

Monitoring Report

Voluntary Carbon Standard 2007

Wastewater Treatment with biogas production (UASB) and heat utilization at General Starch Co. Ltd.

Monitoring Period: 1st June 2007 to 31st March 2008

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1. Project Background

By means of this Monitoring Report greenhouse gas emission reductions achieved by the project activity “Wastewater Treatment with biogas production (UASB) and heat utilization at General Starch” (WWT GS) are being verified and certified as per requirements of the **Voluntary Carbon Standard, version 2007**.

The project was successfully verified under VCS 1 in 2007, and the reference documents shall be made available. The project verification report is dated 31st Aug 2007.

2. Monitoring Background

Section B of the PDD (Application of the baseline and monitoring methodology) provides all details in regard to calculation of emission reductions and the monitoring plan to be followed by the project activity. Both the emission reduction calculations and the monitoring plan are based on the approved CDM methodologies AM 0022 version 4.

3. Monitoring Results

3.1. Monitoring period

This is the first monitoring report of this project activity. It covers the period from 1st June 2007 to 31st March 2008 (Both days included).

Papop Renewable Co.,Ltd is the **Built Operating Transfer (BOT)** Project for Biogas plant project of General Starch Co.,Ltd. They set up a well-defined management and operational system. This system includes the operation and management of the monitoring plan, which specifies the requirements and procedures for parameters monitoring, data recording and data archiving according to ISO9001:2000 since 8th February 2007 which is certified by Global Certification Limited.

The System Control And Data Acquisition (SCADA) is used to record operating data of biogas plant such as Waste water flow of UASB #1 (Ref. FM3) and UASB #2 (Ref. FM5), Biogas produced by UASB #1 (Ref. GM1) and UASB #2 (Ref. GM2), Biogas sent to boiler (Ref. GM3), %CH₄ etc. The SCADA flow diagram is shown as figure 1.

The new gas meter (GM4) was installed at the pipeline between surge tanks and flare system to measure the amount of biogas sent to flare system on 29th January 2008. The new revision of SCADA flow diagram is shown in figure 2.

List of Serial no. of main monitoring equipments are provided in the following table;

Flow meter	Serial number	Position	Calibration record
FM3	S/N 6B00EB20000	Waste water volume flow to UASB #1	External calibration by Endress+Hauser Date 25 /3/2008
FM5	S/N 6B00E920000	Waste water volume flow to UASB #2	External calibration by Endress+Hauser Date 08/12/2004 Date 25/3/2008

Gas meter	Serial number	Position	Calibration record
GM1	t-mass AT 70 S/N EJ-10214	Biogas produced from UASB #1	Internal calibration by Papop Co.,ltd Date 10/01/2008
GM2	t-mass AT 70 S/N F8-12093	Biogas produced from UASB #2	External calibration by Endress+Hauser Date 30/01/2007 Internal calibration by Papop Co.,ltd Date 11/01/2008
GM3	t-mass AT 70 S/N EJ-10213	Biogas sent to Boiler	External calibration by Endress+Hauser Date 07/02/2006 Internal calibration by Papop Co.,ltd Date 27-28/03/2007
GM4	t-mass 651 S/N 9B09BDO2000	Biogas sent to flares	Original Certificate Date 29/11/2007
%CH4	ABB EL 1020-IR 3.241376.5	Biogas sent to Boiler	Internal calibration by Papop Co.,ltd Date 12/10/2007 Date 29/01/2008 Calibration by using standard gas 70% Me- thane balance Carbon dioxide
Master Cal	69160049	Turbine gas meter	Date 26 January 2007 by PTT Public Co.,Ltd

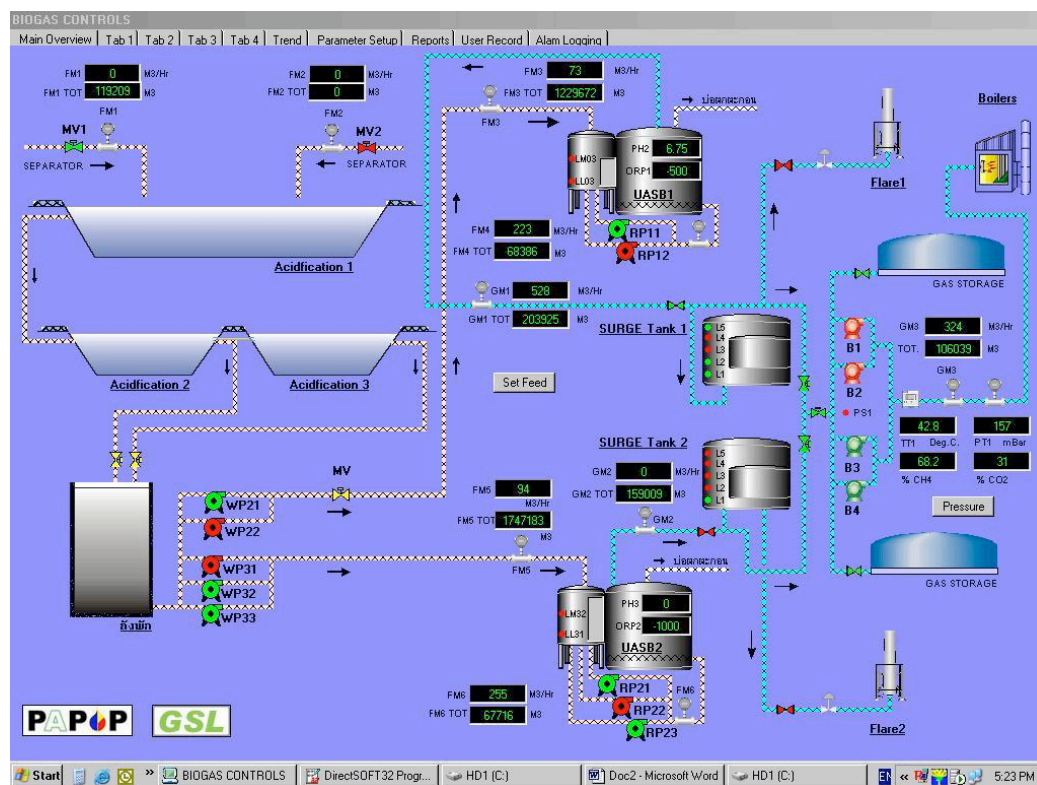


Figure 1: SCADA flow diagram of biogas plant before install gas meter at flare system (GM4)

