CDM Monitoring Report

Siam Quality Starch Wastewater Treatment and Energy Generation Project in Chaiyaphum, Thailand

UNFCCC Project Registered No. 1993
Monitoring Report No. 01 (Version 1.0)

Monitoring Period
15 April 2009 – 30 November 2009

Project Participants
Siam Quality Starch Company Limited
Mitsubishi UFJ Securities Co.,Ltd

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CARBON PARTNERS ASIATICA

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Siam Quality Starch Wastewater Treatment and Energy Generation Project in Chaiyaphum, Thailand

This report is prepared for the purpose of verification and certification of Certified Emission Reductions (CERs) resulting from project activity “Siam Quality Starch Wastewater Treatment and Energy Generation Project in Chaiyaphum, Thailand” under the Clean Development Mechanism (CDM). In line with the CDM rules, this Monitoring Report forms a core part of the documents to be submitted to meet the requirement of project verification.

1. Project Description

1.1. Project Information

Project Title:	Siam Quality Starch Wastewater Treatment and Energy Generation Project in Chaiyaphum, Thailand
Project Reference number:	1993
Registration Date:	15 April 2009
Crediting period:	15 April 2009 onwards
Project Participants:	Siam Quality Starch Co., Ltd. (Thailand)
CERs Monitoring Period:	April 15 to November 30, 2009
Methodology (ies) Applied:	AM0013 version 4 and AMS-I.C version 12

1.2. Description of the Project Activity

Project Objective

Siam Quality Starch Co., Ltd. (SQS) is a Native and Modified starch manufacturer whose factory, with a production capacity of 200,000 tpy, is located in the North Eastern region of Thailand. The starch production process involves extraction and refinement of tapioca roots. This production process emits a large amount of organic content wastewater, which not only affects the local environment, but also releases methane, a potent greenhouse gas (GHG).

To alleviate GHG emission and other environmental issues, a new anaerobic digestion and methane recovery system coupled with a thermal energy generation system have been implemented to replace the previous open lagoon treatment system from which methane was freely emitted into the atmosphere.

Project Activity

The Project involves installation and operation of an anaerobic digestion and methane recovery system for the treatment of wastewater. The captured methane will be utilized in the thermal

energy generation system as fuel for burners that produce heated air for the factory's drying process, which prior to the project activity implementation was fuelled entirely by bunker oil, a fossil fuel.

The Project reduces GHGs through two activities. The first is avoidance of methane that was previously emitted from the open lagoons, and the second is from displacement of bunker oil by utilizing captured methane generated from biogas digester as fuel.

2. CERs Calculation Methodology

The CDM methodologies AM0013 version 4 and AMS-I.C version 12 are used to compute the CERs.

2.1. Project Boundary

The overall boundary of project activities is illustrated by the schematic diagram below.

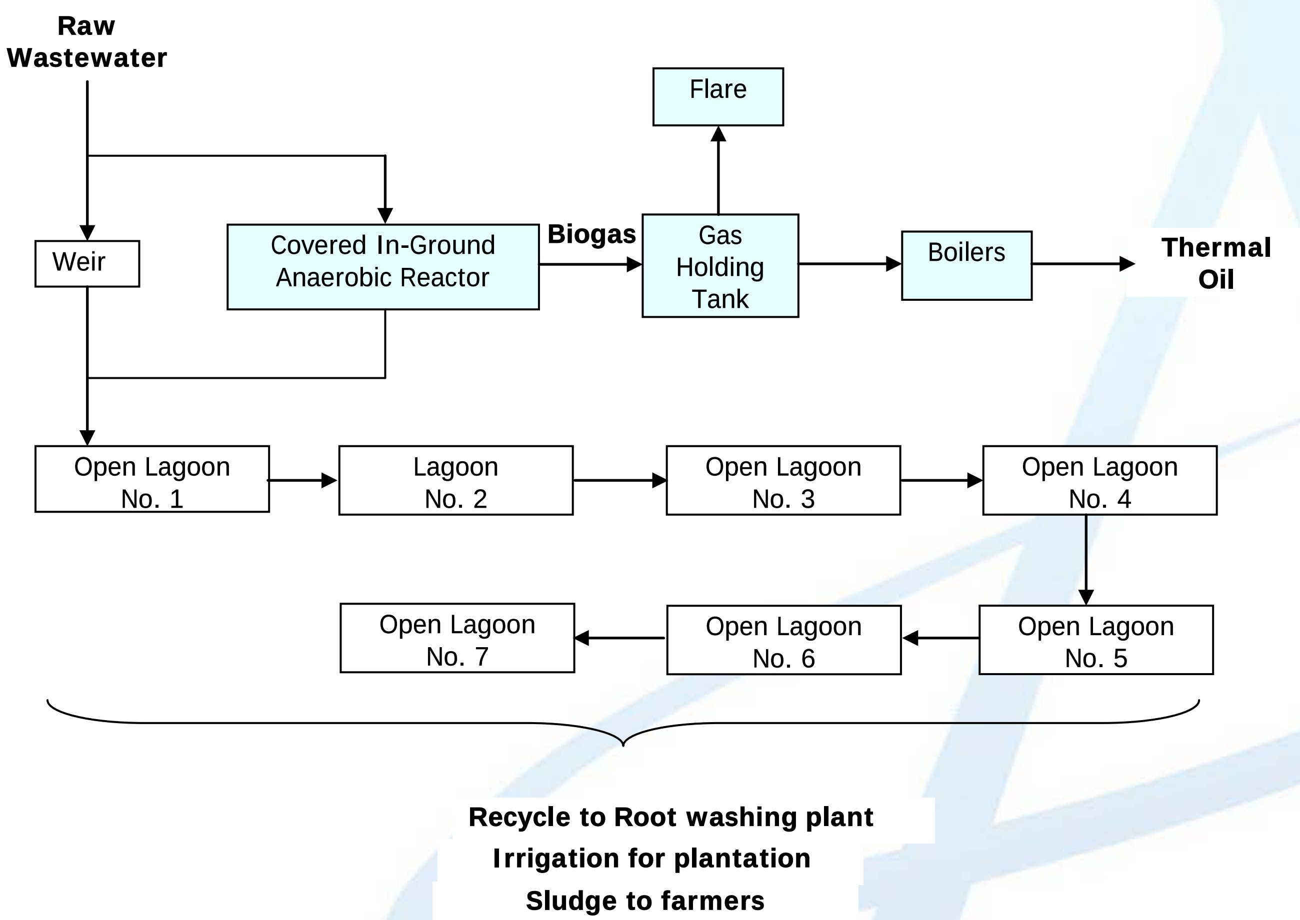

Figure 1: Schematic diagram of project boundary

The project activity involves three main technologies as follows:

- Wastewater treatment system;
- Thermal energy generation system; and
- Flare system.

