CLEAN DEVELOPMENT MECHANISM
PROJECT DESIGN DOCUMENT FORM (CDM-PDD)
Version 02 - in effect as of: 1 July 2004)

CONTENTS

Annexes

SECTION A. General description of project activity

A.1 Title of the project activity:

>> "Swine manure to biogas power project in Ratchaburi, Thailand"
(Hereinafter referred to as " the project" or "the project activity".)

A.2. Description of the project activity:

>> The project activity is supposed to be conducted from January 1, 2006, in a pig farm named Kanchana Hybrid (Nernthong) Farm located in Ratchaburi province, Thailand.

The farm breeds 46,200 heads from baby to fattened pigs. The wastewater, that is, swine manure from pig houses is currently collected altogether and delivered to open lagoons where anaerobic treatment emits CH_4 into the air. The pig farm uses grid electricity that leads carbon dioxide emission.

This treatment method is a common practice in Thailand and satisfies today's wastewater regulations on effluent standards (BOD and COD). There is no plan to introduce further regulation on wastewater including methane emission. Although the government promotes biogas (methane) utilization, because of a financial problem, there is a very small number of biogas plants installed compared with the traditional stabilization pound or open-pond system. Thus, open lagoon treatment will stay the best treatment method if not considering GHG emission reduction.

The project activity consists of the anaerobic digestion and the biogas power generation. The wastewater from the pig farm will be treated in a closed anaerobic digester to produce methane, which will be used for electricity generation (to be sold to the grid) at the next step.

By capturing biogas in a closed digester, the project will reduce CH_4 that would have otherwise been emitted from the existing open lagoons under anaerobic condition in the baseline scenario. In addition, the electricity generation using the collected biogas will displace grid electricity and its associated CO_2 emissions.

This project brings additional income to the project owner. Electricity produced is supposed to be sold to PEA (Provincial Electricity Authority) under Very Small Power Producer (VSPP) scheme in Thailand.

The project activity also contributes to the sustainable development of the host country in the following aspects.

- Improvement of the quality of wastewater,
- Contribution to sustainable use of natural resources and alleviation of domestic environmental burden like CO_2, SOx or NOx by supplying renewable electricity,
- Enhancement of skills and know-how of local staff and technicians through training, which will provide opportunity in developing their own standardized technology,
- Transfer of the state-of-the-art technology of the digester and biogas power generator to the host country, and
- Improvement of the quality of life of people in the surrounding area as the result of the above.
- Satisfaction of the future trend to expand biogas utilization under government's policy.

A.3. Project participants:

>>The following entities are the project participants.

Thailand

1. Project owner: Kanchana Hybrid (Nernthong) Farm (hereinafter referred to as KHF).

   KHF is a pig farm of the pig farm group owner who has seven pig farms in all and the third largest private swine producer in Thailand (the pig farm group owner will be hereinafter referred to as "the group owner" since it has no official registered name).

   The group owner is affiliated with the Swine Raiser Association of Thailand (SRAT).

2. Adviser in Environmental Affairs in Thailand: Energy for Environment Foundation (hereinafter referred to as EfE).

   EfE is an institution engaged in enhancement of biomass utilization in Thailand. It aims to promote a wider use of biomass in producing electricity and other forms of energy. For that mission, it provides technical advice, financing consultation, knowledge and information about biomass and policy recommendation to the public.

Thailand ratified the Kyoto Protocol on August 28, 2002.

Japan

1. Project developer: Takuma Co., Ltd.

   Takuma is a Japanese plant manufacturing company. Its main products are commercial/ industrial boilers, waste incineration plant and water management plant. The project developer has advanced biogas power technology with one model plant in Hiroshima prefecture (for swine manure) and one commercial plant (for kitchen waste) in Kyoto prefecture, Japan.

Japan ratified the Kyoto Protocol on June 4, 2002.

A.4. Technical description of the project activity:

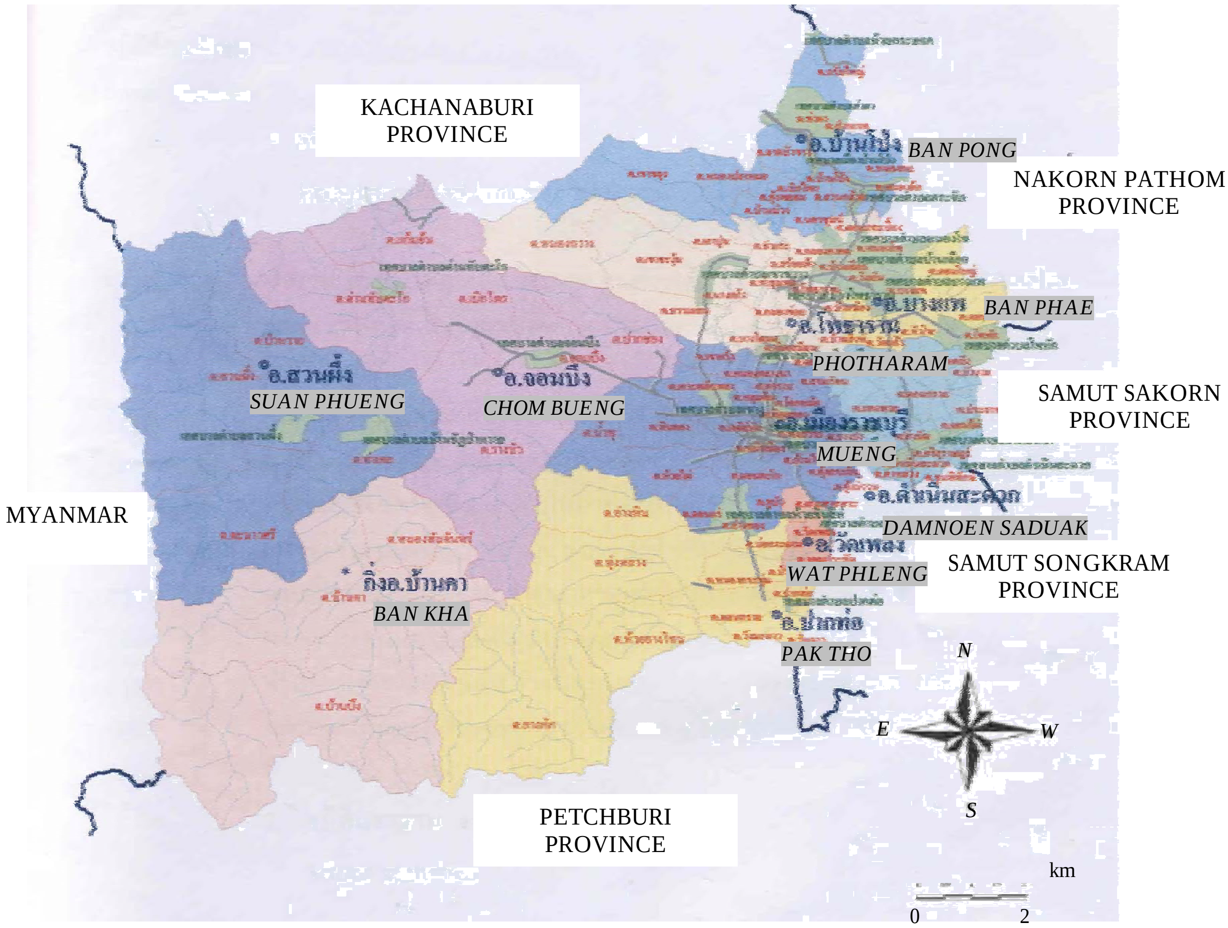
A.4.1. Location of the project activity:

>>The project site is located in Ratchaburi province, 100 km southwest of Bangkok.

Figure A-1: Project Location

(Source: United Nations Thailand)

Figure A-2: Map of Ratchaburi Province



A.4.1.1.	Host Party(ies):

>>The Kingdom of Thailand.

A.4.1.2.	Region/State/Province etc.:

>>Nernthong Ratchaburi, Thailand

A.4.1.3.	City/Town/Community etc:

>>194 Moo 11, Tambon Tungluang, Pak Tho District, Ratchaburi Province, 70140

A.4.1.4. Detail of physical location, including information allowing the unique identification of this project activity (maximum one page):

>>

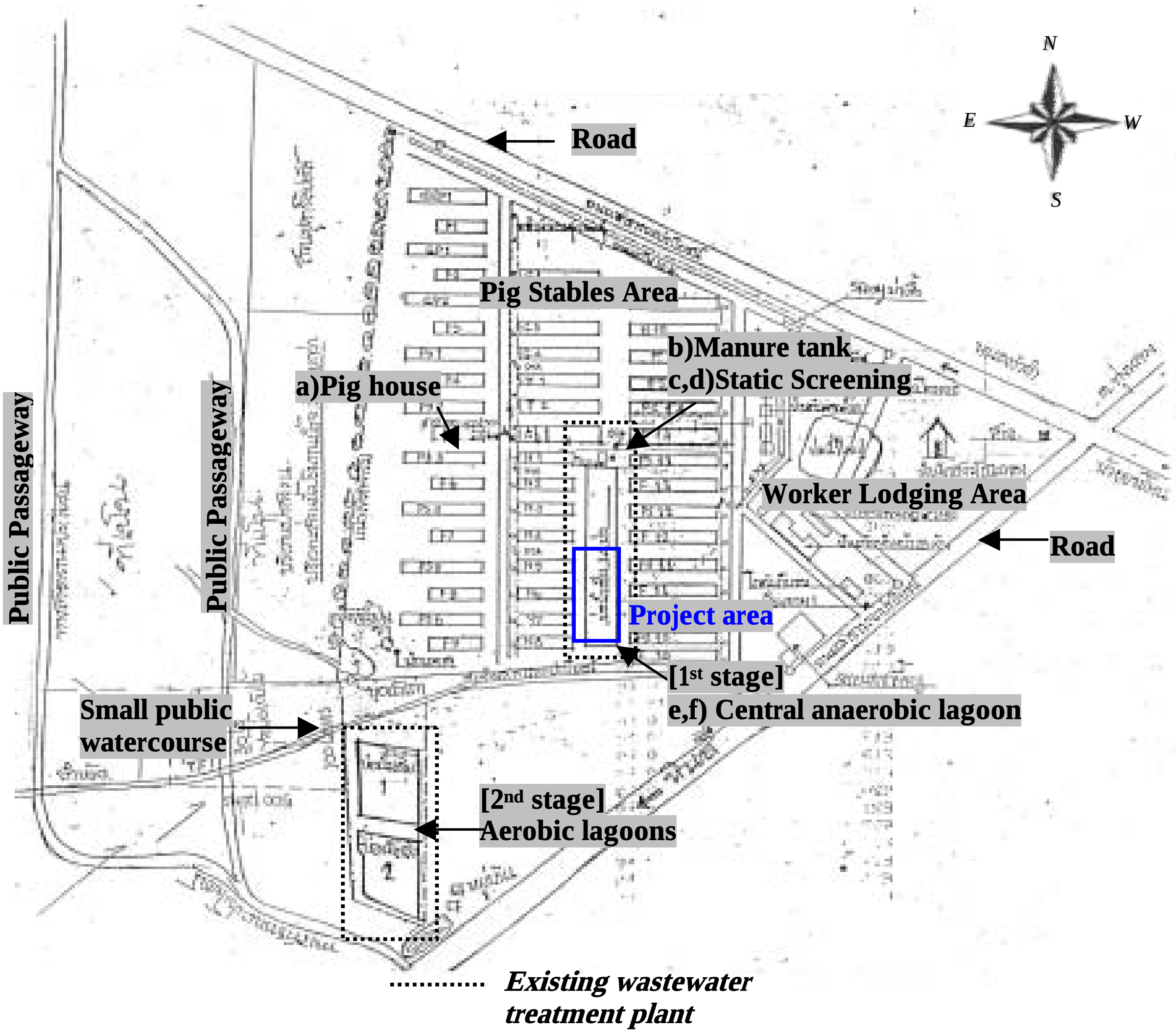
Physical location of the project site

The proposed project site will be located within Kanchana Hybrid (Nernthong) Farm, Kanchana Ratchaburi, centre Thailand. KHF covers an area of 250 rai, equivalent to 400,000 square metres (1 rai = 1,600 m^2). The farm is operating as a breeding and nursling farm. It keeps approximately 46,000 pigs in 49 pigsties which are grouped into 21 units, with 181 operators working on site.

Operation of the pig farm

Figure A-3 shows the current operation of the farm. KHF treats swine manure in three open lagoons covering the area of 30 rai (48,000 m^2). Since the manure is delivered to the central lagoon under anaerobic condition as the 1st treatment stage, the central lagoon is defined as the main CH_4 emission source. The manure then goes to two aerobic lagoons as the 2nd stage.

Figure A-3: Current situation of the pig farm



a) Pig house

c) Screening

d) Impurity

b) Manure tank

e) Upstream of the anaerobic lagoon. Methane bubbles on the surface.

f) Downstream of the anaerobic open lagoon

The pig houses are divided into 6 main groups according to the pig type; sires, sows and gilts, piglets, weaners, nursling pigs and fattened pigs groups. Pigs are brought up to be medium-sized pigs and sent to fattening farms.

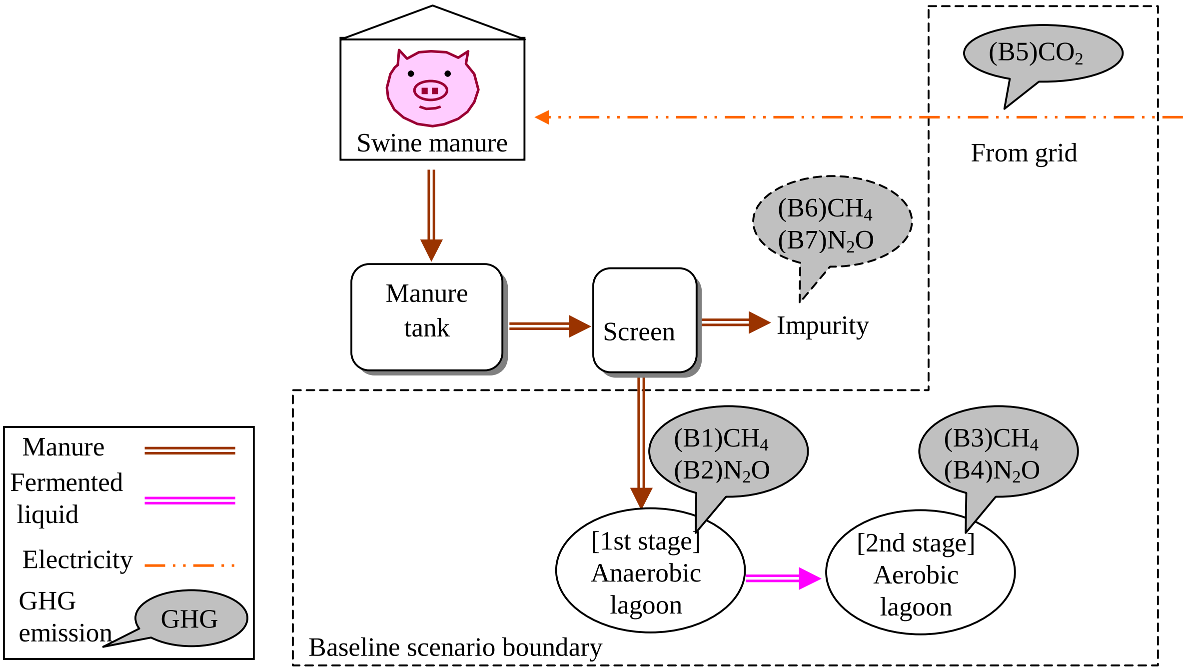
The pig house design is a confined type, and naturally ventilated in the open air. The barn construction is of lifted floor type, which is different to the slatted floor type in fattening farm. The lifted floor allows easy access for cleaning, which is considered suitable for breeding and nursling farm as sanitary is much concerned.