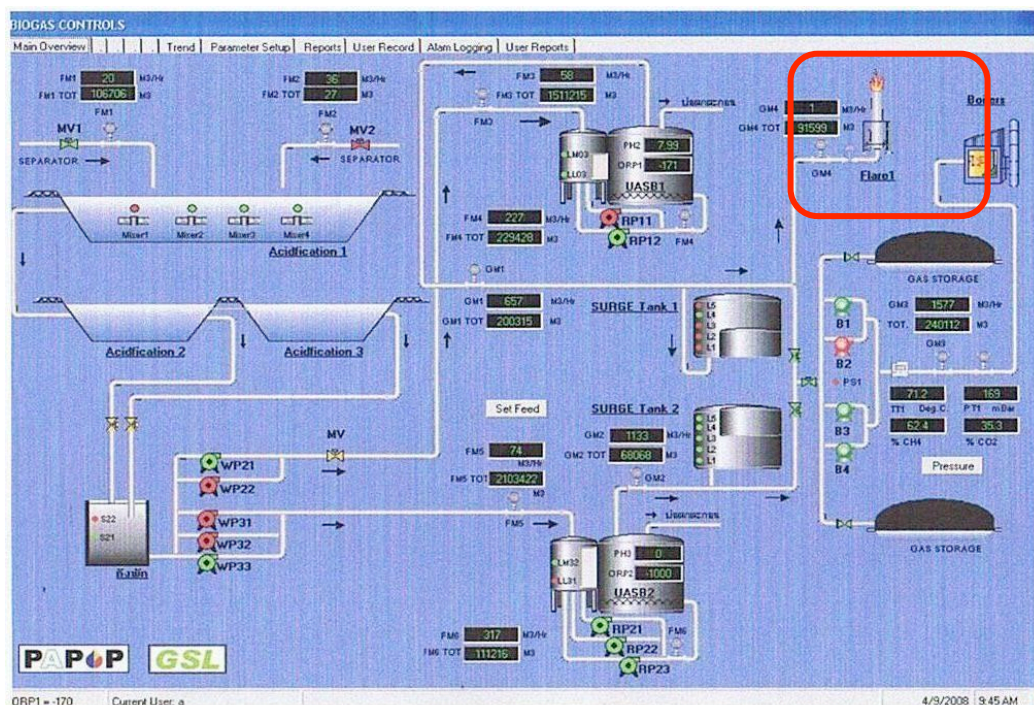


Figure 2: SCADA flow diagram of biogas plant after installed gas meter at flare system (GM4)

3.2. Presentation of monitoring results

All monitoring data is available in excel sheets "GSL_Monitoring report (from Jun 07to Mar 08).xls", "GSL_Monitoring data of UASB#1 & UASB#2 (Jun to Dec 2007).xls" and "GSL_Monitoring data of UASB#1 & UASB#2 (Jan to Mar 2008).xls"

The spreadsheets include an extract of the log of monitored data of the project activity:

- covering the parameters associated with water volume, gas volume (generated and burnt), COD concentration, gas concentration taking into account of monitoring parameters ID no 1-5, 8-12, 16 of AM0022,
- Baseline and emission reduction estimation calculation

3.3. Treatment of missing monitored data

During the months of September, October and November 2007, flow-meters and gas-meters faced some technical problems and a lot of data are missing. We can split this monitoring period in three groups:

Period A: (5 September to 19 September, 26 September to 2 October and 26 October to 31 October) Days where wastewater flows were not reported and a lot of gas meters are also missing.

Period B : (23 August to 4 September, 20 September to 25 September, 3 October to 25 October, 1 November to 23 November) Days where some of the gas meters were sent for repair or bubbles avoided to read the data (but where wastewater flows are available),

Period C : (In 2007: 24th November to 31st December and 1st June to 22nd of August, In 2008: 1st January to 31st March) Days where all parameters were recorded normally.

For period A, due to the lack of data, no emission reductions will be claimed.

For period B, biogas production will be estimated in a conservative manner thanks to wastewater flow values and COD data and different biogas production rates estimated for period C:

1st step : we estimate the volume of biogas produced during period B :

$$\begin{aligned} \text{Biogas}_{\text{produced, period B}} &= \text{Biogas}_{\text{produced period C}} * (\text{COD}_{\text{load UASB1, period B}} + \text{COD}_{\text{load UASB2, period B}}) / \\ &(\text{COD}_{\text{load UASB1, period C}} + \text{COD}_{\text{load UASB2, period C}}) \\ &= 7,937,234 * (2,883,506 + 3,883,404) / (8,070,928 + 8,748,116) \\ &= 3,193,436 \text{ Nm}^3 \end{aligned}$$

2nd Step : we estimate the volume of biogas sent to the boiler during period B :

$$\begin{aligned} \text{Biogas}_{\text{boiler period B}} &= \text{Biogas}_{\text{boiler period C}} * (\text{COD}_{\text{load UASB1, period B}} + \text{COD}_{\text{load UASB2, period B}}) / (\text{COD}_{\text{load}} \\ &\text{UASB1, period C} + \text{COD}_{\text{load UASB2, period C}}) \\ &= 7,720,263 * (2,883,506 + 3,883,404) / (8,070,928 + 8,748,116) \\ &= 3,106,141 \text{ Nm}^3 \end{aligned}$$

3rd step : we estimate the volume of biogas sent to the flare during period B :

$$\begin{aligned} \text{Biogas}_{\text{flare period B}} &= \text{Biogas}_{\text{flare period C}} * (\text{COD}_{\text{load UASB1, period B}} + \text{COD}_{\text{load UASB2, period B}}) / (\text{COD}_{\text{load}} \\ &\text{UASB1, period C} + \text{COD}_{\text{load UASB2, period C}}) \end{aligned}$$

$$= 458,991 * (2,883,506 + 3,883,404) / (8,070,928 + 8,748,116)$$

$$= 184,669 \text{ Nm}^3$$

4th step : we apply different conservative factor to the biogas volumes estimated above to take into account uncertainties (biogas volumes used to estimate baseline emission will be multiplied by 0.9 and parameters used to estimate project emissions will be multiplied by 1.1) :

Period	Biogas produced	Biogas sent to boiler	Biogas sent to flare
A	---	---	---
B	3,193,436 * 1.1	3,106,141 * 0.9	184,669*1.1
C	7,937,234	7,720,263	458,991
Total	11,450,014	10,515,790	662,0127

3.4. Calculation methodology

Emission reductions were calculated on the basis of formulae provided in AM0022 version 4 and applied to the project on the basis of an ex-ante calculation in the project PDD.