To elaborate on each project component, influent fresh wastewater from the starch factory is firstly treated in a Covered In-Ground Anaerobic Reactor (CIGAR) which has a capacity of 90,000 m^3. Anaerobic bacteria activity decreases the loading of Chemical Oxygen Demand (COD) dramatically, by about 74%. The anaerobic process results in the production of methane-rich biogas, which is trapped within the digester and recovered.

In the thermal energy generation system, the recovered biogas from digester will be fed into two thermal oil burners (2 x 5,234 kW) installed at factory 1, and two others (2 x 5,234 KW) installed at factory 2. All burners can co-fire biogas and bunker oil.

Finally, any excess biogas will be combusted in the flare system, when there is overpressure in the biogas stream. It is also sometimes utilized for the purpose of checking that the flare system is properly functioning.

The wastewater exiting the CIGAR system is fed into the existing open lagoons, for secondary treatment. Final effluent is then discharged using a pump to the nearby eucalyptus plantation, within SQS's factory bounds. Sludge, when removed, is given (free of charge) to local farmers as fertilizer for application on tapioca fields.

2.2. Calculation methodology

The methodologies and tool applied for the calculation of CERs are:

- CDM methodology AM0013 "Avoided methane emission from organic wastewater treatment" Version 04; and
- CDM methodology AMS-I.C "Thermal energy for the user" Version 12; and
- CDM "Tool to determine project emission from flaring gases containing methane"

As per the abovementioned methodologies and tool, the calculation of CERs is governed by the following equations.

$$\mathbf{ER_y = BE_y - PE_y} \quad \text{(Eq. 1)}$$

Where, BE_y is Baseline Emission that calculated from;

$$\mathbf{BE_y = BE_{lagoon,y} + BE_{fuel\_oil,y}} \quad \text{(Eq. 2)}$$

While the PE_y is Project Emission that calculated from;

$$\mathbf{PE_y = PE_{lagoon,y} + PE_{phys\_leak,y} + PE_{sludge,y} + PE_{enegy\_cons,y} + PE_{stack,y}} \quad \text{(Eq. 3)}$$

Where;

ER_y = Emission reductions (tCO_2e/yr)

BE_y	= Baseline emissions (tCO_2e/yr)
PE_y	= Project emissions (tCO_2e/yr)
$BE_{lagoon,y}$	= Baseline CH_4 emissions from the open lagoons in year *y* (tCO_2e/yr)
$BE_{fuel\_oil,y}$	= Baseline CO_2 emissions from the combustion of fuel oil in year *y* (tCO_2/yr)
$PE_{lagoon,y}$	= Project CH_4 emissions from the open lagoons in year *y* (tCO_2e/yr)
$PE_{phys\_leak,y}$	= Project CH_4 emissions due to the physical leakage from the anaerobic digester in year *y* (tCO_2e/yr)
$PE_{sludge,y}$	= Project CH_4 emissions from the land application of sludge in year y (tCO_2e/yr)
$PE_{energy\_cons,y}$	= Project CO_2e emissions from the consumption of energy on the account of the project activity in year y (tCO_2e/yr)
$PE_{stack,y}$	= Project CH_4 emissions from incomplete combustion of biogas in the flare and boilers in year y (tCO_2e/yr)

It is noted that neither dewatering process nor leakage are associated with the project activity and both were excluded from the project emission calculation as indicated in the CDM-PDD.

As per the methodology AM0013, for the purpose of calculating the actual emission reductions achieved, the lower of the following two values must be assumed as the baseline emission:

(i) Baseline methane emission less the physical leakage or;
(ii)The actual methane captured and flared/used for energy generation

In case (ii) is lower, and is therefore taken as baseline emission, physical leakage from anaerobic digester for estimating emission reduction shall be taken as zero as per AM0013.

3. Monitoring Plan

3.1. Monitoring Team and System

Consistent with the CDM-PDD, SQS appointed a CDM monitoring team consisting of a CDM project manager, plant engineer and environmental officer to fully implement data collecting, quality control and internal evaluation process.

To ensure maximum accuracy of monitored data, data record keeping has been carried out only by members of the specifically-appointed monitoring team. All monitored parameters were recorded in the data log book which was submitted to the plant engineer and CDM project manager on a daily and monthly basis as per the CDM-PDD. Within the control room, relevant parameters were logged on a real-time basis and any manually recorded data were input into the digital database.

The management structure and monitoring procedures are in accordance with ISO 9001.

3.2. Monitored Parameters

Table 1: Summary of monitored parameters

Data	Position/ID No.	Parameter as in PDD	Description in PDD	Unit	Frequency of measure as given in AM0013	Remark
1	(1)/FIC-001	$F_{digester}$/ $F_{dig\_out,m}$	Flow rate of wastewater fed into/ discharge out of digester	m^3/day	Continuously	Digester is kept in hydraulic balance, only one monitoring point is necessary as per CDM-PDD.
2	(-)/-	OP_m	Number of operation days in month	Day/month	-	-
3	(2)/-	$COD_{conc\_in,baseline,m}$	COD conc. of effluent entering the lagoon in the baseline	Kg COD/m^3	At least monthly	-
4	(3)/TIC-001	T2	Ambient Temperature	Celsius	Daily	
5	(4), (5), (6), (7),(8), (9)/ meter rods	$D_{lagoon,project}$	Depth of open lagoons	m	Daily	
6	(10),(11),(12),(13) /Truck scale 01;02;03;04	$Q_{sludge,m}$ / $Q_{sludge,y}$	Amount of sludge generated/ and removed in month or year	Ton Sludge	Continuously	Weight difference between loaded truck and unloaded truck
7	(-)/-	$COD_{conc\_sludge,m}$	COD conc. of sludge removed in month	Kg COD/ m^3 sludge	At least monthly	-
8	(14)/GFM-001 (Burner 1 + 2) (15)/GFM-002 (Burner 3 + 4) (28)/GFM-003 (Burner) (29)/GFM-004(Burner) (30)/GFM-005(Burner) (31)/GFM-006(Burner)	$Q_{fuel\_oil,y}$	Quantity of fuel oil displaced in year y	TJ/yr	Calculated	Thermal energy displaced for Hot Oil production by biogas generated in project activity
9	(16)/-	$COD_{conc\_dig\_out,m}$	COD out of biodigester to lagoons	Kg COD/m^3	At least monthly	-
10	(14)/GFM-001 (Burner 1 + 2) (15)/GFM-002	$Q_{biogas\_total,y}$	Quantity of biogas produced and collected in the digester in	Nm^3/yr (normal cubic meter)	Continuously	Installed meters to monitor on wet basis and