The pig farm utilizes grid-connected electricity for all the energy needed, without using fossil fuel. Therefore electricity from the grid will be one of the sources of GHG (CO_2) emissions.

In general, most of the area around the farm is for vegetable gardening and also vast area. There are a few houses located next to the post-treatment lagoons. Moving slightly further from the farm, the closest local community composes of a temple, a small local school and some houses. The surrounding area is not considered crowded. Currently, there are no complaints on the odour and contamination from wastewater to public watercourses. Besides, some houses nearby the post-treatment lagoons even use the treated water for their own plantations.

Current swine manure treatment

Figure A-4: Current situation of manure treatment and GHG emission



Currently, most of the swine manure in this farm is flushed from the place where it is deposited, using fresh or recycled water. One pig emits around 325g of manure on average a day. The wastewater of the pig farm is approximately 1,050 m^3/day. Manure is collected to a manure tank and successively roughly screened in order to remove impurity such as food residue and pigs' hair. The impurity is made into compost. The screened wastewater next goes to the central lagoon. The wastewater is currently treated in two stages; the 1st stage with the central anaerobic open lagoon and the 2nd stage with the aerobic open lagoon. Strictly speaking, the 2nd stage consists of 2 anaerobic open lagoons, but they are closely connected with each other and regarded as one lagoon.

In the 1st stage, the wastewater contains heavy organic load and that makes the lagoon anaerobic condition. Under anaerobic condition, organic material turns into CH_4[1]. Wastewater next goes to the 2nd stage, the aerobic lagoon. Most of CH_4 emission is finished in the 1st stage, only a little CH_4 is emitted in the 2nd stage. N_2O is also emitted in each stage.

[1] The mechanism of methane production from swine manure is provided in 4.2.1 of IPCC guidelines for National Greenhouse Gas Inventories: Reference Manual; " Livestock manure is principally composed of organic material. When this organic material decomposes in an anaerobic environment (i.e., in the absence of oxygen), methanogenic bacteria, as part of an interrelated population of micro- organisms, produce methane.
The principal factors affecting methane emission from animal manure are the amount of manure produced and the portion of the manure that decomposes anaerobically. The amount of manure that is produced is dependant on the amount produced per animal and the number of animals. The portion of the manure that decomposes anaerobically depends on how the manure is managed. When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits), it tends to decompose anaerobically and produce a significant quantity of methane."

On the other hand, as for the breeding (sire and sow) pigsties, the raw manure can be directly collected. Approximately 60 percent of the raw manure can be collected before using water-jet to flush down the rest to the wastewater collection channel. Thus, the directly collected manure, which is not described in the figure A-4, will be excluded from the project activity.

The operator normally collects the raw manure once a day and cleans the floor once a week. Collected row manure will become compost and be sold in the market together with the impurity-derived compost.

Table A-1: Type and number of pigs in Kanchana Hybrid farm

Type	Number (heads)	Raw manure collection rate (%)	Number for flushing manure (heads)
Sire	240	60	96
Sow	8,960	60	3,584
Gilt	540	0	540
Piglet	12,265	0	12,265
Weaner	3,820	0	3,820
Nursling pigs	16,450	0	16,450
Finisher (Fattened pig)	3,920	0	3,920
Total	46,195		40,765

A.4.2. Category(ies) of project activity:

>> "Methane recovery" associated with "Renewable electricity generation for a grid".

A.4.3. Technology to be employed by the project activity:

>>

General description of the project

The project activity is installation of an anaerobic digester and a power generator for the 1st stage of manure treatment. The biogas plant of the project will be constructed nearby the existing central lagoon with the available space of 10 rai (16,000 m^2). The project avoids methane emissions from swine manure treatment. The biogas electricity also reduces CO_2 from fossil fuel of the grid electricity.

In the first stage, the swine manure will be treated in anaerobic digester, where manure will be utilized to recover methane for energy production in order to use within the factory and export to the grid. The wastewater will go through an aerobic open lagoon as the 2nd stage, which has low organic load and most of it turns into CO_2 (carbon neutral), thus emits reduced amount of CH_4.

N_2O will be emitted in each process.

The pre-treatment process is common for the baseline scenario (as shown in Section B). Therefore, though there can be CH_4 and N_2O leakage from impurity, the amount is the same in the baseline and the project, such emissions are not calculated.

Anaerobic digestion
This is the main emission reduction process in this project. The screened wastewater goes to the 1st stage, anaerobic digester. Organic matter is fermented in the anaerobic condition and all of the biogas produced is collected.

Power generation
Biogas is recovered as a fuel for electricity generation. The power generator has the capacity of 235kW (5,645kWh/d). No fossil fuel will be used in the project activity including start up or auxiliary fuel. Biogas electricity will be utilised for system power, pig farm operation and office use, and the surplus electricity will be sold to the grid.

Table A-2: Electric power balance (kWh/d)

Power generation	5,030
Digester consumption	1,200
Pig farm consumption	3,375
Export to grid	455

The biogas electricity replaces the grid electricity which uses fossil fuel and reduces CO_2. CO_2 from the power generator comes from biogas and considered carbon neutral.

Figure A-5: Flowchart of Treatment System in the project activity

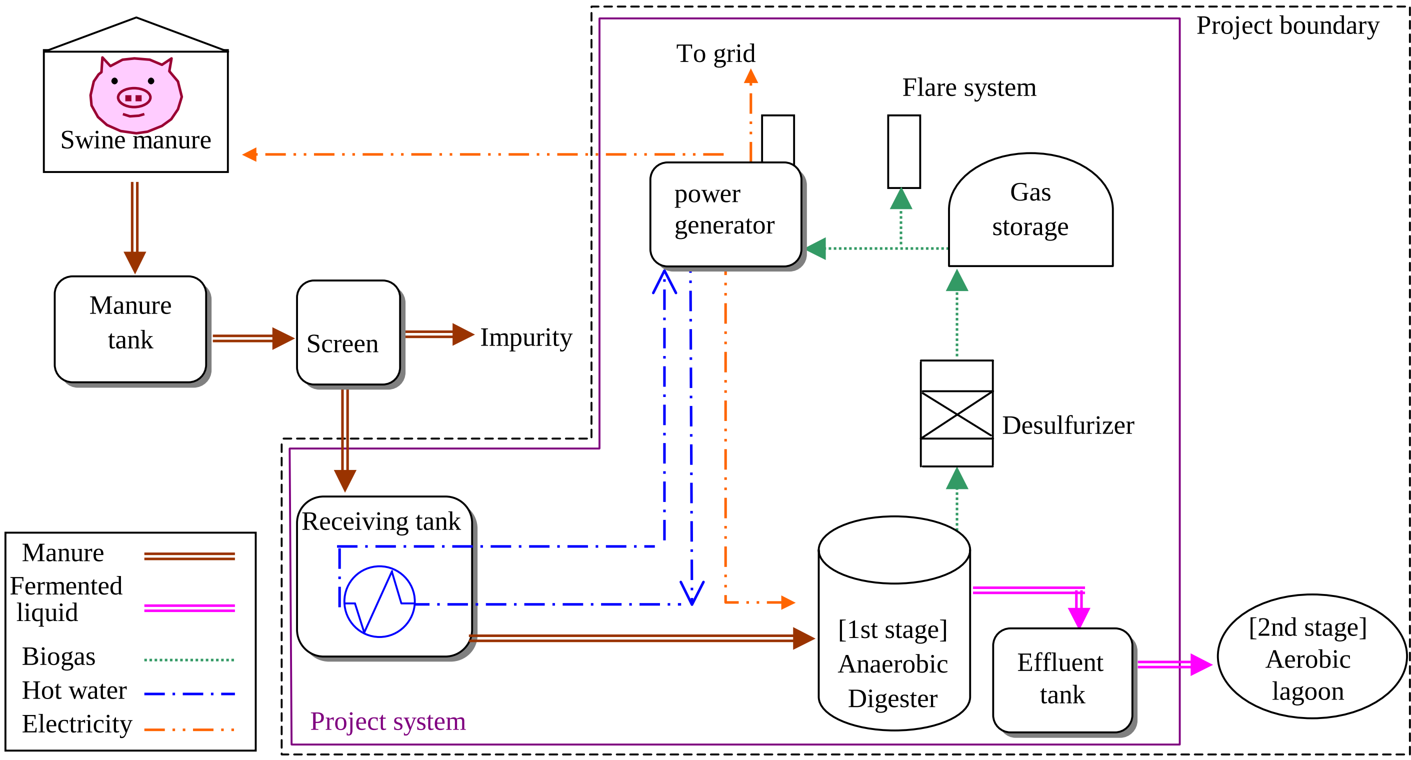
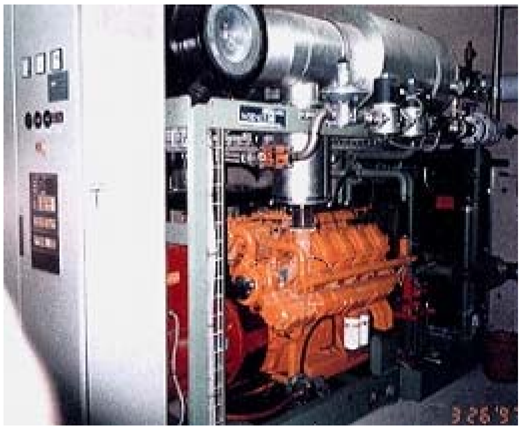


Figure A-6: Equipments to be implemented



Power generator

A.4.4. Brief explanation of how the anthropogenic emissions of anthropogenic greenhouse gas (GHGs) by sources are to be reduced by the proposed CDM project activity, including why the emission reductions would not occur in the absence of the proposed project activity, taking into account national and/or sectoral policies and circumstances:

>>The swine manure is now treated in three open lagoons. The project activity involves the capture of methane from the swine manure that would otherwise be released into the atmosphere, through the use of an anaerobic digester. The recovered biogas will be used as a renewable fuel for power generation, further contributing to emission reductions. The emission reduction by the project is estimated 22,000 tonnes in CO_2 equivalent annually.

As described in further detail in Section B.2, The project will not occur in the absence of the project activity, due to there being no incentive to change the current practice of treating the manure in an open lagoon system. More precisely, the existing lagoon system meets current environmental standard, and the returns from the sale of electricity and compost which will be produced from the impurity of screened swine manure is not sufficiently high for this alone to warrant capital investment. The project will not be materialized without the expectation of additional revenue from the sale of CERs.

A.4.4.1. Estimated amount of emission reductions over the chosen crediting period:

>>Estimated amount of emission reductions from 2007-2016 is 220,845t-CO_2/y.

A.4.5. Public funding of the project activity:

>>There is no public funding involved in this project.

SECTION B. Application of a baseline methodology

B.1. Title and reference of the approved baseline methodology applied to the project activity:

>> This project is conducted on a newly proposed baseline methodology "GHG emission reduction and power generation from manure management system", which is mainly based on AM0006 “GHG emission reduction from manure management system". The description of emission reduction from renewable electricity was added, which was not found in the original AM0006. Formulas for calculating emission reduction were also altered, and the order of formulas was altered accordingly.

According to the modalities and procedures of the CDM, the approved methodology follows the baseline approach 48(a), "existing actual and historical emissions, as applicable".

B.1.1. Justification of the choice of the methodology and why it is applicable to the project activity:

>> The new methodology is applicable to the project activity with the following conditions.

- **The project context is represented by farms operating under a competitive market;**
  Ratchaburi has recently been the province with highest number of swine of 1.17 million heads during the past few years, and Kanchana Hybrid Farm, operated by the third largest business group in swine business in Thailand, maintains approximately 4% of pigs produced in this province. This implies that the pig farm is operated under the competitive market.

- **The manure management system introduced as part of the project activity, as well as the manure management system in the baseline scenario, must be in accordance with the regulatory framework of the country;**
  The swine manure is currently treated in bar screening, collection tank and three open lagoons. Dry solid excrement and the urine manure are collected separately before cleaning process. All these activities are in accordance with the regulatory framework of Thailand.

- **Livestock populations are managed under confined conditions. Barn systems and barn flushing systems should neither be the baseline scenario nor the project activity;**
  Pigs are managed in confined pigsties. Barn systems and barn flushing systems are neither the baseline scenario nor the project activity.

- **Livestock populations comprise only cattle, buffalo and/ or swine;**
  Livestock population in the project comprises only swine.

- **The manure management system introduced as part of the project activity, as well as the manure management system in the baseline scenario, may consist of several stages of manure treatment, including all options (or a combinations of them) listed below in step 1 under “Additionality”, but excluding the discharge of manure into natural water resources (e.g. rivers or estuaries);**
  The project consists of anaerobic digester and aerobic lagoon. It does not discharge the manure into natural water resources.

- **The captured methane is used for electricity generation, which avoids emissions due to displaced electricity in a well-defined grid electricity;**
  The project generates biogas-originated renewable electricity which is supplied for the in-house use for the pig farm and also exported to PEA (Provincial Electricity Authority).

- **The capacity of the renewable biogas power generation of the project activity is lower than 15MW.**
  The power generator has the capacity of 240kW, which is lower than the capacity provided in the methodology.

B.2. Description of how the methodology is applied in the context of the project activity:

>>

Identification of the baseline scenario and demonstration of additionality of the project activity

The methodology follows the steps below. The application to this project is then described.

- Determination of the baseline scenario, taking into account national and/or sectoral policies and circumstances.
- Explanation of why the project will not be implemented as part of the baseline, and is therefore additional.
- Assessment of potential leakage
- Calculation of baseline and project emissions.

The following steps are conducted to determine the baseline scenario.

Step 1: List of possible baseline scenario options

The current swine manure treatment system consists of anaerobic and aerobic treatment. The baseline scenario identification will cover the whole system.

The following list of scenario alternatives is composed of a combination of different animal waste treatment stages. Each alternatives was chosen considering prevailing practices in the company, available technologies and treatment efficiency as key aspects.