As per the equations set out in AM0022, the following equations are used to calculate project emission reductions from monitored data.

Total project emissions (t CO₂eq)

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

$$E_{project} = E_{CH4_lagoons} + E_{CH4_NAWTF} + E_{CH4_IC+Leaks}$$

Where:

$E_{project}$ are the Total Project Emissions (tCO₂e)

$E_{CH4_lagoons}$ are the fugitive methane emissions from lagoons from equations 2 (tCO₂e)

E_{CH4_NAWTF} are the fugitive methane emissions from the new anaerobic waste water treatment facility (tCO₂e)

$E_{CH4_IC+leakss}$ are the methane emissions from inefficient combustion and leaks (tCO₂e)

Formula 1	Jun07- Mar08
E_{project}	7,038
E _{CH4_lagoons}	-
E _{CH4_NAWTF}	-
E _{CH4_IC+Leaks}	7,038

Fugitive Methane Emissions from Lagoons

$$E_{CH_4_lagoons} = M_{lagoon_anaerobic} \cdot EF_{CH_4} \cdot GWP_{CH_4} / 1000$$

Where:

$E_{CH_4_lagoons}$ is the methane emissions from the lagoons (tCO₂e)

$M_{lagoon_anaerobic}$ is the amount of organic material removed by anaerobic processes in the lagoon system (kg COD³)

EF_{CH_4} is the methane emission factor (kg CH₄ / kg COD). A default COD to Methane conversion factor of 0.21kg CH₄/kgCOD is used⁴. If the methodology is used for waste water containing materials not akin to simple sugars a CH₄, a different emissions factor different has to be estimated and applied. Where a metric for organic wastewater flows other than COD is to be applied, the developer should set out the case for a relevant carbon emission factor.

GWP_{CH_4} is the Global Warming Potential of methane ($GWP_{CH_4} = 21$)

Formula 2 (project)	Jun07- Mar08
$E_{CH_4_lagoons}$	-
$M_{lagoon_anaerobic}$	-
EF_{CH_4}	0.241
GWP_{CH_4}	21

Whereby the mass balance in the considered lagoon system provides the amount of organic material removed by anaerobic processes.

$$M_{lagoon_anaerobic} = M_{lagoon_total} - M_{lagoon_aerobic} - M_{lagoon_chemical_ox} - M_{lagoon_deposition}$$

Where:

M_{lagoon_total} is the total amount of organic material removed in the lagoon system from equation 5 (kg COD)

$M_{lagoon_aerobic}$ is the amount of organic material degraded aerobically in the lagoon system (kg COD). Surface aerobic losses of organic material in pond based systems equal to 254 kg COD per hectare of pond surface area and per day is assumed to be lost through aerobic processes. Where other more project specific losses can be determined, these should be applied.

$M_{lagoon_chemical_ox}$ is the amount of organic material lost through chemical oxidation in the lagoon system (kg COD)

$M_{lagoon_deposition}$ is the amount of organic material lost through deposition in the lagoon system from equation 6 (kg COD)

Formula 3 (project)	Jun07- Mar08
$M_{lagoon_anaerobic}$	-
M_{lagoon_total}	724
$M_{lagoon_aerobic}$	1,240
$M_{lagoon_chemical_ox}$	-
$M_{lagoon_deposition}$	-

Registered project No 1040 (Korat Waste to Energy)¹ carried out a sensitivity analysis to determine the suitability of the surface oxidation factor utilised in this project analysis. Also, deposition, total removal and chemical oxidation are project specific factors that must be quantified on a project-specific basis. Considering strong similarities between the two projects, the analysis was applied to this project.

To assess the amount of COD entering the lagoon system the amount two waste water flows need to be quantified:

- a) the amount of COD actually entering the lagoon system from the new wastewater treatment facility which is equivalent to the amount of COD entering the new wastewater treatment facility minus the amount of COD removal as a result of the new wastewater treatment facility, and
- b) the amount of COD actually entering the lagoon system, bypassing the new wastewater treatment facility.

The first part is determined with:

$$M_{lagoon_input} = M_{input_total} \cdot (1 - R_{NAWTF})$$

Where:

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

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

R_{NAWTF} is the total organic material removal efficiency of the new project water treatment facility (-). It is a project specific factor used to estimate how much COD will be removed from the system. The most appropriate manner to estimate this factor is to undertake pilot plant trials with a pilot scale digester system prior to project implementation. Where this is not possible, manufacturers estimates as to equipment removal efficiencies may be applied. This factor will be used to determine estimates of COD flows to the project lagoon system, and the related monitoring methodology (AM0022 “Avoided Wastewater and On-site Energy Use Emissions in the Industrial Sector”) sets out how the actual amount of COD can be monitored to allow calculation of actual project emissions.

$$M_{lagoon_input_bypass} = M_{input_bypass}$$

Where

M_{input_bypass} is the total organic material that is entering the lagoon untreated. It is equivalent to the waste water flow of the bypass and the same COD load (mg/l) as measured for the waste water entering the lagoon.

The second part is not recognized by AM0022 even though AM0022 monitoring method identifies this parameters. It is, however, not included in the calculation for AM0022 projects. For the purposes of this calculation M_{lagoon_input} is defined as

M_{lagoon_input} (as defined in AM0022) plus $M_{lagoon_input_bypass}$.