	(Burner 3 + 4) (28)/GFM-003 (Burner) (29)/GFM-004(Burner) (30)/GFM-005(Burner) (31)/GFM-006(Burner) (17)/GFM-007(Flare) (32)/GFM-008 (total meter)		year y			normal cubic meter
11	(18)/MTA-001	W_{CH4}	Fraction of methane in biogas	m^3 CH_4/m^3 biogas (wet basis)	Continuously	-
13	(-)/-	NC	Nitrogen content of sludge	Kg N/ Kg sludge	Monthly	-
14	(19)/WM-01 (electricity meter)	$Q_{elec\_cons,y}$	Quantity of electricity consumed due to the project activity	MWh	Continuously	-
15	(-)/-	CO_2 EF_{elec}	CO_2 emission factor for electricity consumed at project site	tCO_2e/MWh	Calculated	Obtained from official sources and calculated as per AMS-I.D
16	(14)/GFM-001 (Burner 1 + 2) (15)/GFM-002 (Burner 3 + 4) (28)/GFM-003 (Burner) (29)/GFM-004(Burner) (30)/GFM-005(Burner) (31)/GFM-006(Burner) (17)/GFM-007(Flare)	Q_{biogas_burner} / Q_{biogas_flare}	Volumetric flow rate of the biogas at normal conditions in the hour h. Same basis measurement (dry or wet) for all component in biogas	Nm^3/hr (normal cubic meter)	Hourly	Installed biogas flow meters to monitor in wet basis and normal cubic meter
17	(20)/TIC-003	T_{flare}	Temperature of the exhaust gas of the flare	Celsius	Continuously	-
18	(21)/Flare detector & hour counter	Flare operation parameter	minutes that flare is detected during the hour h	Minute/hr	Continuously	
19	(22)/TIC-002	T	Temperature of biogas	Celsius	Continuously	-
20	(23)/PIC-002	P	Pressure of biogas	Bar (Gauge)	Continuously	-

21	(24)/BU-01 (25)/BU-02 (26)/BU-330-001 (27)/BU-330-002	$Q_{burner\_stack,y}$	Amount of burner stack gas in year y	Nm^3/yr	Continuously	Obtain from flow rate of burner stack gas and amount of time gas combusted in the burner. BU-01, BU-02, BU-330-001 and BU-330-002 are the counters of operation hours of burners
22	(24)/- (25)/- (26)/- (27)/-	W_{CH4_stack}	Fraction of methane in burner stack gas	Nm^3 CH_4/ Nm^3 stack gas	At least quarterly	Measure on dry basis (quarterly measurement by outsource laboratory)

Remark:

- "Position" in column two means position of measurement point specified in PID diagram in
- Figure **2**. "ID No." means code of measurement devices or methods specified in PID diagram.
- Normal Cubic Meter (Nm3) is the volume of substance at normal condition (0 ^{O}C and 1 atm), this condition is applicable to all readings of biogas flow meters.
- Normal Cubic Meter (Nm3) from the reading of burner stack gas is reference to 25 ^{o}C and 1 atm.

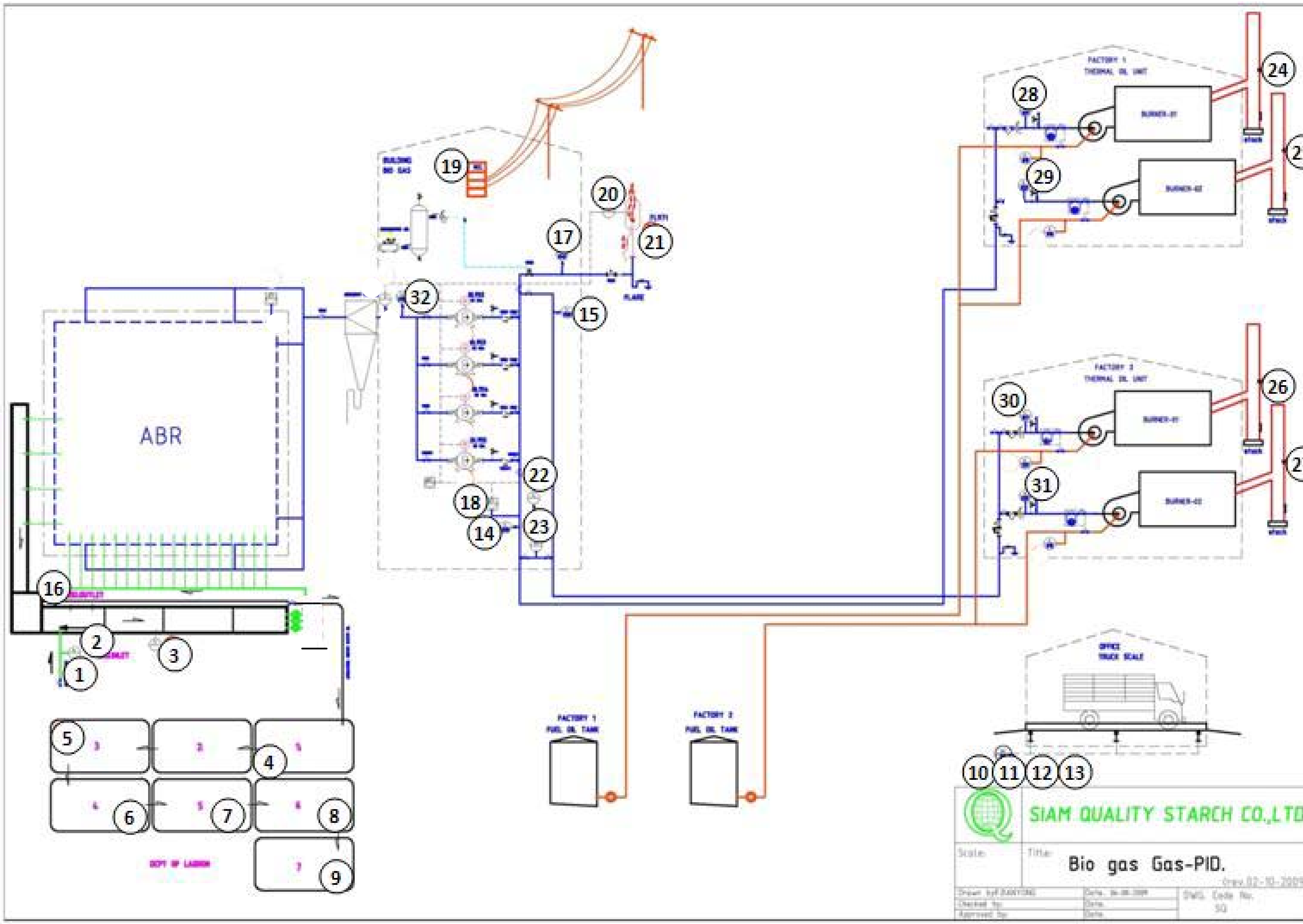

Figure 2: Monitoring instrument location

3.3. Quality Control/Quality Assurance

As stated in PDD, quality assurance and quality control are extremely important in ensuring the accurate quantification of emission reductions achieved. Calibration procedures have been conducted in accordance with industry common practice. Calibration standards, frequencies and certificates will be provided to the DOE during the site visit.

4. Delivered Emission Reduction

4.1. Fixed values

Fixed values adopted for the calculation of CERs is summarized in the following table. These parameters are consistent with section B.6.1 and B.6.2 in the CDM-PDD.

