff.brad.ac.uk/yysentur/course/dp1008m/Student-t-table.pdf>

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Approach applied to the project activity:

Common terms used:

$\bar{X}$ = average of the parameter, COD in this case

s = standard deviation of the data set

n = number of sample readings

$s / \sqrt{n}$ = standard error of the data

²⁷Reference file : memo_production.pdf

The 95% confidence interval is represented as $\bar{X} - \left(A * \frac{s}{\sqrt{n}} \right)$ and $\bar{X} + \left(A * \frac{s}{\sqrt{n}} \right)$. The value of A depends on degrees of freedom i.e. n-1. Higher the value of n, lower the value of A. For a 125 value of n, the value of A is 1.980 ; which refers to the normal distribution.

	COD ww,in,AFFR	COD ww,in,CL2	COD ww,in,CL2	COD _{ww,} out,CL	COD ww,out,lagoon
$\bar{X}$	26,406	15,843	15,825	996	534
s	4,162	2,569	2,588	439	214
n	125	125	125	125	125
A	1.980	1.980	1.980	1.980	1.980
X	25,669	15,388	15,367	1,074	572

The above values of lower and upper bound of intervals are used for ingoing COD and outgoing COD respectively, for conservative estimation of Emission Reductions.