¹ **Project 1040 : Korat Waste To Energy available on website :**
<http://cdm.unfccc.int/Projects/DB/KPMG1175141470.89/view>

Total Material Removed in the Lagoon System is:

$$M_{lagoon_total} = M_{lagoon_input} \cdot R_{lagoon}$$

Where:

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

R_{lagoon} is the total organic material removal ratio of the lagoon (-). It is a project specific factor, and is equal to the proportion of organic material removed (through all routes) within the boundaries of the lagoon system under consideration. This factor should be determined by carrying out a series of biochemical tests prior to project implementation. These tests will determine the COD flows into the system, and the COD flows out of the system at the system boundary. The relative difference of COD flowing in and out of the system over a period of time will allow determination of the Total Organic Material Removal Ratio.

and where M_{lagoon_input} includes $M_{lagoon_input_bypass}$

$M_{lagoon_input_bypass} = 0$, because no waste water was bypassing the new waste water treatment facility due to the capacity expansion of the new waste water treatment facility since 2006 (UASB2).

$M_{lagoon_anaerobic}$ becomes zero when all wastewater is treated in the new waste water treatment facility as all remaining COD entering the lagoon is removed on aerobic basis.

Material Deposition into the Lagoon System is:

$$M_{lagoon_deposition} = M_{lagoon_input} \cdot R_{deposition}$$

Where:

$R_{deposition}$ is the organic material deposition ratio of the lagoon. It is equal to the proportion of organic material physically sedimented in lagoons within the project boundaries. It is a project specific factor derived by assessing the relative ability of COD in the waste water stream to sediment in the project boundaries, through pre project analysis.

Formula 4 (project)	Jun07- Mar08
M_{lagoon_input}	824
M_{input_total}	23,586
R_{NAWTF}	96.51%
$M_{input_lagoon_bypass}$	-

Formula 5 (project)	Jun07- Mar08
M_{lagoon_total}	724
M_{lagoon_input}	824
R_{lagoon}	87.88%

Formula 6 (project)	Jun07- Mar08
$M_{\text{lagoon deposition}}$	-
$M_{\text{lagoon input}}$	824
$R_{\text{deposition}}$	-

Methane emissions from new anaerobic waste water treatment facility

In accordance with AM0022, methane emissions from the ABR at KWTE should be assessed and estimated based on measurements, technology supplier data and expert estimates. They may be disregarded if documented evidence for their insignificance is given.

Methane emissions from Inefficient Combustion Emissions

Methane emissions from inefficiency combustion are calculated as:

$$E_{CH_4_IC+Leaks} = \left(\sum_r V_r \cdot C_{CH_4_r} \cdot (1 - f_r) \cdot GWP_{CH_4} \right) + PE_{flare}$$

Where:

the sum is made over two routes r for methane destruction (heating and power generation);

V_r is the biogas combustion process volume in route r (Nm³)

C_{CH_4} is the methane concentration in biogas (tCH₄/Nm³) to be measured on wet basis.

f_r is the proportion of biogas destroyed by combustion (-)

PE_{flare} are the project emissions from flaring of the residual gas stream (tCO₂e) calculated following the procedures described in the “Tool to determine project emissions from flaring gases containing Methane”. PE_{flare} can be calculated on an annual basis or for the required period of time using this tool.

Formula 7	Jun07- Mar08
$E_{CH_4_IC+Leaks}$	7,038
$E_{CH_4_IC_heat}$	3,872
V_{heat}	10,515,790
f_{heat}	98.5%
$E_{CH_4_IC_elec}$	-
V_{elec}	-
f_{elec}	98.0%
PE_{flare}	3,166
GWP_{CH_4}	21
$C_{CH_4_r}$	0.00117

In the project activity, biogas will be flared when biogas production exceeds the capacity of the dual fuel burners or during maintenance shut down of the starch plant. Project emissions from the flare will be calculated using the “Tool to determine project emissions from flaring gases containing Methane”. Since no continuous monitoring takes place, the default flare efficiency prescribed by the tool is utilized. The calculation steps for project emissions are as follows:

STEP 1. Determination of the mass flow rate of the residual gas that is flared

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

Formula 1 flaring tool:

$$FM_{RG,h} = P_{RG,n,h} \times FV_{RG,h}$$

Where:

$FM_{RG,h}$: Mass flow rate of the residual gas in hour h (kg/h)

$P_{RG,n,h}$: Density of the residual gas at normal conditions in hour h (kg/Nm³)

$FV_{RG,h}$: Volumetric flow rate of the residual gas in dry basis at normal conditions in the hour h (Nm³/h)

Flaring tool: 1	Jun07- Mar08
$FM_{RG,h}$	82
$P_{RG,n,h}$	0.909
$FV_{RG,h}$	90
V_1	662,127

As stated in the “Tool to determine project emissions from flaring gases containing Methane”, a simplified approach may be taken, in which only the volumetric fraction of methane is measured and the difference to 100% is considered as nitrogen (N₂). From this simplified composition of the gas $P_{RG,n,h}$ is calculated as:

Formula 2 flaring tool

$$\rho_{RG,n,h} = \frac{P_n}{\frac{R_u}{MM_{RG,h}} \times T_n}$$

Where:

Variable	SI Unit	Description
$\rho_{RG,n,h}$	kg/m ³	Density of the residual gas at normal conditions in hour h
P_n	Pa	Atmospheric pressure at normal conditions (101 325)
R_u	Pa.m ³ /kmol.K	Universal ideal gas constant (8 314)
$MM_{RG,h}$	kg/kmol	Molecular mass of the residual gas in hour h
T_n	K	Temperature at normal conditions (273.15)

with $MM_{RG,h} = 65\% \times 16 + 35\% \times 28$

STEP 2 though STEP 4 are not applicable for this project

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

The quantity of methane in the residual gas flowing into the flare is the product of the volumetric flow rate of the residual gas ($FV_{RG,h}$), the volumetric fraction of methane in the residual gas ($f_{VCH4,RG,h}$) and the density of methane ($\rho_{CH4,n,h}$) in the same reference conditions (normal

conditions and dry or wet basis). Considering that the gas is cooler than 60 degree Celsius, the reported density is expressed on dry basis already.

$$TM_{RG,h} = FV_{RG,h} \times f_{v_{CH_4, RG,h}} \times P_{CH_4,h}$$

Where:

$FV_{RG,h}$: Volumetric flow rate of the residual gas in dry basis at normal conditions in hour h (Nm³/h)

$f_{v_{CH_4, RG,h}}$: Volumetric fraction of methane in the residual gas on dry basis in hour h

$P_{CH_4,h}$: Density of methane at normal conditions (kg/m)

Flaring tool: 13	Jun07- Mar08
$TM_{RG,h}$	41
$FV_{RG,h}$	90
$f_{v_{CH_4, RG,h}}$	0.636
$P_{CH_4,h}$	0.716

STEP 6: Determination of the hourly flare efficiency

The determination of the hourly flare efficiency depends on the operation of flare (e.g. temperature), the type of flare used (open or enclosed) and, in case of enclosed flares, the approach selected by project participants to determine the flare efficiency (default value or continuous monitoring).