Table 2: Summary of fixed parameters used in calculation

Parameters	PDD Reference	Sources	Unit	Figure
Maximum methane producing capacity	B_o	AM0013	$kgCH_4/kgCOD$	0.21
Global warming potential for methane	GWP_CH_4	AM0013	tCO_2e/tCH_4	21
CO_2 emission factor for thermal energy generation using fuel oil	CO_2EF_{fuel}	IPCC 2006 table 2.2	tCO_2/TJ	77.4
Oxidation factor for fuel oil	OX_{fuel}	IPCC 2006 table 1.4	Fraction	1
Rate of physical leakage from digester	LF	AM0013	Fraction	0.15
Methane correction of sludge in year y	MCF_{la}	AM0013	Fraction	0.05
Emission factor of nitrogen from sludge applied to land	EF_{N2O}	AM0013	kgN_2O/kgN	0.016
Global warming potential for nitrous oxide	GWP_N_2O	IPCC	tCO_2e/tN_2O	310
COD concentration of final effluent in the baseline	$COD_{conc\_out,baseline,m}$	Thai government regulation, registered CDM-PDD	$kgCOD/m^3$	0.12
Fraction of anaerobic degradation as a function of depth, for depth 1 – 5 m.	F_d	AM0013	Fraction	0.5
Maximum quantity of fuel oil consumed in year y in the absence of project activity	$Q_{fuel\_oil,y}$	SQS's 3 year historical record, registered CDM-PDD	TJ	140.6

4.2. Monitored Values

Table 3: Monitored Values for Baseline Calculations (Aggregated to monthly results)

Definition of Parameter	Flow rate of wastewater fed in to digester	Operation day in month	Ambient Temp.	COD concentration of effluent entering to lagoon in baseline	Q'ty of fuel oil displaced
Source of data	Meter FIC-001	Operation Plan	Thermometer TIC-001	SQS's Laboratory	Meters GFM 001 – 002 & 007
Parameters	$F_{\_digester}$ (m^3/month)	$OP_{\_m}$ (day/month)	T2 (Celsius)	$COD_{\_conc\_in, baseline, m}$ ($kgCOD/m^3$)	$Q_{fuel\_oil,y}$ (TJ/month)
APR 2009	0	0	0	-	0
MAY 2009	96,976	21	26	3.6	5.7
JUNE 2009	152,672	30	28	5.9	15.8
JULY 2009	139,289	31	27	5.8	16.8
AUG 2009	129,289	31	27	5.4	14.9
SEP 2009	117,350	30	26	4.8	12.2
OCT 2009	105,889	30	27	4	10.3
NOV 2009	135,621	30	26	5	14.0
Total/Average	**877,086**	**203**	**27**	**4.9**	**90**

Table 4: Monitored Values for Baseline Calculations (Cont.)

Definition of Parameter	Depth of Open Lagoons					
Source of data	SQS's Operator Log sheet					
Parameters	$D_{lagoon,project}$ (meters)					
	Lagoon 1	Lagoon 3	Lagoon 4	Lagoon 5	Lagoon 6	Lagoon 7
APR 2009	4.5	4.6	4.6	4.7	4.6	4.7
MAY 2009	4.6	4.7	4.7	4.7	4.6	4.7
JUNE 2009	4.6	4.6	4.4	4.4	4.6	4.7
JULY 2009	4.6	4.6	4.4	4.4	4.6	4.7
AUG 2009	4.6	4.5	4.3	4.3	4.6	4.7
SEP 2009	4.5	4.5	4.4	4.4	4.5	4.7
OCT 2009	4.5	4.5	4.5	4.5	4.6	4.7
NOV 2009	4.6	4.6	4.5	4.5	4.6	4.7
Total/Average	**4.6**	4.5	4.6	4.6	4.7	4.6

Table 5: Monitored Values for Project Emission Calculations

Definition of Parameter	Flow rate of wastewater out of digester	Amount of Sludge removed	Q'ty of biogas Produced & collected in the digester	Fraction of CH4 in biogas	COD in the sludge used for land application	Nitrogen content of sludge
Source of data	Meter FIC-001	Truck scale 01 - 04	Meters GFM-001, -002, -003 -004, -005, -006 and - 007	CH4 Analyzer MTA-001	SQS's Laboratory	Outsource Laboratory
Parameters	$F_{\_digester}$ m^3/month	$Q_{sludge,m}$ / $Q_{sludge,m}$ kg/month	$Q_{biogas\_total,m}$ (wet basis) Nm^3/month	$W_{\_CH4}$ (dry basis) $m^3CH4/m^3biogas$	$COD_{sludge,m}$ kg COD/Kg Sludge	NC kg N/kg Sludge
APR 2009	-	-	0	-	0	-
MAY 2009	96,976	-	380,933	0.49	0	-
JUNE 2009	152,672	-	928,262	0.48	0	-
JULY 2009	139,289	-	985,964	0.48	0	-
AUG 2009	129,289	-	874,234	0.48	0	-
SEP 2009	117,350	-	712,138	0.49	0	-
OCT 2009	105,889	24,590	683,565	0.43	0.100	0.003
NOV 2009	135,621	111,780	763,324	0.52	0.102	0.003
Total/Average	**877,086**	**136,370**	**5,069,769**	**0.48**	**0.101**	0.003

Table 6: Monitored Values for Project Emission Calculations (Cont. 1)

Definition of Parameter	Q'ty of electricity consumed due to project activity	Q'ty of fuel oil consumed due to project activity	Flow rate of biogas used at burner	Flow rate of biogas fed to flare	COD out of digester to lagoons	Temperature of exhaust gas at flare
Source of data	Meter (WM-01)	No fuel oil use	Meters GFM-001, -002, -003 -004, -005 and -006	Meters GFM 007	SQS's Laboratory	Thermometer TIC-003
Parameters	$Q_{elec\_con,y}$ MWh/m	$Q_{elec\_con,y}$ TJ/m	$Q_{biogas\_burner,y}$ (wet basis) Nm^3 biogas/m	$Q_{biogas\_flare,y}$ (wet basis) Nm^3 biogas/m	$COD_{conc\_dig\_out,m}$ kg COD/m^3	T_{flare} (C)
APR 2009	-	-	0	-	-	-
MAY 2009	32	-	380,485	448	3.6	630
JUNE 2009	67	-	928,262	-	5.9	-
JULY 2009	70	-	985,964	-	5.8	-
AUG 2009	57	-	874,234	-	5.4	-
SEP 2009	51	-	712,138	-	4.8	-
OCT 2009	44	-	683,565	-	4	-
NOV 2009	46	-	763,324	-	5	-
Total/Average	**367**	**-**	**5,327,972**	**448**	**4.9**	**630**

Table 7: Monitored Values for Project Emission Calculations (Cont. 2)