1) Solid storage – Land application
2) Pit storage – Land application
3) Storage lagoon – Land application
4) Anaerobic lagoon – Land application
5) Press (Solid separation) anaerobic lagoon – Aerobic lagoon
6) Digester – Aerobic lagoon
7) Solid separation – Composting – Land application
8) Forced Aeration– Aerobic lagoon

The dry lot system has been excluded because it is not applicable to the conditions of the swine's barns.

Step 2: Identification of plausible scenarios

The following criteria provide convincing justification for the exclusion of some of the possible baseline scenarios presented in Step 1.

The baseline scenario is first examined by the following aspects.

- Legal constrains
- Historical practice of waste management in the project site
- Availability of waste treatment technology
- Consideration of developments for manure management systems appropriate for the national conditions, including technological innovations.

1) **Solid storage - Land application:** This kind of system is not applicable for manure that has low solid content. Due to washing and flushing systems of the barns, swine waste in this project is liquid, therefore pumped from the barns to the wastewater treatment system.

2) **Pit storage – Land application:** The operator normally collect the raw manure once a day and clean the floor once a week. Therefore, this option will be excluded.

3) **Storage lagoon – Land application:** This system does not consider decay in volatile solids or nitrogen content in treated manure. Because the Thailand legislation requires quality standards for irrigation waters, the area to be irrigated by the storage lagoon effluent with the much larger than if considered an anaerobic lagoon, making this alternative not applicable. The storage lagoon does not comply with the waste treatment quality standards detailed in the environmental impact assessment, as an KHF's commitment. Depending on storage design, this system will not be efficient enough for odour and vector control. So the exclusion of this potential baseline scenario can be justified.

4) **Anaerobic lagoon – Land application:** The anaerobic stabilization lagoon system is a common practice in Thailand. However, the project site implements a more advanced system described in option 5, which eliminates this option 4 from the baseline scenario.

5) **Press (solid separation) anaerobic lagoon– Aerobic lagoon:** This system represents the current manure treatment system in KHF. Collected manure goes through a screen where impurity is removed and runs into open lagoons. This system needs no additional equipment as long as any special regulation will not be introduced. This makes this option the most plausible baseline scenario.

6) **Digester – Aerobic lagoon:** Digester implementation is highly costly, and not common or required in the regulations. Most of the barriers of this technology are described in the additionality test demonstrated in the following step3 and step4, which will conclude that this option is far from the baselines scenario. This option will be considered as a predefined scenario, representative for the project initiative. If electricity is generated as a byproduct of digester, the influence of power generation should also be taken into account.

7) **Solid separation – Composting – Land application:** Composting systems are not adapted to large volumes of water, or moisture contents. This dry aerobic system can only be applied after solid separation stages of activated sludge. For this reason, this option is excluded from the list of possible baseline scenarios. Composting practices in Thailand are more common for the other type of solid waste treatment.

8) **Forced Aeration:** Aeration equipment is used in order to speed up the aerobic biodegradation of the wastewater. The current and future Thai regulation does not require this short-time and costly treatment.

The list of possible scenario has been reduced to one potential baseline and one predefined project activity:

Baseline:
5) Press (solid separation) anaerobic lagoon – Aerobic lagoon

Project:
6) Digester – Aerobic lagoon

Step 3: Economic comparison

Assuming the current manure treatment system the economic baseline, project income and expenditure are examined.

Table B-1: Economic analysis (without CER revenue)
Digester – Aerobic lagoon

(10^3Bahts)

Year			Constructio	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Income													
	Electricity			3,962	3,962	3,962	3,962	3,962	3,962	3,962	3,962	3,962	3,962
	CER	0 US$/ton-CO2		0	0	0	0	0	0	0	0	0	0
		Total		3,962	3,962	3,962	3,962	3,962	3,962	3,962	3,962	3,962	3,962
Expenditure													
	Maintenance			1,295	1,295	1,295	1,295	1,295	1,295	1,295	1,295	1,295	1,295
	Civil work			90	90	90	90	90	90	90	90	90	90
		Total		1,385	1,385	1,385	1,385	1,385	1,385	1,385	1,385	1,385	1,385
Expenditure - income				2,577	2,577	2,577	2,577	2,577	2,577	2,577	2,577	2,577	2,577
Construction			25,500										
Debt													
	Principal rep	10 year payment		2,550	2,550	2,550	2,550	2,550	2,550	2,550	2,550	2,550	2,550
	Interest	3 %		765	689	612	536	459	383	306	230	153	77
Deplication allowa		10 years		2,550	2,550	2,550	2,550	2,550	2,550	2,550	2,550	2,550	2,550
Pre-tax profit				-738	-661	-585	-508	-432	-355	-279	-202	-126	-49
Corporate tax		30 %		0	0	0	0	0	0	0	0	0	0
After tax profit				-738	-661	-585	-508	-432	-355	-279	-202	-126	-49
Cash flow			-25,500	27	27	27	27	27	27	27	27	27	27
		IRR	-										

Even if positive cash flows considered, economically most attractive management system is the current open lagoon. In Thailand, open lagoon treatment is normally the cheapest treatment system to meet the wastewater regulations, thus the most prevailing practice, which concludes that open anaerobic lagoon (solid separated) is the baseline scenario.

Step 4: Assessment of barriers

Although the economic analysis results in Step 3 clarified that the current situation is the baseline scenario and therefore the project is additional, the following analysis will help to reinforce baseline scenario identification and demonstration of additionality of the proposed project.

The following barrier assessments will prove that an anaerobic digester and power production (project scenario) are not commonly used for pig manure treatment.

Investment barriers:
While a biogas extraction and destruction facility can have no revenue, the additional source of revenue is biogas electricity sales. The revenue should be examined whether the project is attractive enough to be carried out even in the absence of the project activity as CDM. As seen in Step 3, it is clear that the project's IRR is not attractive for investment, particularly when considering the threshold for acceptable IRRs for power project in Thailand is around 13%. This amply demonstrates that the project cannot proceed without CDM.

Common practice barriers:
Most pig farms in Thailand have open lagoon systems similar to KHF's existing system to treat the swine manure. There are several farms that use closed anaerobic digestion either in conjunction with open lagoons or alone. These farms do not reflect a general trend for the swine manure treatment, but rather a difference in circumstances. Most of these farms are located in environmentally sensitive areas, such as being in the vicinity of a drinking water source or a populous area, giving rise to political pressure. However, even for these farms, anaerobic digester treatment is hardly the normal course of action.

Environmental regulations:
Currently, KHF meets the regulatory requirements for wastewater discharge levels, and an upgrade to a more advanced treatment is unnecessary. The current practice should therefore remain unchanged.

At present, certain regulations are now applied to control effluent quality discharged from livestock farms. Swine farms are categorized as one of the polluting industries, whose discharge must be controlled and monitored according to the Enhancement & Conservation of National Environment Quality Act B.E.2535 (1992). In accordance with the Act, the discharge from pig farms must comply with the *Industrial Effluent Standards for Industrial Plants and Industrial Estates and the Effluent Standards for Pig Farms*. The standards do not only specify the qualities and characteristics of the effluent, but also the analytical methods that shall be used in measuring such indicators. In addition, there are no plan to strengthen the regulation which may make the current treatment system non-complied within the foreseeable future.

CH_4 emission, however, has no regulation in Thailand, nor any regulation is planned.

A possibility of subsidy utilization must be noted. The project developer found in the field survey that the project owner was constructing a different type of digester with a financial support by the government.
It was the High Upflow Anaerobic Sludge Blanket or H-UASB digester by the Energy Conservation Promotion Fund (ENCON Fund).The ENCON fund has actually given support to H-UASB digesters of the design and specification developed by Chiang Mai University.

The digester to be applied to the proposed project is not an H-UASB digester, so this type of digester can lead to a technology transfer. Besides, subsidy budget is limited and not all subsidy applications are accepted. If this project can adopt ENCON fund using an H-UASB digester, another application will not be accepted and open lagoon treatment will remain as it is emitting methane into the air in the farm. Thus, current open lagoon treatment will be defined as the baseline scenario.

From the above assessments, it is clear that the project will not occur without the assistance of CDM. There is no reason for an upgrade of the existing swine manure treatment system, given that no circumstance exists to necessitate the change. Moreover, the return from the sale of electricity is not sufficiently attractive to warrant investment in a new technology. The project developer intends to use the extra revenue from the sale of CERs in order to increase the returns and attract investors to the project.

B.3. Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered CDM project activity:

>>As described in B.2, the project activity is not the baseline scenario and reduces emission of greenhouse gases, therefore it is clear that the project activity is additional.

B.4. Description of how the definition of the project boundary related to the baseline methodology selected is applied to the project activity:

>> The project boundary for the baseline and project activity is defined as the plant site. The gases and sources related to each scenario are given below.

Figure B-1: Project boundary

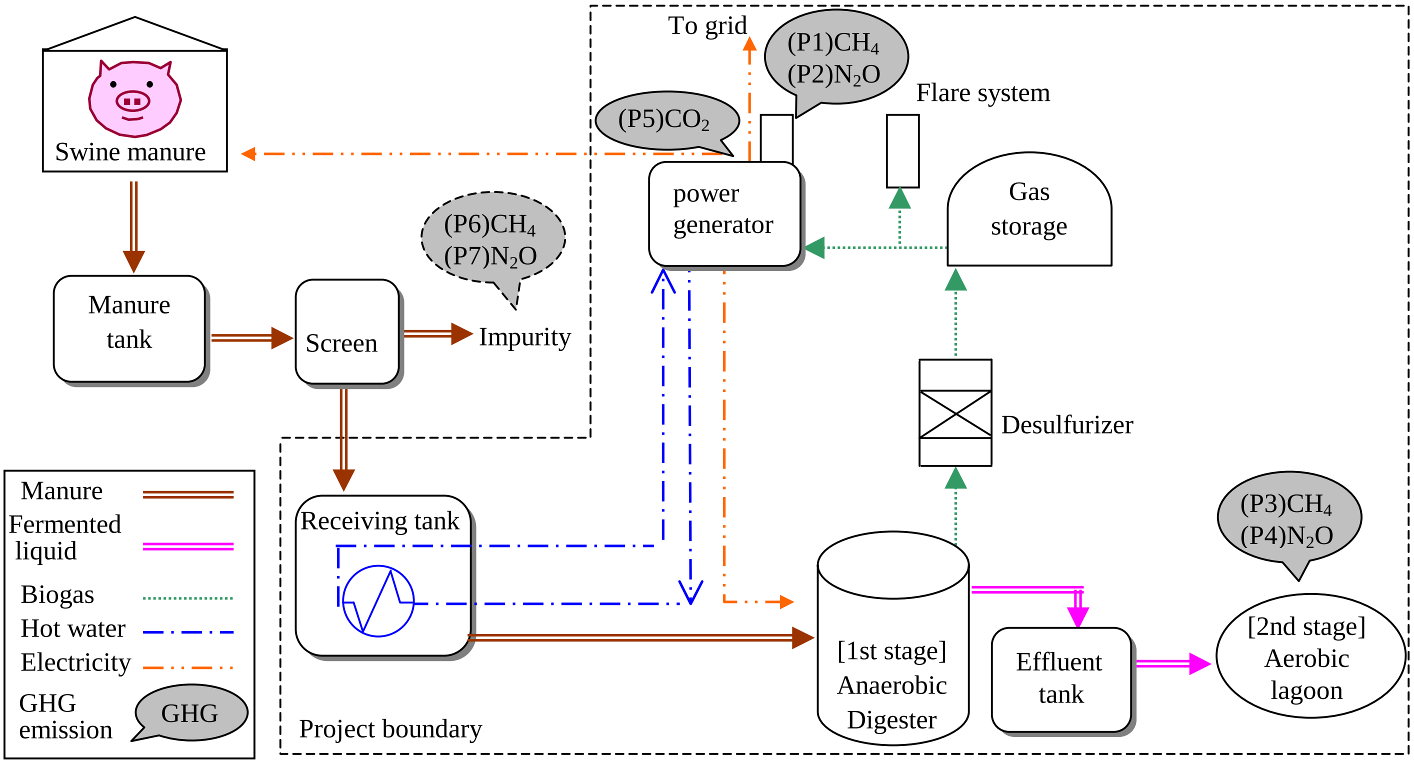


Table B-2: GHG emission and reduction within the boundaries of baseline scenario and project scenario

	Source	GHG	Calculation
Baseline emission	[1st stage] Anaerobic open lagoon	(B1) CH_4	Yes.
		(B2) N_2O	Yes.
	[2nd stage] Aerobic open lagoon	(B3) CH_4	Yes.
		(B4) N_2O	Yes.
	Grid electricity	(B5) CO_2	Yes. Sum of pig farm use and exported amount displaced in the project.
	Impurity (compost)	(B6) CH_4	No. Because the amount of CH_4 emission from impurity in the baseline scenario is the same as that in the project, this value is not taken into account.
		(B7) N_2O	No. Same reason as above.
Project emission	[1st stage] Anaerobic digester	(P1) CH_4	Yes. Unburned fugitive emissions from the stack gas. The amount will be 0.
		(P2) N_2O	Yes. N_2O Emission from stack gas of power generator will be counted.
	[2nd stage] Aerobic open lagoon	(P3) CH_4	Yes.
		(P4) N_2O	Yes.
	Biogas electricity	(P5) CO_2	Yes. Electricity consumed in the pig farm (except for the digester) and exported to the grid will lead to CO_2 reduction. This emission is biomass-oriented, thus the amount is 0.
	Impurity (compost)	(P6) CH_4	No. Because the amount of CH_4 emission from impurity in the project is the same as that in the baseline scenario, this value is not taken into account.
		(P7) N_2O	No. Same reason as above.

[note] There are no emission sources outside of the project boundary.

<u>Baseline emissions</u>

Baseline emissions are calculated consistent with the baseline methodology, applying option B (estimation with referenced data) before project implementation. Once the project is implemented, baseline emissions will be recalculated applying option A (measurement of actual data).

[1st stage] Anaerobic open lagoon (B1-B2)
In the baseline scenario, the swine manure is firstly treated in an anaerobic open lagoon. CH_4 emitted into the atmosphere will be counted for the main source of baseline emission.

Small amount of N_2O will also be emitted into the atmosphere reducing the content of nitrogen, mainly as ammonia.

[2nd stage] Aerobic open lagoon (B3-B4)
After the swine manure is treated in the anaerobic lagoon, the wastewater is discharged to the aerobic open lagoon system. Most of CH_4 is extracted in the former process, and the lagoon is considered aerobic. Hence, CH_4 emission from the lagoon is assumed to be very little.

The amount of N_2O in the 2nd stage will be calculated with reducing nitrogen content in the 1st stage.

Grid electricity (B5)
Grid electricity in the baseline scenario will be defined as electricity for existing pig farm site (except for the digester) and electricity to be displaced by grid export in the project, which will be the same amount with "(P5) Biogas electricity" below.