In case of open flares and use of the default value for the flare efficiency, the flare efficiency in the hour h ($\eta_{flare,h}$) is:

50%, if the flare is detected for more than 20 minutes during the hour h

As the temperature will be 850°C for more than 40 minutes during the hour h, the 50% default was selected.

STEP 7: Calculation of annual project emissions from flaring

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

Formula 15 Flaring tool

$$PE_{flare,y} = \sum_{h=1}^{8760} TM_{RG,h} \times (1 - \eta_{flare,h}) \times \frac{GWP_{CH_4}}{1000}$$

Where:

$TM_{RG,h}$: Mass flow rate of methane in the residual gas in the hour h

$\eta_{flare,h}$: Flare efficiency in hour h

GWP_{CH_4} : Global Warming Potential of methane valid for the commitment period

Flaring tool: 15	Jun07- Mar08
$PE_{flare,y}$	3,166
$TM_{RG,h}$	41
$\dot{n}_{flare,h}$	50%
GWP_{CH4}	21

Considering that the volumetric flow of gas to the flare is not measured directly and other parameter are not measured on an hourly basis, the figures in these equations are based on hourly averages using annual reported data and using the simplifications and default values provided by the flaring tool.

Methane Emissions from Leaks in Biogas System

Leaks in the biogas system include leaks from the anaerobic digester and leaks from the biogas pipeline delivery system. This is estimated to be zero in the project emissions estimates, corresponding to registered project No 1040 (Korat Waste to Energy).

The UASB reactor gas collection system consists of a gas-tight concrete, coated gas dome and the delivery pipe to the boiler site is less than 2km in length.

Moreover, pipeline system is well designed by using High Density Polyethylene (HDPE) as the piping material which has the appropriate properties and good chemical resistance of biogas. Therefore, the leakage of biogas due to pipeline system is negligible in the project emissions.

Baseline emissions

The baseline scenario for the project is based on what would have happened in the absence of the project activities. In this case, the baseline scenario will be continued operation of the open lagoon system:

Formula (8) AM 22 v4

$$E_{BL} = E_{CH4_lagoons_BL} + E_{CO2_heat_BL} + E_{CO2_power_BL}$$

Where:

E_{BL} are the Total Baseline Emissions (tCO₂e)

$E_{CH4_lagoons_BL}$ are the fugitive methane emissions from lagoons in the baseline case (tCO₂e). They are calculated with baseline data based on equation 2 in the section on project emissions.

$E_{CO2_heat+powers_BL}$ are the CO₂ emissions from on site fossil heat and/or power generation in the baseline case (tCO₂) that are displaced by generation based on biogas collected in the anaerobic treatment facility.

$E_{CO2_grid_BL}$ are the CO₂ emissions related to electricity supplied by the grid in the baseline case (tCO₂) that are displaced by generation based on biogas collected in the anaerobic treatment facility.

Total baseline emissions are calculated as:

Formula 8	Jun07- Mar08
E_{BL}	117,639
$E_{CH4_lagoons_BL}$	98,628
$E_{CO2_heat_BL}$	19,011
$E_{CO2_power_BL}$	-

To calculate $E_{CH4_lagoons_BL}$, formulas 2 to 6 are applied using baseline data.

Formula (2 (baseline)) AM 22 v4

$$E_{CH4_lagoons_BL} = M_{lagoon_anaerobic_BL} * EF_{CH4} * GWP_{CH4} / 1000$$

Formula 2 (baseline)	Jun07- Mar08
$E_{CH4_lagoons_BL}$	98,628
$M_{lagoon_anaerobic_BL}$	19,488
EF_{CH4}	0.241
GWP_{CH4}	21

Formula (3 (baseline)) AM 22 v4

$$M_{lagoon_anaerobic_BL} = M_{lagoon_total_BL} - M_{lagoon_aerobic_BL} - M_{lagoon_chemical_ox_BL} - M_{lagoon_deposition}$$

Formula 3 (baseline)	Jun07- Mar08
$M_{lagoon_anaerobic}$	19,488
$M_{lagoon_total_BL}$	20,727
$M_{lagoon_aerobic_BL}$	1,240
$M_{lagoon_chemical_ox_BL}$	-
$M_{lagoon_deposition_BL}$	-

Formula (11) AM 22v4 (corresponding to the logic of formula (4) AM 22 v4 in the project scenario

$$M_{lagoon_input_BL} = M_{input_total}$$

Formula 4 (baseline)	Jun07- Mar08
$M_{lagoon_input_BL}$	23,586
$M_{input_total_BL}$	23,586
R_{NAWTF}	0.00%
$M_{input_lagoon_bypass_BL}$	-

Formula (5 (baseline)) AM 22 v4

$$M_{lagoon_total_BL} = M_{lagoon_input_BL} * R_{lagoon}$$

Formula 5 (baseline)	Jun07- Mar08
$M_{\text{lagoon total BL}}$	20,727
$M_{\text{lagoon input BL}}$	23,586
R_{lagoon}	87.88%

Formula (6 (baseline)) AM 22 v4

$$M_{\text{lagoon_deposition_BL}} = M_{\text{lagoon_input_BL}} \cdot R_{\text{deposition}}$$

Formula 6 (baseline)	Jun07- Mar08
$M_{\text{lagoon_deposition_BL}}$	-
$M_{\text{lagoon_input_BL}}$	23,586
$R_{\text{deposition}}$	-