Definition of Parameter	Flare operation parameter	Biogas Temperature	Biogas Pressure (Gauge)	Amount of burner stack gas	Fraction of CH4 in burner stack gas
Source of data	**Flame Detector & hourly counter**	**Thermometer TIC-002**	**Meter PIC-002**	**Outsource Laboratory (Calculated)**	**Outsource Laboratory**
Parameters	**Flare Operation Parameter (minutes)**	**T (C)**	**P (Bar)**	**$Q_{burner\_stack,y\ (dry\ basis)}$ Nm^3/yr**	**$W_{CH4\_stack\ (dry\ basis)}$ $m^3 CH4/m^3$ stack gas**
APR 2009	-	-	0	-	-
MAY 2009	112	64	397	8,469,863	-
JUNE 2009	-	30	457	16,068,332	-
JULY 2009	-	30	429	15,482,248	5.23E-05
AUG 2009	-	30	454	20,528,318	-
SEP 2009	-	30	457	16,875,288	-
OCT 2009	-	30	456	15,644,802	4.11E-05
NOV 2009	-	30	468	14,030,614	-
Total/Average	**112**	**35**	**446**	**107,099,465**	4.67E-05

4.3. Calculation of Emission Reduction

Baseline Emission

Baseline emission is calculated in the following manner.

$$BE_y = BE_{lagoon,y} + BE_{fuel\_oil,y}$$

$$= MIN\{BE_{lagoon,theoretical,y} : BE_{lagoon,monitored,y}\} + BE_{fuel\_oil,y} \quad \text{(Eq. 4)}$$

- **$BE_{lagoon,y}$**

$BE_{lagoon,y}$ is the baseline methane emission from the open lagoons. As described in AM0013 version 04, the lower figure of the two $BE_{lagoon,y}$ results computed in the following manner should be used for the calculation of emission reductions;

(i) baseline methane emission less the physical leakage, hereafter referred as "$BE_{lagoon,theoretical,y}$"; and

(ii) actual methane captured and flared/used for energy generation, hereafter referred as "$BE_{lagoon,monitored,\ y}$"

(i) $BE_{lagoon,theoretical,y}$

$BE_{lagoon,\ theoretical,y}$ can be estimated from equation 5 below; relevant parameters and monitored data during reporting period are summarized in following table.

$$BE_{lagoon,\ theoretical,\ y} = BE_{total\_emission\_\ lagoon,\ y} - PE_{phys\_leak,y} \quad \text{(Eq. 5)}$$

Where;

$$BE_{total\_emission\_\ lagoon,\ y} = \Sigma_m(COD_{available,m} \text{ X } MCF_{baseline,m}) \times B_o \times GWP\_CH_4$$

And;

$$PE_{phys\_leak,y} = Q_{biogas\_total,\ y} \times W_{CH4} \times \rho_{CH4} \times LF \times GWP\_CH_4$$

Where;

$BE_{lagoon,\ theoretical,\ y}$	= baseline methane emission less the physical leakage (tCO_2e)
$BE_{total\_emission\_lagoon,\ y}$	= baseline methane emission from open lagoons (tCO_2e)
$PE_{phys\_leak,y}$	= project methane emission due to physical leakage from the anaerobic digester (tCO_2e)
$COD_{available,m}$	= monthly COD available for conversion which is equal to sum of the monthly COD entering the digester and COD carried over from the previous month (kg COD/month)

$MCF_{baseline,m}$	= monthly methane conversion factor for the open lagoons in the baseline (fraction)
B_o	= maximum methane producing capacity (kg CH_4/kg COD)
GWP_CH4	= global warming potential for methane (tCO_2e/tCH_4)
Q_{biogas_total}	= Quantity of biogas produced and collected in the digester (Nm^3biogas)
W_{CH4}	= fraction of methane in biogas (m^3CH_4/m^3biogas)
ρ_{CH4}	= Density of methane (tCH_4/Nm^3CH_4)
LF	= rate of physical leakage (fraction)

The summary results for $BE_{lagoon,theoretical,y}$ is given in the table below.

Table 8: Summary results for $BE_{lagoon,theoretical,y}$

Parameters	$BE_{total\_emission\_lagoon,m}$ (tCO_2e/m)	$PE_{\_phys\_leakage,m}$ (tCO_2e/m)	$BE_{lagoon,theoretical,m}$ (tCO_2e/m)
APR 2009	0	0	0
MAY 2009	2,126	424	1,702
JUNE 2009	6,687	1,010	5,677
JULY 2009	7,951	1,069	6,882
AUG 2009	9,334	950	8,384
SEP 2009	8,794	777	8,017
OCT 2009	8,921	659	8,262
NOV 2009	8,652	890	7,761
Total	**52,465**	**5,780**	**46,685**

(ii) $BE_{lagoon,monitored,y}$

Table 9: Summary results for $BE_{lagoon,monitored,y}$

Parameter	$BE_{biogas\_burner,m}$ (tCO_2e/m)	$BE_{biogas\_flare,m}$ (tCO_2e/m)	$BE_{lagoon,\ monitored,m}$ (tCO_2e/m)
APR 2009	0	0	0
MAY 2009	2,337	2.75	2,339
JUNE 2009	6,536	0	6,536
JULY 2009	6,922	0	6,922
AUG 2009	6,151	0	6,151
SEP 2009	5,031	0	5,031
OCT 2009	4,269	0	4,269
NOV 2009	5,762	0	5,762
Total	**37,007**	**3**	**37,010**

$BE_{lagoon,monitored,y}$ can be calculated from equation 6 below. The relevant parameters and monitored data during reporting period are summarized in table above.

$$BE_{lagoon,\ monitored,y} = BE_{biogas\_burner,y} + BE_{biogas\_flare,y}$$
$$= \{Q_{biogas\_burner,y} + Q_{biogas\_flare}\} \times W_{CH4} \times \rho_{CH4} \times GWP\_CH_4 \qquad \text{(Eq. 6)}$$

Where;

$BE_{lagoon,monitored,y}$ = baseline actual methane captured and flared/used for energy generation (tCO_2e)
$BE_{biogas\_burner,y}$ = baseline captured CH_4 used at burners (tCO_2e)
BE_{biogas_flare} = baseline captured CH_4 used at flare (tCO_2e)

Descriptions and values of W_{CH4}, ρ_{CH4} and GWP_CH4 provided in section 4.1

In accordance with AM0013 version 4.0, a comparison between (i) baseline methane emission less the physical leakage ($BE_{lagoon,theoretical,y}$) and (ii) the actual methane captured and flared/used for energy generation ($BE_{lagoon,monitored,y}$) have been made as shown in table below;

Table 10: Comparison of $BE_{lagoon,theoretical,y}$ and $BE_{lagoon,monitored,y}$

Year	Baseline methane emission from open lagoon	
	(i) $BE_{lagoon,theoretical,y}$ (tCO_2e/month)	(ii) $BE_{lagoon,monitored,y}$ (tCO_2e/month)
APR 2009	0	0
MAY 2009	1,702	2,339
JUNE 2009	5,677	6,536
JULY 2009	6,882	6,922
AUG 2009	8,384	6,151
SEP 2009	8,017	5,031
OCT 2009	8,262	4,269
NOV 2009	7,761	5,762
Total	**46,685**	**37,010**

As is apparent from the above table, for the purpose of the calculation of emission reductions, it will be appropriate to apply (ii) which is lower than (i). Therefore, actual methane captured and flare used for energy generation ($BE_{lagoon,monitored,y}$) is selected as the calculation method for the baseline methane emission from open lagoon for this Project ($BE_{lagoon,y}$ = $BE_{lagoon,monitored,y}$ =**37,010** tCO_2e).