Impurity (B6-B7)
Because the amount of CH_4 and N_2O emission from impurity in the baseline scenario is the same as these in the project, these values are not taken into account.

Project emissions

Project emissions are calculated consistent with the baseline methodology, applying option B (estimation with referenced data) before project implementation. Once the project is implemented, project emissions will be recalculated applying option A (measurement of actual data).

[1st stage] Aerobic digester (P1-P2)
The anaerobic digester implemented is a gas tight storage for digested manure. All the amount of CH_4 produced in the digester will be burned in the power generator. So CH_4 does not leak out from the digester. In accordance with the formula 1 of table 4-10 in IPCC Good practice guidance and Uncertainty management in National Greenhouse Gas Inventory, Methane Conversion Factor of Anaerobic digester in this project is considered zero (0), thus, project emission of methane outside the digester is also 0. Once the digester is installed, CH_4 emission will be calculated based on option A and verified from the monitoring result of CH_4 outlet of the stack.

In the anaerobic condition, small amount of N_2O will be emitted into the atmosphere through the stack of the power generator without reducing the content of nitrogen. The emission can be estimated based on the formula 7 in the baseline methodology, and once the digester is installed, N_2O emission will be calculated based on option A and verified from the monitoring result of N_2O outlet of the stack.

CO_2 from the swine manure is carbon-neutral and not included in the project emission.

[2nd stage] Aerobic open lagoon (P3-P4)
After the swine manure is treated in the digester, the wastewater is discharged to aerobic open lagoons. Most of CH_4 is extracted in the former process, and the lagoon is considered aerobic. Hence, CH_4 emission from the lagoon is assumed to be very little.

In the project activity, the closed digester system does not allow fugitive emission of nitrogen into the atmosphere. The amount of N_2O in the 2nd stage will be calculated using the formula 10 of the baseline methodology with the value of $R_N = 0$.

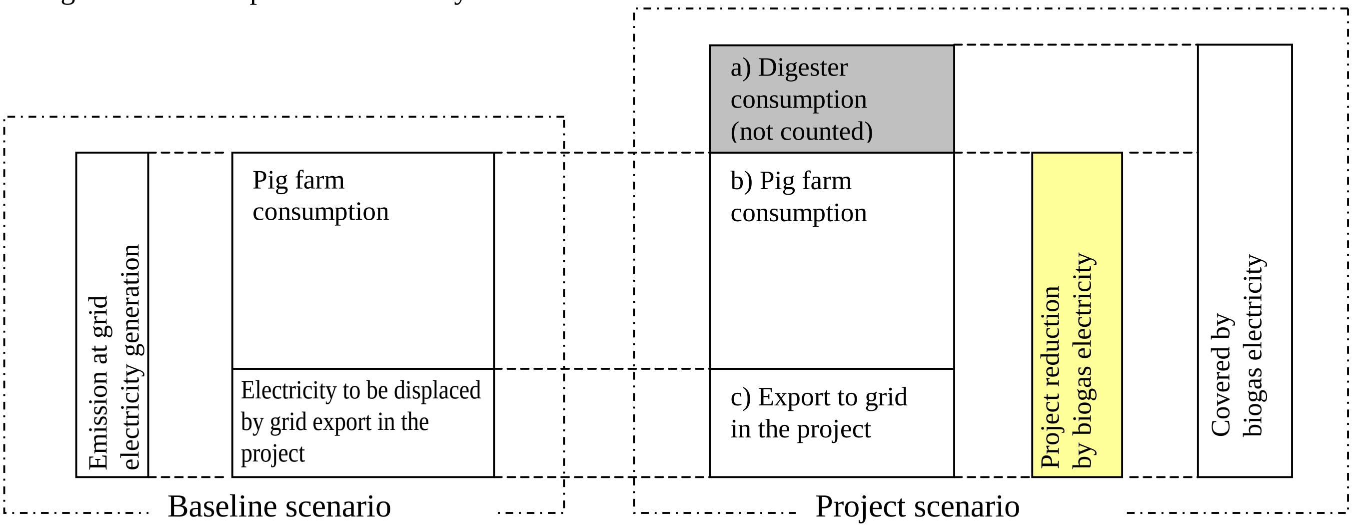
Biogas electricity (P5)

CO_2 emission from biogas electricity is considered 0 as carbon neutral. In the project activity, electricity generated will be supplied to the digester and the pig farm, and the surplus electricity will be exported to the grid.

a) Digester electricity is an additional usage and will not be counted as the emission reduction source.
b) Electricity consumed in the pig farm (including the office) is considered to be the same in the baseline scenario and the project scenario. The project activity provides biogas electricity for in-house use and the amount is considered to be emission reduction.
c) Electricity to be exported in the project activity is defined as the one to be displaced by the project activity in the baseline scenario.

As a result, in the figure of baseline scenario boundary, 'grid electricity' is defined to consist of electricity consumption in the pig farm and electricity to be exported to the grid in the project activity.

Figure B-2: description of electricity



The sum of electricity for pig farm and export to the grid will be the project reduction which will be equal amount to the baseline emission of grid electricity. Therefore, the project reduction by biogas electricity will be defined as the baseline emission of grid electricity.

Impurity (P6-P7)
Because the amount of CH_4 and N_2O emission from impurity in the project is the same as those in the baseline scenario, these values are not taken into account.

B.5. Details of baseline information, including the date of completion of the baseline study and the name of person (s)/entity (ies) determining the baseline:

>>Date of completing the final draft of this baseline section (DD/MM/YYYY)
31/01/2005

Name of person/entity determining the baseline:

Sewerage engineering department
Takuma Co., Ltd.
2-33, Kinrakuji-cho 2-chome, Amagasaki, Hyogo 660-0806, Japan
Tel: +81-6-6483-2701
E-mail: haruki@takuma.co.jp

Energy for Environment Foundation
14th Fl., Si Ayutthaya Bldg., 487/1 Si Ayuttaya Rd.,
Ratchathewi Bangkok 10400
Tel: +66-2642-6424
E-mail: chaiwat.m@efe.or.th

Takuma and Energy for Environment Foundation are the project participants listed in Annex I.

SECTION C. Duration of the project activity / Crediting period

C.1 Duration of the project activity:

C.1.1. Starting date of the project activity:

>> 01/01/2006. The starting date of the construction of the anaerobic digester will be the starting date of the project activity.

C.1.2. Expected operational lifetime of the project activity:

>>50 years (expected)

C.2 Choice of the crediting period and related information:

C.2.1. Renewable crediting period

C.2.1.1. Starting date of the first crediting period:

>>

C.2.1.2. Length of the first crediting period:

>>

C.2.2. Fixed crediting period:

C.2.2.1. Starting date:

>>01/01/2007.

C.2.2.2. Length:

>>10 years

SECTION D. Application of a monitoring methodology and plan

D.1. Name and reference of approved monitoring methodology applied to the project activity:

>> This project is conducted on a newly proposed monitoring methodology "GHG emission reduction and power generation from manure management system", which is mainly based on AM0006 "GHG emission reduction from manure management system", adding the description of emission reduction from renewable electricity, which was not found in the original AM0006.

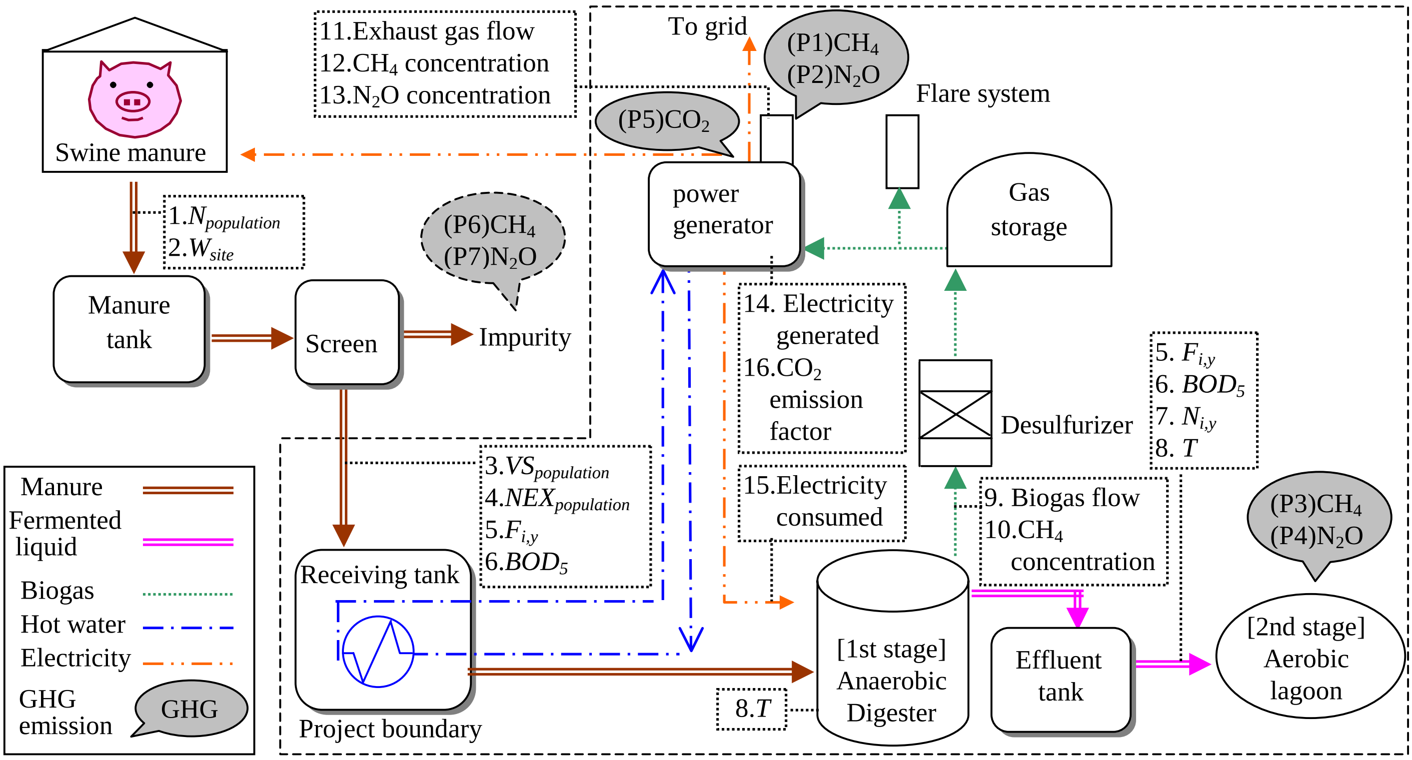
D.2. Justification of the choice of the methodology and why it is applicable to the project activity:

>>The monitoring methodology involves the monitoring of activity levels for the determination of baseline emissions from open lagoons and grid electricity generation. It also monitors the variables necessary to establish project emissions.

The monitoring methodology is applicable when used in conjunction with the accompanying baseline methodology, and with the applicability conditions defined in B.1.1.

The gases and sources of project emission on monitoring points are provided below.

Figure D-1: Monitoring points (indicated in the squares with broken line)



D.2. 1. Option 1: Monitoring of the emissions in the project scenario and the baseline scenario

D.2.1.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

ID number *(Please use numbers to ease cross-referencing to D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment
D.2-1	Number	Animal population	Heads	Measured	Weekly	100%	Paper. At least two years from completion period or last CERs issued	The number of pigs whose manure is flushed as defined in Table A-1. To be collected for each livestock population from 1996 Revised IPCC Guidelines and IPCC GPG 2000. This parameter will be incorporated in formula 1, 6, 7 and 10 of baseline methodology as $N_{population}$.
D.2-2	Mass	Average weight of Animals	kg	Measured and calculated	Records of entrance and exit of animals to the barn	100%	Paper. At least two years from completion of authorisation period or last CERs issued	To be collected for each livestock population from 1996 Revised IPCC Guidelines and IPCC GPG 2000. This parameter will be incorporated in formula 2 and 8 as W_{site}.

D.2-3	Concentration	Volatile solid excretion per animal and day	kg dry matter /animal /day	Measured	Monthly	100%	Paper. At least two years from completion of authorisation period or last CERs issued	Monitoring of this data is only required if measured site-specific data is used. To be collected for each livestock population from 1996 Revised IPCC Guidelines and IPCC GPG 2000. This parameter will be incorporated in formula 1 and 6 as $VS_{population}$.
D.2-4	Concentration	Nitrogen excretion per animal and day	kg dry matter /animal / day	Measured and calculated	Monthly	100%	Paper. At least two years from completion of authorisation period or last CERs issued	Monitoring of this data is only required if measured site-specific data is used. To be collected for each livestock population from 1996 Revised IPCC Guidelines and IPCC GPG 2000. This parameter will be incorporated in formula 7 and 10 as $NEX_{population}$.
D.2-5	Flow rate	Manure flow between each treatment stage	m^3/day	Measured	Monthly	100%	Paper. At least two years from completion of authorisation period or last CERs issued	Only required for option A in step 4 of the baseline methodology. To be measured between each treatment stage of the project manure management system. This parameter will be incorporated in formula 3 and 9 as $F_{i,y}$.

D.2-6	Concentration	5 days Biochemical Oxygen Demand (BOD) in manure between each treatment stage	mg/l	Measured	Monthly	100%	Paper. At least two years from completion of authorisation period or last CERs issued	Only required for option A in step 4 of the baseline methodology. To be measured between each treatment stage of the project manure management system. This parameter will be incorporated in formula 4 as BOD_5.
D.2-7	Concentration	Total nitrogen content in manure between each treatment stage	mg/l	Measured	Monthly	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	Only required for option A in step 4 of the baseline methodology. To be measured between each treatment stage of the project manure management system. This parameter will be incorporated in formula 9 as $N_{i,y}$.
D.2-8	Temperature	Temperature of manure between each treatment stage	℃	Measured	Monthly	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	Only required for option A in step 4 of the baseline methodology. To be measured between each treatment stage of the project manure management system. This parameter will be incorporated in formula 5 as T.

D.2-9	Flow rate	Biogas flow extracted by digester	Nm^3/h	Measured	Every working day	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	Only applicable to project activities including an anaerobic digester. This parameter guarantees the correct performance of digester and gas recovery. This parameter will verify the correct anaerobic fermentation process in the project activity multiplied by D.2-10 (considering the effect of inhibitors).
D.2-10	Percentile	CH_4 concentration in biogas flow	%	Measured	Daily	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	Only applicable to project activities including an anaerobic digester. This parameter guarantees the correct performance of digester and gas recovery.
D.2-11	Flow rate	Exhaust gas flow	Nm^3/h	Measured	Semiannual, monthly if unstable	100%	Paper and electronic. Duration of crediting period	Only applicable to project activities including an anaerobic digester. This parameter is used for verifying CH_4 and N_2O emission in the project activity.
D.2-12	Percentile	CH_4 concentration in exhaust gas flow	%	Measured	Semiannual, monthly if unstable	n/a	Paper and electronic. Duration of crediting period	Only applicable to project activities including an anaerobic digester. This parameter will verify the correct anaerobic fermentation process in the project activity multiplied by D.2-11 (considering the effect of inhibitors).