Result from formula (9), AM 22 v4:

Whereby on Site Heat Generation Emissions displaced by generation based on biogas collected in the anaerobic treatment facility are calculated as follows (replacement of power from the grid does not apply):

In calculating CO₂ emissions from on site heat displaced by biogas collected in the anaerobic treatment, the use of fossil fuels is considered:

Formula (9) AM 22 v4

$$E_{\text{CO}_2_heat} = F \cdot NCV \cdot EF$$

Where:

F is the corresponding amount of fossil fuel displaced by the use of biogas for the generation of on site heat (unit). This is estimated as product of : (1) Average specific fuel consumption for the output of the facility, estimated using 3 years historical data; and (2) the annual production
 NCV is the net calorific value of the fossil fuel considered (TJ/unit). Site specific local NCV values should be applied where available; however, should this information not be available, IPCC data may suffice for that specific country.⁷

EF is the carbon emission factor of the fossil fuel considered (tCO₂/TJ).

Formula 9	Jun07- Mar08
$E_{\text{CO}_2_heat}$	19,011
F	6,080
NCV	0.0404
EF	77.40

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

- 1m^3 of 100% of CH_4 has NCV = $1.04^2 (\text{MJ}/\text{ft}^3) / 0.02832 (\text{m}^3/\text{ft}^3) = 36.723 \text{ MJ}$
- 1m^3 biogas at 63.6% concentration of methane = $36.723 * 63.6\% = 23.36 \text{ MJ}$
- Combustion efficiency on HFO as well as biogas is considered to be 98.5% in absence of the manufactures data.
- 1 ton of heavy fuel oil = $40,400 \text{ MJ}^3$
- Therefore: 1m^3 biogas = $(23.36/40,400) = 0.000578$ tons of heavy fuel oil

A 63.6% is the average actual value of Methane concentration of biogas is used in this crediting period of monitored data.

Emission reductions

$$ER = E_{BL} - E_{project}$$

Formula 12	Jun07- Mar08
ER	110,601
E_{BL}	117,639
$E_{project}$	7,038

However, this figure needs to be adjusted should the determination of conservativeness show that deductions have to be made. As can be seen below, such adjustments are to be made, resulting in the following conservative estimate of emission reductions.

	Jun07- Mar08
$ER_{conservative}$	110,601
ER	110,601
Conservativeness estimate	-8,260

The quantity of verifiable VCU in the reporting period can therefore be summarized as:

Year	Estimation of emission reductions (tonnes of CO ₂ eq)	Conservative estimation of emission reductions (tonnes of CO ₂ eq)
Jun07- Mar08	110,601	110,601
Total estimated reductions (tonnes of CO ₂ eq) of verification period	110,601	110,601

² Source: Oil and Thailand 2005.

http://www.dede.go.th/dede/fileadmin/usr/wpd/static/thai_oil_2005/50Conversion.pdf

³ IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 1: Introduction, Table 1.2, value for "Residual fuel oil"

Determination of conservativeness

It must be verified this equation delivers a conservative estimate of emission reductions i.e. that the

emissions of CH₄ from the lagoons in the baseline situation are not higher than the total emissions of

biogas from the digester and the lagoons in the project situation. Therefore calculate:

$$E_{CH_4_lagoon_BL} - (E_{CH_4_lagoon} + E_{CH_4_nawtf} + E_{CH_4_coll})$$

Formula 13	Jun07- Mar08
=	-8,260
E _{CH₄_lagoon_BL}	98,628
E _{CH₄_lagoon}	-
E _{CH₄_NAWTF}	-
E _{CH₄_Coll}	106,888

4. Monitoring Results Summary

Monitoring parameters according to AM0022 v4

ID no	Parameter	Ex-post values	
1	WW _{input}	1,281,351 m3	Monitored data during credit period from June 2007 to March 2008
	UASB 1	598,266 m3	
	UASB 2	683,085 m3	
2	WW _{out}	1,281,351 m3	Assume; WW out = WW input
	UASB 1	598,266 m3	
	UASB 2	683,085 m3	
3	MCOD _{in}	23,641,002 kgCOD	Monitored data during credit period from June 2007 to March 2008
4	MCOD _{out}	825,488 kgCOD	Calculated base on the Average of %R _{NAWTF}
5	V _{boiler}	10,515,037 Nm3	Monitored data during credit period from June 2007 to March 2008
6	- blank -		
7	EL	- MWh	
8	F	6,079 ton	Calculated base on the Net calorific value of biogas
9	V ₁	662,072 Nm3	Calculated base on the actual data during credit period from June 2007 to March 2008
10	V _{genset}	- Nm3	
11	C _{CH4}	0.001169 tCH4/Nm3	methane concentration of biogas measured on wet basis for biogas with 63.6% CH4 volumetric share
12	PE _{flare}	3,165 tCO2	
13	M _{ox_agent}	0 kgCOD	
14	E _{ta_genset}	98%	
15	E _{ta_boiler}	98.5%	Assume due to the absence of manufacturer data
16	WW _{bypass}	0 m3	
17	LOSS _{pipeline}	0 %	
18	M _{removed}	22,815,514 kgCOD	Calculated by MCOD _{in} - MCOD _{out}
19	NCV _{biogas}	23.36 MJ/Nm3	1m3 CH4 NCV = 35.7 * CH4 volumetric share in biogas

Monitoring parameters according to flaring tool

P _{CH4,h}	0.909 kg/Nm3	the difference to 100% is considered to be N2 (simplified approach of flaring tool)
η _{flare,h}	50% %	
f _{CH4RG,h}	63.6% %	volumetric fraction of methane in residual gas
P _{CH4,n}	0.716 kg/Nm3	

Other parameters

EF _{CH4}	0.241 kgCH4/kgCOD	Source: KWTE project No 1040, default value is 0.21 but a different factor can be used. Here: with B0 = 0.25
R _{biogas}	87.88% %	Source: KWTE project No 1040 registered at UNFCCC CDM EB
R _{deposition}	0.00% %	Source: KWTE project No 1040 registered at UNFCCC CDM EB
E _{CH4_NAWTF}	0 tCO2/year	Source: KWTE project No 1040 registered at UNFCCC CDM EB
R _{NAWTF}	96.51% %	measured using COD _{in} and COD _{out} multimonth data of Jun07- March08
CEF	0.52 tCO2/MWh	Annex 1 of Monitoring report
EF _{flaring}	77.400 tCO2/TJ	Source: IPCC 2006
NCV _{flaring}	0.0404 TJ/t	Source: IPCC 2006
P _{CH4,n}	0.716 kg/Nm3	Density of methane according to tool to determine project emissions from flaring gases containing methane
η _{flare}	50%	