$BE_{fuel\_oil, y}$

$BE_{fuel\_oil,y}$ is baseline CO_2 emission from the combustion of fuel oil that is, displaced by biogas due to the project activity. According to the AM0013, the emission reduction claim for the displacement of fossil fuel should be capped according to the average of historical 3 years consumption which was validated as 140.6 TJ/year. This translates to a cap on the baseline CO_2 emission from the displacement of fuel oil of 10,882 tCO_2e/year. Nevertheless, this cap does not affect the CER calculations for this monitoring period, and is expected to start to affect the project only in the next monitoring period. Relevant parameters and monitored data during reporting period and the result are expressed in following table.

Table 11: Summary results for $BE_{fuel\_oil,y}$

Parameter	Energy in biogas displaced (actual, TJ/m)	$BE_{Fuel\ oil}$ (actual) (tCO_2e/m)	Energy in biogas displaced (capped, TJ/yr)	$BE_{Fuel\ oil}$ (capped at 140.6TJ/yr) (tCO_2e/m)
APR 2009	0	0	90 TJ Not over 140.6 TJ So, no cap	0
MAY 2009	5.7	438		438
JUNE 2009	15.8	1,225		1,225
JULY 2009	16.8	1,297		1,297
AUG 2009	14.9	1,153		1,153
SEP 2009	12.2	943		943
OCT 2009	10.3	800		800
NOV 2009	14.0	1,080		1,080
Total	**90**	**6,936**		**6,936**

The baseline emission (BE_y) calculated in accordance with Equation 4 is summarized as follows.

Table 12: Summary of baseline emission of the project

Parameter	$BE_{lagoon,y}$ (tCO_2e/m)	$BE_{Fuel\ oil,y}$ (TJ/m)	BE_y (tCO_2e/m)
APR 2009	0	0	0
MAY 2009	2,339	438	2,777
JUNE 2009	6,536	1,225	7,762
JULY 2009	6,922	1,297	8,220
AUG 2009	6,151	1,153	7,303
SEP 2009	5,031	943	5,974
OCT 2009	4,269	800	5,068
NOV 2009	5,762	1,080	6,842
Total	**37,010**	**6,936**	**43,946**

Project Emission

Project emissions are summarized in the table below.

Table 13: Summary results of project emissions

Month	$PE_{\_stack,m}$ (tCO_2e/m)	$PE_{\_phys\_leakage,m}$ (tCO_2e/m)	$PE_{\_lagoon,m}$ (tCO_2e/m)	$PE_{\_sludge,m}$ (tCO_2e/m)	$PE_{\_energy\_cons,m}$ (tCO_2e/m)	Total PE (tCO_2e/m)
APR 2009	0	0	0	0	0	0
MAY 2009	10	0	485	0	16	511
JUNE 2009	19	0	1,483	0	34	1,536
JULY 2009	20	0	1,255	0	35	1,310
AUG 2009	2	0	1,084	0	29	1,115
SEP 2009	2	0	823	0	26	850
OCT 2009	2	0	582	0.6	22	607
NOV 2009	2	0	914	2.7	23	942
Total	**56**	**0**	**6,626**	**3.3**	**186**	**6,872**

Remark:

- As per AM0013, version 4.0, if lower (ii) "actual methane captured and flare/ used for energy generation ($BE_{lagoon,monitored,,y}$)" was used as baseline emission, then, emission from physical leakage from digester ($PE_{\_phys\_leak}$) is considered as zero.
- For $PE_{stack,y}$, the CE_{burner} factor of 0.997 was applied to the calculation in May to July 2009, while 0.999 was applied to August to November, 2009.
- $PE_{lagoon,y}$ is project CH_4 emissions from the in the secondary treatment open lagoons system (tCO_2e)
- $PE_{phys\_leak,y}$ is project CH_4 emission due to the physical leakage from anaerobic digester (tCO_2e)
- $PE_{sludge,y}$ is project CH_4 emission from the land application of sludge (tCO_2e)
- $PE_{energy\_cons,y}$ is project CH_4 emission from the consumption of energy on the account of the project activity (tCO_2e)
- $PE_{stack,y}$ is project CH_4 emission from the incomplete consumption of biogas in the flare and boilers (tCO_2e)

Emission Reduction

Consistent with AM0013 version 4.0, the emission reduction achieved during this monitoring period can be calculated from difference between baseline emission in year y (BE_y) and project emission in year y (PE_y) as:

$$ER_y = BE_y - PE_y$$

Table 14: Summary results of emission reductions

Parameter	$BE_{lagoon,y}$ (tCO_2e/m)	$BE_{Fuel\_oil,y}$ (tCO_2e/m)	PE_y (tCO_2e/ym)	ER_y (tCO_2e/m)
APR 2009	0	0	0	0
MAY 2009	2,339	438	511	2,266
JUNE 2009	6,536	1,225	1,536	6,226
JULY 2009	6,922	1,297	1,310	6,909
AUG 2009	6,151	1,153	1,115	6,188
SEP 2009	5,031	943	850	5,124
OCT 2009	4,269	800	607	4,462
NOV 2009	5,762	1,080	942	5,900
Total	**37,010**	**6,936**	**6,872**	**37,074**

4.4. Summary of Emission Reduction

The emission reduction achieved due to the implementation and operation of a new anaerobic digester and methane recovery and utilization system by SQS during 15 April to 30 November 2009 is **37,074 t CO_2e**.

APPENDIX I

Converting volume to mass flow rate for the biogas flows

To calculate emission reduction from the project, the total biogas produced from digester ($Q_{biogas,total,y}$), biogas flow rate fed to burners ($Q_{biogas\_burner,y}$), biogas flow rate fed to flare ($Q_{biogas\_flare,y}$) and methane content in biogas (W_{CH4}) is to be measured and monitored in the same basis as wet or dry. In SQS project, the biogas flow rate is measured on wet basis (where flow measurement is not possible in dry basis for a wet stream), whereas the methane content in biogas is measured in dry basis. Therefore, the concept of "Tool to determine mass flow rate of greenhouse gas in gaseous stream", hereafter referred as "the Tool", is applied to convert the volumetric biogas flow rate from wet to dry basis. It is noted that the registered PDD preceded the publication of the Tool.

The following equations are used for the calculation of total methane mass flow.