D.2-13	Percentile	N_2O concentration in exhaust gas flow	%	Measured	Semiannual, monthly if unstable	n/a	Paper and electronic. Duration of crediting period	Only applicable to project activities including an anaerobic digester. This parameter will verify N_2O emission in the project activity multiplied by D.2-11.
D.2-14	Electricity generation	Electricity generated	kWh	Measured	Continuously	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	The difference between D.2-14 and D.2-15 will be incorporated in formula 13 as “Amount of electricity supplied by the project”, which determines the baseline emission of CO_2 by electricity displacement.
D.2-15	Electricity consumption	Electricity consumed in the digester	kWh	Measured	Continuously	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	Same as D.2-14.
D.2-16	CO_2 emission factor	CO_2 emission factor for grid	tCO_2/MWh	Calculated	Annually	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	This parameter will be calculated from formula 11 and 12 based on “Actual and forecast total energy generation and fuel requirement” of EGAT Power Development Plan, and incorporated in formula 13.

D.2.1.2. Description of formulae used to estimate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

>>

This section provides how the formulas in the baseline methodology are applied to this project activity. In this project activity, baseline and project emissions will be estimated using official default factors before the project implementation, and be recalculated using actually monitored data after the project implementation. Therefore, this section describes a selection method of formulas in the baseline methodology and default factors, followed by explanation of formulas for calculating baseline/ project emissions before/ after the project implementation respectively.

Formulas and parameters for emissions calculation

Greenhouse gas emissions included in the project boundary are calculated for the project and the baseline manure management system separately, using the same methodological approach. Emission reductions result from the difference between project and baseline emissions. The methodology to calculate emissions is based on approaches presented in the 1996 Revised IPCC Guidelines and in the IPCC GPG 2000.

As illustrated in Figure D-1, manure management systems comprise two treatment stages and emissions should be determined for each treatment stage separately. The following steps are required for the calculation of both, baseline and project emissions:

1. Identification of the pig population N in the project site. If the livestock populations comprise several species, populations should be identified according to the categorization of (sub-) populations in the 1996 Revised IPCC Guidelines and the IPCC GPG 2000.
2. Determination of the volatile solids (VS) and the nitrogen excretion (NEX) rates. Total volatile solids and nitrogen supplied to the manure management system are determined by the excretion rates VS and NEX and the monitored pig population. Emissions of the project and the baseline scenario are both calculated on the basis of the monitored total volatile solid and nitrogen quantities supplied to the manure management system.
3. Calculation of CH_4 and N_2O emissions from manure management in the first treatment stage, by applying appropriate emission factors to the quantity of volatile solids and nitrogen supplied to the manure management system.
4. In each treatment stage of the manure management system volatile solids and nitrogen loads are reduced. To calculate emissions from the treatment stage considered, the quantity of volatile solids and nitrogen supplied to the next treatment stage have to be determined. For this purpose two methodological approaches are applied:

Option A [Actually monitored data: After the project implementation]: Between each treatment stage of the manure waste management system the waste flow F, the biochemical oxygen demand BOD, the temperature T and the nitrogen content N are measured during monitoring. N_2O and CH_4 emissions are then calculated by applying appropriate emission factors to the measured quantity of biochemical oxygen and nitrogen supplied to the manure management system. This approach can only be applied in the actual project manure management system, as it requires regular monitoring of these parameters, which is not possible for hypothetical baseline scenario. The project activity adopts option A for the baseline/ project emissions calculation after the project implementation.

Option B [Referenced data: Before the project implementation]: The reduction of the volatile solids and nitrogen during a treatment stage is estimated based on referenced data for different treatment types. Emissions from the next treatment stage are then calculated following the approach outlined in step 3 and 4 above, but with volatile solid and nitrogen quantities adjusted for the reduction from the previous treatment stage. This approach can be applied to both the project and the baseline scenario. The project activity adopts option B for baseline/ project emissions estimation before the project implementation.

5. Repetition of step 4 for the 2^{nd} treatment stage.

Steps 1 to 5 will be applied to the manure management system of the project activity and to the manure management system that has been identified as the baseline scenario. Net emissions reductions are the difference between emissions in the baseline and project manure management system.

EMISSIONS ESTIMATION BEFORE THE PROJECT IMPLEMENTATION

Before the project is implemented, the project developer estimates baseline and project emissions based on option B with the IPCC default values for the methane conversion factor MCF, the maximum methane production capacity B_o, the volatile solid excretion per animal VS and nitrogen excretion rate NEX. Once the project is implemented, both emissions will be recalculated based on option A with actually monitored parameters consistent with the monitoring methodology. Number in brackets represents formulas in the baseline methodology.

Methane emissions from manure management

The main factors affecting methane emissions from manure management are the amount of manure produced and the portion of manure decomposition under anaerobic conditions. The type of manure management system and the climate (primarily temperature) are the primary factors that determine the extent of anaerobic decomposition.

Methane emissions will be calculated by each (anaerobic and aerobic) treatment stage.

1st stage (Anaerobic treatment)

$$E_{CH4,mm,1,y} = GWP_{CH4} \times MCF_1 \times D_{CH4} \times \frac{365}{1000} \times \sum_{population} VS_{population} \times B_{o,population} \times N_{population} \quad (1)$$

where:

$E_{CH_4,mm,1,y}$	Are the CH_4 emissions from manure management in the first treatment stage of a manure management system during the year y in tons of CO_2 equivalent.
GWP_{CH_4}	Is the approved Global Warming Potential (GWP) of CH_4.
MCF_1	Is the methane conversion factor (MCF) for treatment of manure in the first treatment stage in percent.
D_{CH_4}	Is the CH_4 density (0.67 kg/m^3 at room temperature (20 ºC) and 1 atm pressure).
$VS_{population}$	Is the volatile solid excretion per day on a dry-matter basis for a defined livestock population in kg-dm/animal/day.
$B_{o,population}$	Is the maximum CH_4 production capacity from manure per animal for a defined livestock population in m^3 CH_4/kg-dm.
$N_{population}$	Is the livestock of a defined population.The project is only for swine, so population in the formula indicates only one species.

Methane conversion factors (MCFs) define the portion of the methane production capacity B_0 that is achieved. The MCFs depend on the type of manure management system, the temperature of the stored manure, the duration of storage and the handling practices of the system. The project activity uses default values from Table 4.10 and Table 4.11 of the IPCC GPG 2000.

Volatile solids are the degradable organic material in livestock manure. Default values are used for the estimation of volatile solid excretion from Appendix B of Chapter 4.2 in the Reference Manual of the 1996 Revised IPCC Guidelines.

Apart from the project activity, if one project consists of different sub-populations such as cattle, buffalo and/or swine, methane emissions from manure management should be estimated separately for these sub-populations, according to Appendix B of Chapter 4.2 in the Reference Manual of the 1996 Revised IPCC Guidelines. For emissions calculation, the monitored livestock of each defined population should be used. Also, if site-specific or regional or national data for MCF, B_o and VS are very costly obtained or not available, conservative default values shall be used following the guidance; The maximum methane production capacity B_o varies by species and diet. Where default values are used, they should be taken from Appendix B of Chapter 4.2 in the Reference Manual of the 1996 Revised IPCC Guidelines, taking into account the site-specific characteristics. Where diets in the project are more similar to diets in developed countries, appropriate default values from developed countries may be selected.

Volatile solids contents in raw manure

The volume of volatile solids is assumed to be proportional to the average weight of pigs. In order to collect the default weight and VS volume to the site-specific value, the following formula is used.

$$VS_{site} = \left(\frac{w_{site}}{w_{default}}\right) \times VS_{default} \qquad (2)$$

where:

VS_{site}	Is the adjusted volatile solid excretion per day on a dry-matter basis for a defined livestock population at the project site in kg-dm/animal/day.
W_{site}	Is the average animal weight of a defined population at the project site in kg.
$W_{default}$	Is the default average animal weight of a defined population in kg.
$VS_{default}$	Is the default value (IPCC or US-EPA) for the volatile solid excretion per day on a dry matter basis for a defined livestock population in kg-dm/animal/day.

2nd stage (Aerobic treatment)

Methane emissions from the second treatment stage will be calculated *ex ante* following formula 6 as option B, on the basis of total volatile solids adjusted for volatile solid reductions in the 1st stage:

$$E_{CH4,mm,i,y} = GWP_{CH4} \times MCF_i \times D_{CH4} \times \left[\prod_{n=1}^{i-1}\left(1 - R_{VS,n}\right)\right] \times \frac{365}{1000} \times \sum_{population} VS_{population} \times B_{o,population} \times N_{population} \; (6)$$

where:

$E_{CH_4,mm,i,y}$	Are the CH_4 emissions from manure management in the first treatment stage of a manure management system during the year y in tons of CO_2 equivalent.
GWP_{CH_4}	Is the approved Global Warming Potential (GWP) of CH_4.
MCF_i	Is the methane conversion factor (MCF) for the treatment of manure in stage i in percent.
D_{CH_4}	Is the CH_4 density (0.67 kg/m^3 at room temperature (20 ºC) and 1 atm pressure).
$R_{VS,n}$	Is the relative reduction of volatile solids in the treatment stage n in per cent.

$VS_{population}$	Is the volatile solid excretion per day on a dry-matter basis for a defined livestock population in kg-dm/animal/day.
$B_{0,population}$	Is the maximum CH_4 production capacity from manure per animal for a defined livestock population m^3 CH_4/kg-dm.
$N_{population}$	Is the livestock of a defined population.

<u>Nitrous oxide emissions from manure management</u>

1st stage (Anaerobic treatment)

Nitrous oxide (N_2O) from manure management is produced from the combined nitrification -denitrification process that occurs on the nitrogen in manure. The majority of nitrogen in manure is in ammonia (NH_3) form. Nitrification occurs aerobically and converts this ammonia into nitrate, while denitrification occurs anaerobically, and converts the nitrate into N_2O. Temperature, pH, biochemical oxygen demand (BOD), and nitrogen concentration affect the N_2O generation rate.

N_2O emissions from manure management systems are calculated based on the approach in the 1996 Revised IPCC Guidelines and the IPCC GPG 2000.

Similarly as in the case of CH_4 emissions, the approach to calculate N_2O emissions for the first stage of manure treatment is different from approaches for the 2nd stage. In the first stage of manure treatment, direct N_2O emissions from manure management are calculated by multiplying the amount of N excretion for each defined livestock population by an emission factor for the type of manure management system:

$$E_{N2O,mm,1,y} = GWP_{N2O} \times EF_{N2O,mm,1} \times CF_{N2O\text{-}N,N} \times \frac{1}{1{,}000} \times \sum_{population} NEX_{population} \times N_{population} \quad (7)$$

where:

$E_{N_2O,mm,1,y}$	Are the nitrous oxide emissions from the first stage of the manure management systems in tonnes of CO_2 equivalents per year.
GWP_{N_2O}	Is the approved Global Warming Potential (GWP) for N_2O.
$EF_{N_2O,mm,1}$	Is the N_2O emission factor for the first treatment stage of the manure management system in kg N_2O-N/kg N (EF_3 in 1996 Revised IPCC Guidelines and IPCC GPG).
$CF_{N_2O\text{-}N,N}$	Is the conversion factor N_2O-N to N (44/28).
$NEX_{population}$	Is annual average nitrogen excretion per animal of the defined livestock population in kg N/animal/year.
$N_{population}$	Is the livestock of a defined population.

The N_2O emission factor for the treatment of manure $EF_{N_2O,mm,1}$ will be estimated with default values from Table 4.12 and Table 4.13 of the IPCC GPG

2000 before the project implementation. Once the project is implemented, site-specific, regional or national data will be adopted for recalculation.

Nitrogen excretion from raw manure

Similarly as VS, as for the nitrogen excretion *NEX*, default values from Table 4.20 in the IPCC Guidelines (adjusted with the factors in Table 4.14 of the IPCC GPG for young animals) will be used and should be corrected for the animal weight at the project site in the following way, assuming that the nitrogen excretion is proportional to the weight of the animal:

$$NEX_{site} = \left(\frac{w_{site}}{w_{default}}\right) \times NEX_{default} \qquad (8)$$

where:

NEX_{site}	Is the adjusted annual average nitrogen excretion per head of a defined livestock population in kg N/animal/year.
W_{site}	Is the average animal weight of a defined population at the project site in kg.
$W_{default}$	Is the default average animal weight of a defined population in kg.
$NEX_{default}$	Is the default value (IPCC or US-EPA) for the nitrogen excretion per head of a defined livestock population in kg N/animal/year.

2nd stage (Aerobic treatment)

Nitrous oxide emissions from the second stage will be calculated following the option B, on the basis of the nitrogen quantity adjusted for nitrogen reductions in the previous treatment stage:

$$E_{N2O,mm,l,y} = GWP_{N2O} \times EF_{N2O,mm,i} \times CF_{N2O\text{-}N,N} \times \left[\prod_{n=1}^{i-1}\left(1 - R_{N,n}\right)\right] \times \frac{1}{1000} \times \sum_{population} NEX_{population} \times N_{population} \quad (10)$$

where:

$E_{N_2O,mm,1,y}$	Are the nitrous oxide emissions from the first stage of the manure management systems in tonnes of CO_2 equivalents per year.
GWP_{N_2O}	Is the approved Global Warming Potential (GWP) for N_2O.
$EF_{N_2O,mm,i}$	Is the N_2O emission factor for the treatment stage i of the manure management system in kg N_2O-N/kg N (EF_3 in 1996 Revised IPCC Guidelines and IPCC GPG).
$CF_{N_2O\text{-}N,N}$	Is the conversion factor N_2O-N to N (44/28).
$R_{VS,n}$	Is the relative reduction of nitrogen in the treatment stage n in per cent.

$NEX_{population}$ Is annual average nitrogen excretion per animal of the defined livestock population in kg N/animal/year.
$N_{population}$ Is the livestock of a defined population.

EMISSIONS CALCULATION AFTER THE PROJECT IMPLEMENTATION

Methane emissions from manure management

For the first and second treatment stage, methane emissions will be calculated using the same formulas with two different approaches, corresponding to option A above. Methane emissions are calculated based on the measurement of the biochemical oxygen demand (BOD) and the quantity of manure flowing to that treatment stage:

$$E_{CH4,mm,i,y} = 0.25 \times BOD_{lt,i,y} \times F_{i,y} \times MCF_{i} \times GWP_{CH4} \times \frac{1}{1{,}000{,}000} \qquad (3)$$

where:
$E_{CH_4,mm,i,y}$ Are the CH_4 emissions from manure management in the second or subsequent treatment stage i of the project activity during the year y in tons of CO_2 equivalents.
$BOD_{lt,i,y}$ Is the average long-term biochemical oxygen demand of the manure flow to treatment stage i during the year y in mg/l.
$F_{i,y}$ Is the manure flow to the treatment stage i during the year y in m^3.
MCF_i Is the methane conversion factor (MCF) for the treatment of manure in stage i in per cent.
GWP_{CH_4} Is the approved Global Warming Potential (GWP) of CH_4.