Average data

Wastewater volume in	4,299 m3/operating day	
Wastewater volume out	4,299 m3/operating day	
Flow of untreated wastewater	- m3/operating day	
Wastewater feed stock	Tapioca	
COD _{in}	18,773 gCOD/m3	
COD _{out}	656 gCOD/m3	
COD _{capacity}	80,705 [kg/d]	
Average plant utilization	100%	
Operating days at capacity	305 d/a	Credit period from June 2007 to March 2008

Baseline information

NCV heavy fuel oil	0.0404 TJ/l	Source; IPCC 2006
EF heavy fuel oil	77.4 tCO ₂ /TJ	Source; IPCC 2006
CO ₂ intensity of displaced fuel	279 tCO ₂ /GWh	
CO ₂ intensity of displaced power	520 tCO ₂ /GWh	
GWP _{CH₄}	21	Source; IPCC 2006

Outputs base on the average data

Expected biogas production	29,515 m ³ /day	
Expected biogas production	9,002,213 m ³ /year	
Methane content of biogas	63.6%	Source: the Average data from June 2007 to March 2008
NCV of CH ₄	36.73 MJ/m ³	Source: DEDE, 2005
Energy content of biogas	210,268 GJ/a	

Combustion equipment

Boiler combustion efficiency	98.5%	Assume due to the absence of manufacturer data
Gas engine combustion efficiency	98.0%	Not applicable
Flare combustion efficiency	50.0%	Default value based on Methodology

Thai Natural gas assume as 100% CH ₄ :	
1.04	MJ/lit
0.02832	m ³ /lit
36.73	MJ/m ³

Source: Oil and Thailand 2005 by DEDE

Annex 1 BASELINE INFORMATION

Calculation of grid emission factor

For the proposed project, the baseline is kWh produced by the renewable generating unit multiplied by an emission coefficient calculated as a combined margin (CM), consisting of the combination of operating margin (OM) and build margin (BM) factors, according to the procedures prescribed in the approved methodology ACM0002, in accordance with AMS I.D.

In ACM0002, the baseline emission factor (EF_y) is calculated by followings procedures.

Step 1: Calculate the Operating Margin emission factors ($EF_{OM,y}$) based on one of the four following methods

- (a) Simple OM, or
- (b) Simple Adjusted OM, or
- (c) Dispatch Data Analysis OM, or
- (d) Average OM

The method of Dispatch Data Analysis OM is not selected since data of hourly generation of the set of power plants in the top 10% of grid system dispatch is not publicly available.

The Simple OM method is selected since low-cost/must run resources constitute at 5.6% which is less than 50% of total grid generation in average of the five most recent years as shown in the following table.

Table: National grid generation by energy sources and Low-cost/must run constitution

National Grid Generation By Energy Sources

Unit : GWh

Year	Hydro	Fuel Oil	Diesel Oil	Coal & Lignite	Natural Gas	Others (a)	SPP, VSPP (b)	VSPP (c)	Total	Net import	Grand Total
2002	7,471	2,616	168	16,652	69,538	2	12,566	-	109,013	2,539	111,552
2003	7,299	2,941	180	16,807	76,332	2	13,422	-	116,983	2,183	119,166
2004	6,040	7,138	551	17,993	80,489	2	13,513	1	125,727	3,016	128,743
2005	5,798	8,244	414	18,334	85,703	2	13,700	2	132,197	3,777	135,974
2006	8,125	8,350	143	22,051	86,339	3	13,721	10	138,742	4,409	143,151

Remark

(1)

(1)

(1)

(1)

(1)

(1)

(2)

(2)

(3)

1. Source: Electric Power in Thailand 2006 Report, DEDE, Table 17 page 21

2. Source: Electric Power in Thailand 2006 Report, DEDE, Table 16 page 20

3. Source: Electric Power in Thailand 2006 Report, DEDE, Table 21 page 25

a. Including geothermal, solar cell and wind turbine, etc.

b. Fuel used in SPP, VSPP (Co-generation): NG., coal, lignite, fuel oil, diesel, renewable & others

c. Fuel used in VSPP: Gas engine: Renewable & biogas

Low-cost/must run resources

Unit : GWh

Year	Hydro	Other (a)	Total LCMR	Total	LCMR constitution
2002	7,471	2	7,473	109,013	6.9%
2003	7,299	2	7,301	116,983	6.2%
2004	6,040	2	6,042	125,727	4.8%
2005	5,798	2	5,800	132,197	4.4%
2006	8,125	3	8,128	138,742	5.9%
Average of LCMR constitution					5.6%

Simple OM Calculation

The Simple OM ($EF_{OM,y}$) is calculated according to the following formula:

$$EF_{OM,y} = \frac{\sum_{i,j} F_{i,j,y} * COEF_{i,j}}{\sum_j GEN_{j,y}}$$

Where:	
$F_{i,j,y}$	Amount of fuel i consumed by relevant power sources j in year(s) y
j	refers to the power sources delivering electricity to the grid, not including low-operating cost and must-run power plants, and including imports to the grid
$COEF_{i,j,y}$	the CO ₂ emission coefficient of fuel i (tCO ₂ /mass or volume unit of the fuel)
$GEN_{j,y}$	the electricity (MWh) delivered to the grid by source j

The Simple OM is calculated by using the choice of (ex-ante) the full generation-weighted average for the most recent 3 years for which data are available at the time of PDD submission.

The following spreadsheets are the calculations of the Simple OM.