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

$$\mathbf{F_{i,t} = V_{t,wb} \times v_{i,y,wb} \times \rho_{i,t}}$$

with

$$\mathbf{\rho_{i,t} = \frac{P_t \times MM_i}{R_u \times T_t}}$$

Where;

$F_{i,t}$ = Mass flow rate of greenhouse gas I in the gaseous stream in the time interval t (kg gas/h)

$V_{t,wb}$ = Volumetric flow rate of gaseous stream in actual conditions (P_t, T_t) in the time interval t on a wet basis (m^3 wet gas/h)

$\rho_{i,t}$ = Density of greenhouse gas i in the gaseous stream in actual conditions (P_t, T_t) in time interval t (kg gas i/m^3 dry gas)

$v_{i,t,wb}$ = Volumetric fraction of greenhouse gas i in the gaseous stream in a time interval t on a dry or wet basis (m^3 gas i/m^3 dry gas)

P_t = Absolute pressure of the gaseous stream in time interval t (Pa)

MMi = Molecular mass of greenhouse gas i (kg/kmol)

Ru = Universal ideal gases constant (8314 Pa.m^3/kmol.K)

Tt = Temperature of the gaseous stream in time interval t (K)

The volumetric fraction of the gaseous stream in time interval t on a wet basis ($v_{i,t,wb}$) is determined by converting the volumetric flow from wet basis to dry basis as follows

$$\mathbf{v_{i,t,wb} = v_{i,t,db} / (1 + v_{H2O,t,db})}$$

Where;

$v_{i,t,db}$ = Volumetric fraction of the gaseous stream in time interval t on a dry basis (m^3 gas i/m^3 dry gas)

$v_{i,t,wb}$ = Volumetric fraction of the gaseous stream in time interval t on a wet basis (m^3 gas i/m^3 wet gas)

$v_{H2O,t,db}$	= Volumetric fraction of H_2O in the gaseous stream in time interval t on a dry basis (m^3 H_2O/m^3 dry gas)

The volumetric fraction of H_2O in time interval t on a dry basis ($v_{H2O,t,db}$) should be estimated as per the procedure provided below.

$$\mathbf{v_{H2O,t,db} = \frac{m_{H2O,t,db} \times MM_{t,db}}{MM_{H2O}}}$$

Where;

$v_{H2O,t,db}$	= Volumetric fraction of H_2O in the gaseous stream in time interval t on a dry basis (m^3 H_2O / m^3 dry gas)
$m_{H2O,t,db}$	= Mass fraction of H_2O in the gaseous stream in time interval t on a dry basis (kg H_2O / kg dry gas)
$MM_{t,db}$	= Molecular mass of the gaseous stream in time interval t on a dry basis (kg dry gas / k mol dry gas)
MM_{H2O}	= Molecular mass of H_2O (kg H_2O/kmol H_2O)

And $MM_{t,db}$ is determined as follows:

$$\mathbf{MM_{t,db} = \Sigma_K(v_{k,t,db} \times MM_k)}$$

Where;

$MM_{t,db}$	= Molecular mass of the gaseous stream in time interval t on a dry basis (kg dry gas / kmol dry gas)
$v_{k,t,db}$	= Volumetric fraction of gas k in the gaseous stream in time interval t on a dry basis (m^3 gas k / m^3 dry gas)
MMk	= Molecular mass of gas k (kg / kmol)
k	= All gases contained in the gaseous stream (e.g. N_2, CO_2, O_2, CO, H_2, CH_4, N_2O, NO, NO_2, SO_2, SF_6 and PFCs)

The mass fraction of water in time interval t on a dry basis ($m_{H2O,t,db}$) can be determined using one of the following two options.

Option 1: Measurement of the moisture content in gaseous stream
Option 2: Simplified calculation without any measurements of the moisture content

Option 2 is selected, as no test of moisture content in biogas stream has been carried out. This option does not require measuring the moisture content of the gas but provides a simple and conservative approach to determine the absolute humidity of the gaseous stream. It is assumed that the gas is saturated with H_2O or that no H_2O is in the gas, whichever is more conservative in the context of the underlying methodology.

If it is conservative to assume that no H2O in vapor phase is in the gaseous stream, assume $m_{H2O,t,db} = 0$. If it is conservative to assume that the gaseous stream is saturated with H_2O, determine $m_{H2O,t,db}$ as follows:

$$m_{H2O,t,db,Sat} = \frac{p_{H2O,t,Sat} \times MM_{H2O}}{(P_t - p_{H2O,t,Sat}) \times MM_{t,db}}$$

Where:

$m_{H2O,t,db,sat}$	= Saturation absolute humidity in time interval ton a dry basis (kg H_2O/kg dry gas)
$p_{H20,t,Sat}$	= Saturation pressure of H_2O at temperature T_t (Pa)
T_t	= Temperature of the gaseous stream in time interval t (K)
P_t	= Absolute pressure of the gaseous stream in time interval t (Pa)
MM_{H2O}	= Molecular mass of H_2O (kg H_2O/kmol H_2O)
$MM_{t,db}$	= Molecular mass of the gaseous stream in a time interval t on a dry basis (kg dry gas / kmol dry gas)

For the case of baseline emission calculation of this project, the most conservative value is to assumed that $m_{H2O,t,db,sat} = [p_{H2O,t,Sat} \times MM_{H2O}]/[(P_t - p_{H2O,t,Sat}) \times MM_{t,db}]$. In the other hand, for project emission calculation, it is conservative to assumed that $m_{H2O,t,db,sat} = 0$.

The following equation should be used to convert the volumetric flow of the gaseous stream from actual conditions to normal conditions of temperature and pressure:

$$V_{t,wb,n} = V_{t,wb} \times [(273.15/T_t) \times (P_t/101325)]$$

The abovementioned equation is applied when the wet flow rate of biogas is used to calculate with fraction of methane content which is measured in dry basis, to calculate the flow rate of methane gas in dry basis. The results of such a conversion are presented in the following table.

Conditions of biogas generated and utilized in the project

MONITORED PERIOD	Actual condition of biogas at biogas flow meters				Reference condition at normal condition	
	Biogas fed to burner		Biogas fed to flare		All meters	
	Temp. (C)	Press.Abs (Pa)	Temp. (C)	Press.Abs (Pa)	Temp. (C)	Press.Abs (Pa)
APRIL 2009	0	0	0	0	0	0
MAY 2009	64	141,065	64	141,065	0	101,325
JUNE 2009	30	146,325	0	0	0	101,325
JULY 2009	30	146,325	0	0	0	101,325
AUG 2009	30	146,325	0	0	0	101,325
SEP 2009	30	146,325	0	0	0	101,325
OCT 2009	30	146,325	0	0	0	101,325
NOV 2009	30	146,325	0	0	1	101,325
AVERAGE	**35**	**145,574**	**64**	**141,065**	**0**	**101,325**