Both, the biochemical oxygen demand *BOD* and the manure flow *F* between the treatment stages should be monitored for the project manure management system. Usually, the five-day biochemical oxygen demand BOD_5 is measured. The long-term biochemical oxygen demand can then be calculated with the BOD_5 and the reaction constant k as follows:

$$BOD_{lt} = \frac{BOD_5}{\left(1 - 10^{-5k}\right)} \qquad (4)$$

where:
$BOD_{lt,i}$ Is the long term biochemical oxygen demand of the manure flow to treatment stage i in mg/l.

$BOD_{5,i}$ Is the five-day biochemical oxygen demand of the manure flow to treatment stage i in mg/l.
k Is the reaction constant for the biochemical oxygen demand.

The reaction constant can be assumed as approximately 0.1 for wastewater at 20°C (Metcalf & Eddy, 1991) [2], but varies with the temperature. Values for the reaction constant *k* at different temperatures can be calculated with the help of the Van't Hoff-Arrhenius relationship, where θ is 1.056 for temperatures between 20 and 30ºC, and 1.135 for temperatures between 4 and 20ºC. Frequently a referential value of 1.047 is used for wastewater in lukewarm conditions (Metcalf & Eddy, 1991).

$$k_T = k_{20} \times \theta^{(T-20°C)} \qquad (5)$$

where:
k_T Is the reaction constant for the biochemical oxygen demand at the temperature T.
k_{20} Is the reaction constant for the biochemical oxygen demand at 20°C.
T Is the temperature of the manure flow to the treatment stage i in degree Celsius.
Θ Is a constant in the Van't-Hoff-Arrhenius relationship.

Nitrous oxide emissions from manure management

For the first and second treatment stage, nitrous oxide emissions can be calculated using the same formulas with two different approaches, corresponding to option A above. N_2O emissions will be calculated based on measurements of the nitrogen content in the manure flowing to that treatment stage:

$$E_{N2O,mm,i,y} = GWP_{N2O} \times EF_{N2O,mm,i} \times N_{i,y} \times F_{i,y} \qquad (9)$$

where:
$E_{N2O,mm,i,y}$ Are the N_2O emissions from manure management in the second or subsequent treatment stage i of the project activity during the year y in tons of CO_2 equivalents.
GWP_{N2O} Is the approved Global Warming Potential (GWP) for N_2O.
$EF_{N2O,mm,i}$ Is the N_2O emission factor for the treatment stage i of the manure management system in kg N_2O-N/kg N (EF3 in 1996 Revised IPCC Guidelines and IPCC GPG).

[2] Metcalf and Eddy. Wastewater Engineering: Treatment, disposal, reuse. McGraw-Hill International Editions, Civil Engineering Series. International Edition 1991.

$N_{i,y}$ Is the average nitrogen content in the manure flowing to the treatment stage i during the year in kg N/m³.

$F_{i,y}$ Is the manure flow to the treatment stage i during the year y in m^3.

Project emissions

Project emissions in a certain year are the sum of CH_4 and N_2O emissions from manure management in the 1st and 2nd treatment stage and CO_2 emissions from grid electricity in the project activity in tons of CO_2 equivalents.

$$E_{y,project} = \sum_i E_{CH4,mm,i,y,project} + \sum_i E_{N2O,mm,i,y,project} + E_{CO2,grid,,y,project} \quad (14)$$

Where:

$E_{y,project}$ Are the net GHG emissions due to the project activity during the year y in tons of CO_2 equivalents.

$\sum_i E_{CH4,mm,i,y,project}$ Are the net CH_4 emissions from manure management in the 1st and subsequent treatment stages due to the project activity during the year y in tons of CO_2 equivalents.

$\sum_i E_{N2O,mm,i,y,project}$ Are the net N_2O emissions from manure management in the 1st and subsequent treatment stages due the project activity during the year y in tons of CO_2 equivalents.

$E_{CO2,grid,y,project}$ Are the CO_2 emissions from grid electricity in the project activity in the year y. Calculation is omitted because the value is zero (0) in the project activity.

D.2.1.3. Relevant data necessary for determining the baseline of anthropogenic emissions by sources of GHGs within the project boundary and how such data will be collected and archived :

ID number *(Please use numbers to ease cross-referencing to D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment
D.2-1	Number	Animal population	Heads	Measured	Weekly	100%	Paper. At least two years from completion period or last CERs issued	The number of pigs whose manure is flushed as defined in Table A-1. To be collected for each livestock population from 1996 Revised IPCC Guidelines and IPCC GPG 2000. This parameter will be incorporated in formula 1, 6, 7 and 10 of baseline methodology as $N_{population}$.
D.2-2	Mass	Average weight of Animals	kg	Measured and calculated	Records of entrance and exit of animals to the barn	100%	Paper. At least two years from completion of authorisation period or last CERs issued	To be collected for each livestock population from 1996 Revised IPCC Guidelines and IPCC GPG 2000. This parameter will be incorporated in formula 2 and 8 as W_{site}.
D.2-3	Concentration	Volatile solid	kg dry matter	Measured	Monthly	100%	Paper.	Monitoring of this data is

		excretion per animal and day	/animal /day				At least two years from completion of authorisation period or last CERs issued	only required if measured site-specific data is used. To be collected for each livestock population from 1996 Revised IPCC Guidelines and IPCC GPG 2000. This parameter will be incorporated in formula 1 and 6 as $VS_{population}$.
D.2-4	Concentration	Nitrogen excretion per animal and day	kg dry matter /animal / day	Measured and calculated	Monthly	100%	Paper. At least two years from completion of authorisation period or last CERs issued	Monitoring of this data is only required if measured site-specific data is used. To be collected for each livestock population from 1996 Revised IPCC Guidelines and IPCC GPG 2000. This parameter will be incorporated in formula 7 and 10 as $NEX_{population}$.
D.2-5	Flow rate	Manure flow between each treatment stage	m^3/day	Measured	Monthly	100%	Paper. At least two years from completion of authorisation period or last CERs issued	Only required for option A in step 4 of the baseline methodology. To be measured between each treatment stage of the project manure management system. This parameter will be incorporated in formula 3 and 9 as $F_{i,y}$.
D.2-6	Concentration	5 days Biochemical	mg/l	Measured	Monthly	100%	Paper. At least two	Only required for option A in step 4 of the baseline

		Oxygen Demand (BOD) in manure between each treatment stage					years from completion of authorisation period or last CERs issued	methodology. To be measured between each treatment stage of the project manure management system. This parameter will be incorporated in formula 4 as BOD_5.
D.2-7	Concentration	Total nitrogen content in manure between each treatment stage	mg/l	Measured	Monthly	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	Only required for option A in step 4 of the baseline methodology. To be measured between each treatment stage of the project manure management system. This parameter will be incorporated in formula 9 as $N_{i,y}$.
D.2-8	Temperature	Temperature of manure between each treatment stage	℃	Measured	Monthly	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	Only required for option A in step 4 of the baseline methodology. To be measured between each treatment stage of the project manure management system. This parameter will be incorporated in formula 5 as T.
D.2-14	Electricity generation	Electricity generated	kWh	Measured	Continuously	100%	Paper and electronic. At least two	The difference between D.2-14 and D.2-15 will be incorporated in formula 13

							years from completion of authorisation period or last CERs issued	as “Amount of electricity supplied by the project”, which determines the baseline emission of CO_2 by electricity displacement.
D.2-15	Electricity consumption	Electricity consumed in the digester	kWh	Measured	Continuously	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	Same as D.2-14.
D.2-16	CO_2 emission factor	CO_2 emission factor for grid	tCO_2/MWh	Calculated	Annually	100%	Paper and electronic. At least two years from completion of authorisation period or last CERs issued	This parameter will be calculated from formula 11 and 12 based on “Actual and forecast total energy generation and fuel requirement” of EGAT Power Development Plan, and incorporated in formula 13.

D.2.1.4. Description of formulae used to estimate baseline emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

>>The formulas to quantify the baseline emissions, except for electricity baseline emissions, are the same as those of project emission described in D.2.1.2.

Baseline emissions of displaced electricity

The electricity baseline emissions are determined from a weighed average emission factor of the grid mix and electricity generated from the project activity and to displace the grid electricity (the sum of pig farm use and grid export). Parameters will be calculated by each fuel type and power generation based on the actual and forecast total energy generation and fuel equipment form EGAT Power Development Plan.

The annual electricity production in the project is around 2MWh, which consists only 0.001% of the annual electricity generation in Thailand. This means the project does not have the influence on future power development plan in the country. Thus, the project is considered to be an operating margin.

Total CO_2 emissions of the grid can be calculated from fuel consumption data, as follows.

CO_2 emission from grid (tCO_2)	=	Grid fuel consumption (10^3toe)	x	Net caloric value (TJ/10^3toe) 41.868[3]	x	Carbon emission factor (tC/TJ)	x	Fraction of Carbon oxidised	x	Mass conversion factor (tCO_2/tC) 44/12		(11)

The Grid CEF (tCO_2/MWh) is then calculated by dividing the CO_2 (tCO_2) emission by the total grid electricity generated in the grid (MWh).

CO_2 emission Factor (tCO_2/MWh)	=	Sum of all CO_2 emission from grid (tCO_2)	÷	Grid electricity generated (MWh)		(12)

The CO_2 emission displaced by the project is calculated by multiplying the weighed average emission factor of the current generation mix by the amount of electricity generated in the project.

Baseline CO_2 emission from grid electricity (tCO_2/y)	=	Amount of electricity supplied by the project (MWh/y)	x	CO_2 emission factor for grid (tCO_2/MWh)		(13)

[3] Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook, table 1-1.

Baseline emissions

Baseline emissions in a certain year are the sum of CH_4 and N_2O emissions from manure management in the 1st and 2nd treatment stage and CO_2 emissions from grid electricity in the baseline scenario in tons of CO_2 equivalents.

$$E_{y,baseline} = \sum_i E_{CH4,mm,i,y,baseline} + \sum_i E_{N2O,mm,i,y,baseline} + E_{CO2,grid,y,baseline} \quad (15)$$

Where:

$E_{y,baseline}$	Are the net GHG emissions in the baseline scenario during the year y in tons of CO_2 equivalents.
$\sum_i E_{CH4,mm,i,y,baseline}$	Are the net CH_4 emissions from manure management in the 1st and subsequent treatment stages in the baseline scenario during the year y in tons of CO_2 equivalents.
$\sum_i E_{N2O,mm,i,y,baseline}$	Are the net N_2O emissions from manure management in the 1st and subsequent treatment stages in the baseline scenario during the year y in tons of CO_2 equivalents.
$E_{CO2,grid,y,baseline}$	Are the CO_2 emissions from grid electricity in the baseline scenario in the year y.

D. 2.2. Option 2: Direct monitoring of emission reductions from the project activity (values should be consistent with those in section E).

D.2.2.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

ID number *(Please use numbers to ease cross-referencing to table D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

D.2.2.2. Description of formulae used to calculate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

>>

D.2.3. Treatment of leakage in the monitoring plan

D.2.3.1. If applicable, please describe the data and information that will be collected in order to monitor leakage effects of the project activity

ID number *(Please use numbers to ease cross-referencing to table D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

D.2.3.2. Description of formulae used to estimate leakage (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

>> Although CH_4 and N_2O from screened impurity can be leakage, the amount is the same in the baseline and project scenario. Therefore, its calculation is not necessary.

D.2.4. Description of formulae used to estimate emission reductions for the project activity (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

>>

Emission reductions

Emission reductions in a certain year are the deference between the baseline emissions and the project emissions, adjusted for leakage effects, if any.

$$ER_y = E_{y,baseline} - E_{y,project} - L_y \quad (16)$$

Where:

ER_y	Are the net emission reductions due to the project activity during the year y in tons of CO_2 equivalents.
$E_{y,baseline}$	Are the net GHG emissions in the baseline scenario during the year y in tons of CO_2 equivalents.
$E_{y,project}$	Are the net GHG emissions due to the project activity during the year y in tons of CO_2 equivalents.
L_y	Are the leakage effects due to the project activity during the year y in tons of CO_2 equivalents.

D.3. Quality control (QC) and quality assurance (QA) procedures are being undertaken for data monitored		
Data *(Indicate table and ID number e.g. 3.-1.; 3.2.)*	Uncertainty level of data (High/Medium/Low)	Explain QA/QC procedures planned for these data, or why such procedures are not necessary.
D.3-1	Low	QA/QC procedures are established.
D.3-2	Low	QA/QC procedures are established.
D.3-3	Low	QA/QC procedures are established.
D.3-4	Low	QA/QC procedures are established.
D.3-5	Low	QA/QC procedures are established.
D.3-6	Low	QA/QC procedures are established.
D.3-7	Low	QA/QC procedures are established.
D.3-8	Low	QA/QC procedures are established.
D.3-9	Low	QA/QC procedures are established.
D.3-10	Low	QA/QC procedures are established.
D.3-11	Low	QA/QC procedures are established.
D.3-12	Low	QA/QC procedures are established.
D.3-13	Low	QA/QC procedures are established.
D.3-14	Low	QA/QC procedures are established.
D.3-15	Low	QA/QC procedures are established.
D.3-16	Low	QA/QC procedures are established.

D.4 Please describe the operational and management structure that the project operator will implement in order to monitor emission reductions and any leakage effects, generated by the project activity

>> The amount of emission reduction achieved in the project will be monitored and calculated, rather than directly monitored. In order to implement a precise and reliable monitoring plan, the project owner will establish monitoring procedure as a part of its environmental management system and its quality management system. Monitoring activity will be conducted using meters and scales which satisfy international standards. These appliances will be maintained periodically. The project developer and adviser will provide all the necessary advice consistent with the national and international standards.

D.5 Name of person/entity determining the monitoring methodology:

>>

Sewerage engineering department
Takuma Co., Ltd.
2-33, Kinrakuji-cho 2-chome, Amagasaki, Hyogo 660-0806, Japan
Tel: +81-6-6483-2701
E-mail: haruki@takuma.co.jp

Energy for Environment Foundation
14th Fl., Si Ayutthaya Bldg., 487/1 Si Ayuttaya Rd.,
Ratchathewi Bangkok 10400
Tel: +66-2642-6424
E-mail: chaiwat.m@efe.or.th

SECTION E. Estimation of GHG emissions by sources

E.1. Estimate of GHG emissions by sources:

>>

Selection of each formula and parameter was set in the way described in D.2.1.2.