The electricity delivered to the grid by source j, $GEN_{j,y}$

Power sources delivering electricity to the grid, not including LC/MR, including imports

Unit : GWh

Year	Fuel Oil	Diesel Oil	Coal & Lignite	Natural Gas	SPP, VSPP (b)	VSPP (c)	Net import	Total
2004	7,138	551	17,993	80,489	13,513	1	3,016	122,701
2005	8,244	414	18,334	85,703	13,700	2	3,777	130,174
2006	8,350	143	22,051	86,339	13,721	10	4,409	135,023
Sum (2004 - 2006)								387,898

The amount of fuel i consumed by the relevant power sources j, $F_{i,j,y}$

Fuel consumption for electric generation to national grid

Year	Fuel Oil (million litres)	Diesel Oil (million litres)	Coal Lignite (thousand tons)	Natural Gas (MMscf)	SPP, VSPP (b)	VSPP (c)	Net import
2004	1,697	120	16,537	724,560	-	-	-
2005	1,996	83	16,571	764,118	-	-	-
2006	2,030	41	17,166	857,103	-	-	-

Remark (4) (4) (4) (4) (5) (5)

4. Source: Electric Power in Thailand 2006 Report, DEDE, Table 19, page 23 (excluding fuel consumption from SPP and VSPP)

5. As the amount of fuel consumption in SPP and VSPP is not available, therefore it is not taken into account. This is conservative.

Fuel consumption for electric generation to national grid (tons)

Year	Fuel Oil (tons)	Diesel Oil (tons)	Coal & Lignite (tons)	Natural Gas (tons)
2004	1,578,210	100,800	16,537,000	14,774,376
2005	1,856,280	69,720	16,571,000	15,580,996
2006	1,887,900	34,440	17,166,000	17,477,037

Remark: density of fuel

Fuel oil	0.93 kg/l	source: DEDE, IEA
Diesel oil	0.84 kg/l	source: DEDE, IEA
NG	0.72 kg/m3	source: PTT PCL, Thailand

The CO₂ emission coefficient of fuel i

CO2 emission coefficient of fuel 'i', COEF_i

Parameter	Fuel Oil	Diesel Oil	Coal & Lignite	Natural Gas
NCV _i (TJ/Gg)	40.4	43.0	11.9	48.0
EF _{CO2,i} (kg/TJ)	77,400	74,100	101,000	56,100
OXID _i	1	1	1	1
COEF _i (tCO2/ton)	3.13	3.19	1.20	2.69

Remark

As no local CO2 emission factor per unit of energy is available, 2006 IPCC default values are used.

The Simple OM, EF_{OM,y}

Calculation of (F_{i,j,y} * COEF_{i,j})

Year	Fuel Oil (tCO2)	Diesel Oil (tCO2)	Coal & Lignite (tCO2)	Natural Gas (tCO2)	Total (tCO2)
2004	4,935,000	321,179	19,875,820	39,784,438	64,916,437
2005	5,804,513	222,149	19,916,685	41,956,505	67,899,852
2006	5,903,388	109,736	20,631,815	47,062,164	73,707,103
Sum	16,642,901	653,064	60,424,321	128,803,108	206,523,393

Simple OM emission factor (EF_{OM,y})

Year	Total (GWh)	Total (tCO2)	EF _{OM,y} (tCO2/MWh)
2004	122,701	64,916,437	0.529
2005	130,174	67,899,852	0.522
2006	135,023	73,707,103	0.546
Sum (2004 - 2006)	387,898	206,523,393	
EF _{OM,y} (2004 - 2006)			0.532

From the table, EF_{OM,y} = 0.53 tCO₂/MWh

Step 2 : Calculate the Build Margin emission factor (EF_{BM,y})

The Build Margin (EF_{BM,y}) is calculated according to the following formula:

$$EF_{BM,y} = \frac{\sum_{i,m} F_{i,m,y} * COEF_{i,m}}{\sum_m GEN_{m,y}}$$

The Option 1, *ex-ante* calculation of the Build Margin emission factor, is selected.

The calculation of the Build Margin is based on the most recent information available on plants already built for sample group *m*.

Since the detail information of the SPP and VSPP power plants is not available, only information of IPP and EGAT powerplants is available and is reported by DEDE (Electric Power in Thailand, 2006). The sample group *m*, therefore, consists of the power plants listed in the following table.

Powerplants that have been built most recently

Plant name (sample group m)	Commercial Operation Date COD	Plant Capacity (MW)	Generation in 2006 (GWh)	Type of Fuel	Efficiency (Btu/kWh)	Energy (TJ)	EF CO _{2,i} (tCO ₂ /TJ)	Emissions (tCO ₂)	EF BM,y (tCO ₂ /MWh)
Krabi	Aug 2003	340.0	1,126	Fuel oil	8,918	10,592	77.40	819,817	
Ratchaburi, Cogeneration	April 2002	2,041.0	15,002	Natural Gas	7,214	114,155	56.10	6,404,103	
EPEC	Mar 2003	350.0	2,385	Natural Gas	7,020	17,660	56.10	990,737	
Glow	Jan 2003	713.0	5,425	Natural Gas	6,979	39,936	56.10	2,240,402	
BLCP	Aug 2006	673.3	4,024	Coal	8,910	37,819	101.00	3,819,682	
Total			27,962					14,274,740	0.51
Total grid generation			138,742						
Generation of group m is part of total grid generation			20.2%						

6. Source: Electric Power in Thailand 2006 Report, DEDE, Table 8, page 10 and Table 18 page 22

These power plants have been built most recently and they comprised 20.2% of the system generation in year 2006.

From the table, $EF_{BM,y} = 0.51 \text{ tCO}_2/\text{MWh}$

Step 3. Calculate the baseline emission factor EF_y

The baseline emission factor or the Combined Margin is calculated according to the following formula:

$$EF_y = W_{OM} * EF_{OM,y} + W_{BM} * EF_{BM,y}$$

Where the weights W_{OM} and W_{BM} , by default are 50% ($W_{OM} = W_{BM} = 0.5$)

The Baseline Emission Factor EF_y

Parameter	Emission Factor (tCO ₂ /MWh)	Weights
Simple OM EF OM,y	0.53	0.50
Bulid Margin EF BM,y	0.51	0.50
Combined Margin EF y	0.52	

Therefore, the baseline emission factor $EF_y = 0.52 \text{ tCO}_2/\text{MWh}$