Conversion of monitored biogas flow rate from Nm3 to m3

MONITORED PERIOD	Monitored data of biogas flow rate in Nm3		Conversion of biogas flow rate from Nm3 to m3	
	Biogas fed to burner	Biogas fed to flare	Biogas fed to burner	Biogas fed to flare
	Nm3 (wet basis)	Nm3 (wet basis)	Nm3 (wet basis)	Nm3 (wet basis)
APRIL 2009	0	0	0	0
MAY 2009	380,485	448	337,611	397
JUNE 2009	928,262	0	713,387	0
JULY 2009	985,964	0	757,732	0
AUG 2009	874,234	0	671,865	0
SEP 2009	712,138	0	547,291	0
OCT 2009	683,565	0	525,332	0
NOV 2010	763,324	0	586,629	0
TOTAL	**5,327,972**	**448**	**4,139,848**	**397**

Conversion of monitored CH4 content in biogas from dry to wet basis

MONITORED PERIOD	CH4 content in biogas(WCH4)		
	Monitored WCH4	WCH4 used in baseline calculation	WCH4 used in project emission calculation
	% dry basis	% wet basis	% wet basis
APRIL 2009	0.00	0.00	0.00
MAY 2009	0.49	0.41	0.49
JUNE 2009	0.48	0.47	0.48
JULY 2009	0.48	0.47	0.48
AUG 2009	0.48	0.47	0.48
SEP 2009	0.49	0.47	0.49
OCT 2009	0.43	0.42	0.43
NOV 2010	0.52	0.50	0.52
AVERAGE	**0.48**	**0.46**	**0.48**

Mass flow rate of CH4

MONITORED PERIOD	Density of CH4 at actual condition	Mass flow rate of CH4 (in Project Emission Calculation)				
			CH4 fed to flare [Meter at flare]			
	ρCH4 fed to burners and flare	CH4 fed to burner	T_Flare >500 C	T_Flare <500 C	No. T_Flare data	Total
	kg CH4/m3 CH4	kg/month	kg/month	kg/month	kg/month	kg/month
APRIL 2009	0.00	0	0	0	0	0
MAY 2009	0.80	134,424	158	0	0	158
JUNE 2009	0.93	320,563	0	0	0	0
JULY 2009	0.93	339,482	0	0	0	0
AUG 2009	0.93	301,641	0	0	0	0
SEP 2009	0.93	246,726	0	0	0	0
OCT 2009	0.93	209,337	0	0	0	0
NOV 2010	0.93	282,578	0	0	0	0
TOTAL/AVERAGE	**0.80**	**1,834,750**	**158**	**0**	**0**	**158**

Appendix II
Grid Emission Factor for Thailand

Thailand's grid emission factor (GEF) was calculated, in accordance with the procedure provided in an approved small-scale methodology " AMS-I.D : Grid connected renewable electricity generation", and used as grid emission factor to calculate project emission from the electricity consumption on-site. The most recently official information of electricity generation in Thailand is available up to 2007. Therefore, this report was based on the information of electricity generation in Thailand from 2005 to 2007.

Combined Margin Emission Factor (EF_{grid}, CM_y)

Baseline emission factor of Thailand's national grid in 2007

OM/BM	Weight	Emission factor
Operating margin (3-year average, 2005-2007)	0.5	0.5716
Build margin	0.5	0.4398
	$EF_{grid,CM,y}$ (tCO_2/MWh)	**0.5057**

CO2 emission coefficient of each fuel type

Fuel type	Net calorific value[1] (NCV)		CO_2 emission coefficient[2] ($COEF_i$)		
	MJ/Unit	Unit	tCO_2/TJ	tCO_2/Unit	Unit
Natural gas	1.02	MMscf	56.1	57.22	MMscf
Fuel oil	39.77	m litres	77.4	3,078.20	m litres
Diesel oil	36.42	m litres	74.1	2,698.72	m litres
Lignite	10.47	kg	101	1,057.47	k tonnes
Imported coal	26.37	kg	94.6	2,494.60	k tonnes

[1] Electric Power in Thailand 2007, page 42. Also note that the value of lignite is based on Mae Moh site.
[2] Revised 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 2.3, page 2.18-2.19.

Operating margin emission factor (EF_{grid}, OM_y) in 2005 to 2007

Fuel type	Unit	Fuel usage[1]	Generation[2] (GWh)	CO_2 emissions (tCO_2)
		$F_{i,j,y}$	$GEN_{i,y}$	$F_{i,j,y}$ * $COEF_{i,j}$
2005 (excl,SPPs)				
Natural gas	MMscf	764,118	85,703	43,724,360
Fuel oil	m litres	1,996	8,244	6,144,083
Diesel oil	m litres	83	414	223,994
Coal & lignite[3]	k tonnes	16,571	18,334	17,523,335
2005 (SPPs)				
Natural gas	MMscf	92,273	13,700	5,280,046
Fuel oil	m litres	13		39,414
Diesel oil	m litres	0		1,170
Imported coal	k tonnes	858		2,141,556
Imported power[5]	-	-	4,419	0
2006 (excl,SPPs)				

Natural gas	MMscf	857,103	86,339	49,045,148
Fuel oil	m litres	2,030	8,350	6,248,742
Diesel oil	m litres	41	143	110,648
Coal & lignite[3]	k tonnes	17,166	22,051	18,152,530
2006 (SPPs)				
Natural gas	MMscf	91,503	13,731	5,235,985
Fuel oil	m litres	8		23,440
Diesel oil	m litres	0		1,178
Imported coal	k tonnes	866		2,161,550
Imported power[5]	-	-	5,159	0
2007 (excl,SPPs)				
Natural gas	MMscf	783,137	88,166	44,812,665
Fuel oil	m litres	936	3,646	2,881,193
Diesel oil	m litres	23	174	62,071
Coal & lignite[3]	k tonnes	19,650	28,716	20,779,286
2007 (SPPs)				
Natural gas	MMscf	94,725	14,559	5,420,354
Fuel oil	m litres	7		21,470
Diesel oil	m litres	1		3,370
Imported coal	k tonnes	899		2,242,231
Imported power[5]	-	-	4,491	0
Total			406,339	232,279,818
			$EF_{grid,OM,y}$	**0.5716**

[1] Electric Power in Thailand 2007, Table 19, page 23
[2] Electric Power in Thailand 2007, Table 17, page 21
[3] Emissions from coal & lignite are calculated based on CO2 emission coefficient of lignite (Mae Moh)
[4] Electric Power in Thailand 2007, Table 20, page 24
[5] Electric Power in Thailand 2007, Table 22, page 25
[6] EGm,2005-2007 is 406,339GWh

Build margin emission factor (EF_{grid},BM_y) in 2007

Generator	Fuel type	Unit	Fuel usage[1]	Generation[2] (GWh)	CO_2 emissions (tCO_2)
			$FC_{i,y}$	$GEN_{i,y}$	$FC_{i,y}$ * $COEF_i$
IPP	Natural gas	MMscf	193,997.00	34,491	11,100,896
	Diesel oil	m litres	3.60		9,724
	Coal & lignite	k tonnes	3838.92		4,059,548
Total				34,491	15,170,168
				$EF_{grid,BM,y}$ (tCO_2/MWh)	**0.4398**

[1, 2] Energy statistic sector, DEDE