The following sources were used to refer to default key parameters for baseline emissions, such as methane conversion factors (MCF), maximum methane production capacities (B_o), the volatile solid and nitrogen excretion rates (VS and N) and reduction rates for volatile solids and nitrogen (R_{VS} and R_N)[4]:

- 1996 Revised IPCC Guidelines, Chapter 4 of the Reference Manual
- IPCC Good Practice Guidance and Uncertainty management in National GHG Inventories, Chapter 4
- US-EPA 2001: Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations, Chapter 8.2 (http://epa.gov/ost/guide/cafo/devdoc.html)
- Site-specific data, such as the average animal weight and number of animals.

Formulas and parameters are as provided below:

Methane emissions from manure management

1st stage (Anaerobic treatment)

$$E_{CH4,mm,1,y} = GWP_{CH4} \times MCF_1 \times D_{CH4} \times \frac{365}{1000} \times \sum_{population} VS_{population} \times B_{o,population} \times N_{population} \quad (1)$$

Table E-1: Input data variables common to project and baseline

GWP_{CH4}	21	
D_{CH4}	0.67	kg/m^3
$VS_{default}$ *1	0.34	kg-dm/animal/day
$W_{default}$ *1	28	kg/head
$B_{o,population}$ *1	0.29	m^3 CH_4/kg-dm

*1: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual/ Ch.4.2 Methane and Nitrous Oxide Emissions form Domestic Livestock Enteric Fermentation and Manure Management/ Appendix B Table B-2 (Region: Developing countries, Livestock category: Swine), page 4-42.

$$VS_{site} = \left(\frac{W_{site}}{W_{default}} \right) \times VS_{default} \quad (2)$$

VS_{site}	$VS_{default}$	W_{site}	$W_{default}$	Site data	
kg-dm/animal/day	kg-dm/animal/day	kg/head	kg/head	head	Livestock Unit(500kg/LU)
0.548	0.34	45.13	28	46,200	4,170

[4] In this context a conservative approach is to choose for the parameters *MCF*, B_o, R_{VS} and R_N values at the lower end of the possible range for the baseline scenario and at the higher end of the possible range for the calculation of project emissions. For the volatile solid and nitrogen rates (*VS* and *N*), conservative choices are values at the lower end of the possible range.

2nd stage (Aerobic treatment)

$$E_{CH4,mm,i,y} = GWP_{CH4} \times MCF_i \times D_{CH4} \times \left[\prod_{n=1}^{i-1} \left(1 - R_{VS,n}\right) \right] \times \frac{365}{1000} \times \sum_{population} VS_{population} \times B_{o,population} \times N_{population} \quad (6)$$

Methane emission in the project scenario

		GWP_{CH4}	MCF	D_{CH4}	Rvs	VS_{site}	$Bo_{population}$	$N_{population}$	$E_{CH4,mm,1,y}$
		–	–	kg/m^3	%	kg-dm/animal/day	m^3 CH_4 /kg-dm	head	ton-CO_2/year
1st stage	Anaerobic Digester	21	0*2	0.67	40*4	0.548	0.29	40,765	0
2nd stage	Aerobic Lagoon	21	0.1*3	0.67		0.548	0.29	40,765	20
									20

*2: IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories／TABLE 4.10, “MCF VALUES FOR MANURE MANAGEMENT SYSTEMS DEFINED IN THE IPCC GUIDELINES (REVISIONS ARE NOTED IN ITALICS)”, (SYSTEM：Anaerobic Digester Climate：Warm), p4-36.

Default value of Anaerobic Lagoon has the range of 0-100%. The project activity sets the value zero because all of the biogas generated is utilized in the power generator and surplus biogas will be incinerated in the flare stack.

*3: IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories／TABLE 4.11, “MCF VALUES FOR MANURE MANAGEMENT SYSTEMS NOT SPECIFIED IN THE IPCC GUIDELINES (JUDGEMENT BY EXPERT GROUP)” (SYSTEM: Aerobic Treatment Climate: Warm), p4-37.

*4: The value 40 is applied from US EPA Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations/Table 8-11, “Anaerobic Unit Process Performance”(p8-71)/ “Digester type：Complete-mix, 40-70”.

In the formula 6, the VS input value in the stage i will be the subtracted amount of VS reduction between $\sum_{population} VS$ and the stage i-1. For example, VS value in the 2nd stage is $\sum_{population} VS \times (1-R_{vs,1})$, since the reduction rate in the 1st stage is $R_{vs,1}$. The smaller the R_{vs} value in the 1st stage is, the greater the CH_4 emission in the 2nd stage will be. In this project activity, conservative value 40 was adopted for the project activity among the wide range of default value (40-70).

The R_{vs} value in the 1st stage will be incorporated in the calculation of the 2nd stage.

N_2O emissions from manure management

1st stage (Anaerobic treatment)

$$E_{N2O,mm,1,y} = GWP_{N2O} \times EF_{N2O,mm,1} \times CF_{N2O\text{-}N,N} \times \frac{1}{1{,}000} \times \sum_{population} NEX_{population} \times N_{population} \quad (7)$$

Table E-2: Input data variables common to project and baseline

GWP_{N2O}	310	-
$CF_{N2O\text{-}N}$	44/28	-
$W_{default}$	28	kg/head
$NEX_{population}$	16*5	kg/head/year

*5 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual/ Ch. 4.5, Greenhouse Gas Emissions from Agricultural Soils/ TABLE 4-20, "TENTATIVE DEFAULT VALUES FOR NITROGEN EXCRETION PER HEAD OF ANIMAL PER REGION" (Region: Asia & Far East, Type of Animal: swine), p4-99.

$$NEX_{site} = \left(\frac{w_{site}}{w_{default}} \right) \times NEX_{default} \quad (8)$$

NEX_{site}	$NEX_{default}$	W_{site}	$W_{default}$	Site data	
kg-dm/animal/day	kg-dm/animal/day	kg/head	kg/head	head	Livestock Unit(500kg/LU)
25.8	16	45.13	28	46,200	4,170

2nd stage (Aerobic treatment)

$$E_{N2O,mm,l,y} = GWP_{N2O} \times EF_{N2O,mm,i} \times CF_{N2O\text{-}N,N} \times \left[\prod_{n=1}^{i-1} \left(1 - R_{N,n}\right) \right] \times \frac{1}{1000} \times \sum_{population} NEX_{population} \times N_{population} \quad (10)$$

N_2O emission in the project scenario

		GWP_{N2O}	EF_{N2O}	$CF_{N2O\text{-}N}$	R_N	$NEX_{population}$	$N_{population}$	$E_{N2O,mm,1,y}$
		-	-	-	%	kg-dm/animal/day	head	ton-CO_2/year
1st stage	Anaerobic Digester	310	0.001*6	1.57	0*8	25.8	40,765	512
2nd stage	Aerobic Lagoon	310	0.02*7	1.57		25.8	40,765	10,242
								10,754

*6 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories/ TABLE 4.12 "DEFAULT EMISSION FACTORS FOR N_2O FROM MANURE MANAGEMENT (ADDITIONAL SYSTEMS AND CHANGES TO THE IPCC GUIDELINES ARE NOTED IN ITALICS)" (SYSTEM：Anaerobic Digester), p4-43.

*7 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories／TABLE 4.13, ”DEFAULT EMISSION FACTORS FOR N_2O FROM MANURE MANAGEMENT SYSTEMS NOT SPECIFIED IN THE IPCC GUIDELINES (JUDGEMENT BY EXPERT GROUP)” (SYSTEM：Aerobic Treatment), p4-44.

*8 The value 0 is applied from US-EPA Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations/ Table 8-11, “Anaerobic Unit Process Performance(p8-71)”, **“**Digester type: Complete-mix: 0”.

In the formula 10, the N input value in the stage i will be the subtracted amount of N reduction between $\sum_{population} NEX_{population}$ and the stage i-1. For example, NEX value in the 2nd stage is $\sum_{population} NEX_{population} \times (1-R_{N,1})$, since the reduction rate in the 1st stage is $R_{N,1}$.

The R_N value in the 1st stage will be incorporated in the calculation of the 2nd stage.

E.2. Estimated leakage:

>> Although CH_4 and N_2O from screened impurity can be leakage, the amount is the same in the baseline and project scenario. Therefore, its calculation is not necessary.

E.3. The sum of E.1 and E.2 representing the project activity emissions:

>>Same as E.1.

Table E-3: Detailed project emissions

Source	GHG	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1st stage	CH_4 (P1)	0	0	0	0	0	0	0	0	0	0
	N_2O (P2)	512	512	512	512	512	512	512	512	512	512
2nd stage	CH_4 (P3)	20	20	20	20	20	20	20	20	20	20
	N_2O (P4)	10,242	10,242	10,242	10,242	10,242	10,242	10,242	10,242	10,242	10,242
Biogas electricity	CO_2 (P5)	0	0	0	0	0	0	0	0	0	0
PROJECT TOTAL		10,774	10,774	10,774	10,774	10,774	10,774	10,774	10,774	10,774	10,774

E.4. Estimated anthropogenic emissions by sources of greenhouse gases of the baseline:

>>

Methane and N_2O emissions from manure management

As for the CH_4 and N_2O project emissions in the 1st and 2nd stage, same formulas as E.1. are used for baseline emissions.

Methane emission in the baseline scenario

		GWP_{CH4}	MCF	D_{CH4}	Rvs	VS_{site}	$Bo_{population}$	$N_{population}$	$E_{CH4,mm,1,y}$
		–	–	kg/m^3	%	kg-dm/animal/day	m^3 CH_4 /kg-dm	head	ton-CO_2/year
1st stage	Anaerobic Lagoon	21	72*9	0.67	85*10	0.548	0.29	40,765	23,955
2nd stage	Aerobic Lagoon	21	0.1	0.67		0.548	0.29	40,765	5
									23,960

*9 Default value of Anaerobic Lagoon has the range of 0-100%. The default value of "Liquid/ Slurry" was adopted under the definition of Liquid/Slurry, "Dung and urine are collected and transported in liquid state to tanks for storage. Liquid may be stored for a long time (months)", and "To facilitate handling water may be added" from IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories/TABLE4-10 (SYSTEM: Liquid/Slurry, Climate: Warm), p4-36.

*10 The value of "Digester type: One-cell lagoon (75-85)" was adopted from EPA Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations, Table 8-10, Anaerobic Unit Process Performance, p8-55.

Although HRT is set more than 365 days, R_{vs} (80-90) is also applied in the Covered first cell of two cell lagoon (HRT: 30-90days). Thus, most of VS degradation is assumed to complete in the 1st stage and the value of 85% was applied (see *13).

The R_{vs} value in the 1st stage will be incorporated in the calculation of the 2nd stage.

N_2O emission in the baseline scenario

		GWP_{N2O}	EF_{N2O}	$CF_{N2O\text{-}N}$	R_N	$NEX_{population}$	$N_{population}$	$E_{N2O,mm,1,y}$
		-	-	-	%	kg-dm/animal/day	head	ton-CO_2/year
1st stage	Anaerobic Lagoon	310	0.001*11	1.57	25*13	25.8	40,765	512
2nd stage	Aerobic Lagoon	310	0.02*12	1.57		25.8	40,765	7,682
								8,194

*11: IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories/ TABLE 4.12, "DEFAULT EMISSION FACTORS FOR N_2O FROM MANURE MANAGEMENT (ADDITIONAL SYSTEMS AND CHANGES TO THE IPCC GUIDELINES ARE NOTED IN ITALICS.)" (SYSTEM: Anaerobic Lagoon), p4-43.

*12: IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories/ TABLE 4.13, "DEFAULT EMISSION FACTORS FOR N_2O FROM MANURE MANAGEMENT SYSTEMS NOT SPECIFIED IN THE IPCC GUIDELINES (JUDGEMENT BY EXPERT GROUP)" (SYSTEM: Aerobic Treatment), p4-44.

*13: The value “Digester type: Covered first cell of two cell lagoon (25-35)” was applied from EPA Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations/ Table 8-10, “Anaerobic Unit Process Performance (p8-55)”.

Although the R_N value of one-cell lagoon (*10) is 60-80, a half of N reduction in two-cell lagoon is considered to be caused by ammonia volatilization in the 2nd lagoon as referenced in the EPA guidelines below.

The R_N value in the 1st stage is set as 25% from the value of Covered first cell of two cell lagoon/ HRT 30-90days.

The R_N value in the 1st stage will be incorporated in the calculation of the 2nd stage.

EPA(p8-74):

During anaerobic digestion, microbial activity converts half or more of the organic N (Org-N) to soluble ammonia (NH3-N). Cheng (1999) found that 30 percent of the total Kjeldahl N (TKN,which includes ammonia and organic N) entering the covered first cell of a two-cell lagoon was retained in that cell, probably as organic N in slowly degradable organics in the sludge. A similar loss due to settling could be expected in a covered single-cell lagoon. A covered single-cell lagoon will not lose NH3-N to the atmosphere; however NH3-N will be volatilized from the uncovered second cell of a two-cell lagoon. Cheng (1999) also reported that approximately 50 percent of the influent TKN was subsequently lost from the uncovered second cell of the system.

Baseline emissions of CO_2 from displaced grid electricity

The ensuing table represents the grid generation and fuel consumption as projected by EGAT[5] for the first crediting period.

Table E-4: Projection of future energy generation in Thailand

Type of fuel		2007	2008	2009	2010	2011	2012	2013	2014	2015
Hydroelectric	GWh	7,359	7,274	7,216	11,736	12,057	12,072	12,116	12,018	11,981
Natural gas	GWh	116,596	125,960	137,913	145,410	145,648	141,173	139,561	135,732	131,295
	MMSCFD	2,370	2,532	2,758	2,911	2,910	2,794	2,771	2,689	2,598
Heavy oil	GWh	3,027	2,925	2,880	2,899	2,756	2,161	1,959	1,943	1,613
	Mlitres	711	681	666	669	637	508	468	463	379
Diesel oil	GWh	1,115	971	722	624	673	477	592	536	618
	Mlitres	370	330	259	233	245	197	225	211	232
Lignite	GWh	16,798	16,973	17,063	17,176	17,315	17,370	17,282	17,320	17,251
	Mtons	15.90	15.94	15.90	15.90	15.90	15.94	15.90	15.90	15.90
Imported coal	GWh	10,556	12,408	12,378	12,378	12,378	12,408	12,378	12,378	12,378
	Mtons	2.77	3.41	3.40	3.40	3.40	3.41	3.40	3.40	3.40
Other purchases										
Renewable SPP	GWh	1,242	1,251	1,251	1,788	1,788	1,788	1,788	1,788	1,788
Lao PDR (Hydro)	GWh	1,517	1,517	1,517	1,517	1,517	1,517	1,517	1,517	1,517
Renewables RPS	GWh	-	-	-	-	812	1,441	1,993	2,652	3,388
New Plants (Natural Gas)	GWh	-	-	-	-	11,728	29,845	45,486	63,958	83,958
Grand Total	GWh	158,211	169,279	180,941	193,529	206,673	220,252	234,671	249,842	265,787

The annual electricity production in the project is around 2MWh, which consists only 0.001% of the annual electricity generation in Thailand. This means the project does not have the influence on future power development plan in the country. Thus, the project is considered to be an operating margin.
As for “other purchase”, all categories except for New Plants which assume natural gas are defined as renewable energy.

[5] Appendix 7 “Projection of Future Energy Generation” of Thailand Power Development Plan (PDP 2004), System Planning Division, EGAT, 2004

CO_2 emissions for all generation types were obtained using the fuel consumption given in the table above. An illustration of the calculation method is given using projected data for imported coal in 2007. All input data used for the calculations, including the relevant section of EGAT-PDP, is provided in Annex 3.

CO_2 emission from grid (2007) (tCO_2)	=	Grid fuel consumption (10^3toe)	x	Net caloric value (TJ/10^3toe)	x	Carbon emission factor (tC/TJ)	x	Fraction of Carbon oxidised	x	Mass conversion factor (tCO_2/tC)	(11)
	=	2.77×10^3	x	26.38	x	26.8	x	0.98	x	44/12	
	=	7,036,989tCO_2									

CO_2 emission Factor for imported coal (2007) (tCO_2/MWh)	=	Sum of all CO_2 emission from grid (tCO_2)	÷	Grid electricity generated (MWh)	(12)
	=	7,036,989	÷	10,556,000	
	=	0.667 tCO_2/MWh			

The CO_2 emission is summed for all generation types. Following the same procedures as for imported coal, the total CO_2 emission for the grid in 2007 was calculated as 84,430,573 tonnes.
Weighed average emission factor of the grid mix is used to determine the electricity baseline emission.

The total electricity generated given in the table was used to obtain the CO_2 emission factor in 2007.

CO_2 emission Factor (2007) (tCO_2/MWh)	=	Sum of all CO_2 emission from grid (tCO_2)	÷	Grid electricity generated (MWh)
	=	84,430,573	÷	158,210,000
	=	0.534 tCO_2/MWh		

The CO_2 emission displaced by the project is calculated by multiplying the emission factor by the amount of electricity generated in the project in the year.

Baseline CO_2 emission from grid electricity (2007) (tCO_2/y)	=	Amount of electricity supplied by the project (MWh/y)	x	Carbon emission factor for grid (tCO_2/MWh)	(13)
	=	1,398	x	0.534	
	=	746tCO_2/y			

To estimate annual baseline emissions from grid electricity generation for the entire crediting period, the preceding calculations are repeated for each year until 2017. The grid CEFs and emissions so derived are given in the table below. As Power Development Plan only provides the data until 2015, the data on 2016 is not available *ex ante*. The data on 2015 will be used to calculate baseline emission of grid electricity, and actual power development result will be monitored to decide baseline emissions *ex post*.

Table E-5: Annual emission factor and carbon dioxide emissions for Thai Electricity Grid

Year	Carbon Emission Factor (tCO_2/MWh)	CO_2 emission from biogas CO_2 emission (tCO_2)
2007	0.534	746
2008	0.530	741
2009	0.523	732
2010	0.507	709
2011	0.501	701
2012	0.494	691
2013	0.492	688
2014	0.488	683
2015	0.485	678
2016	0.485	678
TOTAL		7,045

Table E-6: Detailed baseline emissions

Source	GHG	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1st stage	CH_4 (B1)	23,955	23,955	23,955	23,955	23,955	23,955	23,955	23,955	23,955	23,955
	N_2O (B2)	512	512	512	512	512	512	512	512	512	512
2nd stage	CH_4 (B3)	5	5	5	5	5	5	5	5	5	5
	N_2O (B4)	7,682	7,682	7,682	7,682	7,682	7,682	7,682	7,682	7,682	7,682
Electricity	CO_2 (B5)	746	741	732	709	701	691	688	683	678	678
BASELINE TOTAL		32,900	32,895	32,886	32,863	32,855	32,845	32,842	32,837	32,832	32,832

E.5. Difference between E.4 and E.3 representing the emission reductions of the project activity:

>>

Table E-7: Total emission reduction

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
TOTAL EMISSION REDUCTION	22,126	22,121	22,112	22,089	22,081	22,071	22,068	22,063	22,058	22,058

E.6. Table providing values obtained when applying formulae above:

>>

Table E-8: Emission and reduction

Source	GHG	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1st stage	CH_4 (P1)	0	0	0	0	0	0	0	0	0	0
	N_2O (P2)	512	512	512	512	512	512	512	512	512	512
2nd stage	CH_4 (P3)	20	20	20	20	20	20	20	20	20	20
	N_2O (P4)	10,242	10,242	10,242	10,242	10,242	10,242	10,242	10,242	10,242	10,242
Biogas electricity	CO_2 (P5)	0	0	0	0	0	0	0	0	0	0
PROJECT TOTAL		10,774	10,774	10,774	10,774	10,774	10,774	10,774	10,774	10,774	10,774

Source	GHG	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1st stage	CH_4 (B1)	23,955	23,955	23,955	23,955	23,955	23,955	23,955	23,955	23,955	23,955
	N_2O (B2)	512	512	512	512	512	512	512	512	512	512
2nd stage	CH_4 (B3)	5	5	5	5	5	5	5	5	5	5
	N_2O (B4)	7,682	7,682	7,682	7,682	7,682	7,682	7,682	7,682	7,682	7,682
Electricity	CO_2 (B5)	746	741	732	709	701	691	688	683	678	678
BASELINE TOTAL		32,900	32,895	32,886	32,863	32,855	32,845	32,842	32,837	32,832	32,832

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
TOTAL EMISSION REDUCTION	22,126	22,121	22,112	22,089	22,081	22,071	22,068	22,063	22,058	22,058

SECTION F. Environmental impacts

F.1. Documentation on the analysis of the environmental impacts, including transboundary impacts:

>> The project's appropriate technology will improve the effectiveness of the existing wastewater treatment system. The facility will help reduce potential environmental impacts; namely, the GHG emission, odours and water contaminations, which are greatly generated from traditional wastewater treatment plant in swine farms.

GHG emissions

Mitigating GHG emission is the primary focus of the project. The major gas targeted is CH_4, which is odourous and is in connection with the global warming effect. The methane capture facility being implemented is capable of recovering CH_4 from the organic waste by anaerobic digestion process. The captured biogas is transferred within a closed system for power generation purpose, reducing the amount of CH_4 emitted into atmosphere.

Odours

As for this farm, there is no complaint on odours from the nearby community at present, as the centre of the piggeries is located sufficiently far from the community.

Considering the influence of the wind, the local wind direction found at the project site is in the southwest direction. It is found that there is a small community situating in the leeward direction. However, the distance is around 1 kilometer away from the piggeries area, and it is sufficiently far from the project site that the odours are not their concerns.

Apart from that, the majority of the population in the nearby community lives in the windward direction, i.e. located away from the project site in the northeast direction. As a result, the odours are currently not the public concern regardless of the wind direction.

Nevertheless, the increase of population may certainly lead to closer distance between the farm and the community in the future. In such case, the methane capture technology in the project is considered additionally beneficial to the community, as it can prevent possible odour complaints, ensuring a sustainable development to the nearby community.

Water contaminations

As for this pig farm, direct discharge of waste and wastewater into public waterways is not present. All waste are collected and treated by proper waste management practices. Also, all wastewater is directed to existing wastewater treatment plant. However, overflow of the treated wastewater from the post-treatment open pond occasionally occurs, especially during the rainy season.

Presently, the existing wastewater treatment plant is capable of reducing the BOD and COD into an order of 94 and 600 mg/litre, respectively. However, the pond is only surrounded by a vast land space and a small vegetating area. Thus, the overflow does not actually cause any public water contamination.

Upon the implementation of the project, the biogas technology will replace the traditional wastewater treatment and effectively improve the effluent quality in the post-treatment ponds. It will greatly reduce the concentration of organic matter nitrogen and phosphorus content in the effluent, further removing risk of groundwater or public water contamination. The treated water will be recirculated and used in the project for cleaning purpose as much as possible.

Electricity

The use of the collected biogas as an electricity fuel will displace grid generated electricity and its associated GHG emissions. It also reduces energy load of the grid.

The Thai government enhances biogas utilization in the country, and pig farm is one of the most feasible plant categories having high potential to generate biogas. Nevertheless, there are very small numbers of biogas plants installed compared with the traditional open lagoon system which requires low investment costs. Biogas electricity under CDM will help utilize potential energy source effectively.

Overall the project's activity will result in positive environmental impacts and help create the more environmental friendly conditions. They can be summarised as followed.

- Reducing atmospheric emissions of GHG emissions, especially CH_4 by methane recovery technology
- Reducing odours
- Decreasing the risk of decease-transmitting vectors and airborne pathogens
- Utilizing renewable energy of biogas displacing fossil fuel derived electricity

F.2. If environmental impacts are considered significant by the project participants or the host Party, please provide conclusions and all references to support documentation of an environmental impact assessment undertaken in accordance with the procedures as required by the host Party:

>> The project activity greatly improves the environment in the surrounding area.

SECTION G. Stakeholders' comments

>>

G.1. Brief description how comments by local stakeholders have been invited and compiled:

>>

Although there is no formal invitation for local people to comment on the farm's plan to setting up a biogas system, many of Ratchaburi natives are aware of the new technology. They would support the project since it will help improve the environment. However, they have not forced the farm to implement the biogas system yet since there is not any negative impact from the farm's environmental management. When there is exact plan to establish the biogas system, the farm intends to arrange consultation activities to give information and receive any feedback.

Local stakeholders consist of villagers in the neighbourhood, community leaders, and vegetable farmers. The relation with the local stakeholders and the pig farm is summarized below.

Neighbours who live nearby the pig farm are very limited to one small temple and approximately 20 – 30 households in the vicinity of 1-2 km. The houses are scattered in one side of the southern fence with only one house locating beside the post-treatment open pond. Mostly the farm neither has any negative impact on their living nor odour from the manure, therefore the farm and the villagers have been peacefully living together for 10 years. Only in some cases, especially during rainy season where the water level from the open pond over rises and spills out to the neighbour's land, that people would complains and the farm immediately solves the problem. This would happen once or twice a year.

As for community leaders, the farm has long been in the neighbourhood thus it is a part of the community. Besides, the farm owner has good relationship and network with local leaders. As long as the farm business does not disturb the community's living, local leaders are willing to be communication medium between the farm and villagers when needed.

For farmers who grow vegetable in the area, they are more involved with the farm's activities especially manure management. Currently, ones who live nearby benefit from using water outflow from the farm that contains some organic matters. The other group of farmers is ones that come to buy fresh manure and dried manure to use as fertilizer for their vegetable. The farm has constantly communicated with these farmers.

In addition, the project developer had a meeting with the designated national authority of Thailand, Ministry of Natural Resources and Environment (MONRE), in a capacity building workshop in March 2005. The project activity went through a DNA approval process simulation. The project developer explained the project from the viewpoints of additionality and sustainable development. The participants from DNA, Ministry of Energy and universities examined the project activity taking the SD criteria of Thailand into account.

G.2. Summary of the comments received:

>> Even though the consultation has not taken place, the farm has received informal concerns from the local stakeholders such as:

1) The pig farm must not deteriorate the local environmental condition
2) The water outflow must not contaminate the water quality for agricultural usage
3) The fertilizer from sludge of the digester has lower quality compared to the fresh manure

The first two comments are quite common particularly in this new era where locals are more aware of their right to good environment. The third comment is evidenced by some vegetable farmers who have tried the new kind of fertilizer.

As for the DNA workshop, the result was very positive. The project was considered to contribute to the sustainable development of Thailand socially, economically and environmentally.

However, a few comments were received. One was that the project activity does not lead to technology transfer because the digester technology is already available in Thailand. The project developer explained that this project has a simple system and accomplishes high-efficient methane recovery and power generation.

The other was that the project needs contribution to local community. The project developer then explained that the project activity does not increase the number of employee because existing employee will be able to operate the facility in their daily activities, but improves their technical skill through operation training which will help develop their own technology standard.

G.3. Report on how due account was taken of any comments received:

>> The anaerobic waste treatment system will definitely help serving the first two comments by making better environment and preventing high BOD water outflow. However, as for the fertilizer, more investigation needs to be done.

The farm manager observes that the sludge fertilizer may have low Nitrogen content so it may not be suitable for vegetable farms. Immediate solution is that, giving the farmers some amount of water from the post-treatment pond together with the sludge in order to fulfil the lacking nutrient.

In the long-run, the analysis of sludge is needed to identify nutrient composition. With agricultural expert's advice, certain substances might be required to make the best fertilizer.

Annex 1

CONTACT INFORMATION ON PARTICIPANTS IN THE PROJECT ACTIVITY

Organization:	Kanchana Hybrid (Nernthong) Farm
Street/P.O.Box:	194 Moo 11, Tambom Tungluang, Pak Tho District,
Building:	
City:	
State/Region:	Ratchaburi
Postfix/ZIP:	70140
Country:	Thailand
Telephone:	
FAX:	
E-Mail:	
URL:	
Represented by:	
Title:	
Salutation:	
Last Name:	
Middle Name:	
First Name:	
Department:	
Mobile:	
Direct FAX:	
Direct tel:	
Personal E-Mail:	

Organization:	Energy for Environment Foundation
Street/P.O.Box:	14th Fl., Si Ayutthaya Bldg., 487/1 Si Ayuttaya Rd.,
Building:	
City:	Ratchathewi Bangkok
State/Region:	
Postfix/ZIP:	10400
Country:	Thailand
Telephone:	+66-2642-6424
FAX:	+66-2642-6426
E-Mail:	Chaiwat.m@efe.or.th
URL:	www.efe.or.th
Represented by:	
Title:	Senior Information Officer
Salutation:	Mr.
Last Name:	Muncharoen
Middle Name:	
First Name:	Chaiwat
Department:	
Mobile:	
Direct FAX:	+66-2642-6426
Direct tel:	+66-2642-6424
Personal E-Mail:	Chaiwat.m@efe.or.th

Organization:	Takuma Co., Ltd.
Street/P.O.Box:	2-33, Kinrakuji-cho 2-chome,
Building:	
City:	
State/Region:	Amagasaki, Hyogo
Postfix/ZIP:	660-0806
Country:	Japan
Telephone:	+81-6-6483-2701
FAX:	+81-6-6483-2766
E-Mail:	haruki@takuma.co.jp
URL:	www.takuma.co.jp
Represented by:	
Title:	Deputy general manager
Salutation:	Mr.
Last Name:	Haruki
Middle Name:	
First Name:	Hiroto
Department:	Sewerage engineering department
Mobile:	
Direct FAX:	+81-6-6483-2766
Direct tel:	+81-6-6483-2701
Personal E-Mail:	haruki@takuma.co.jp

Annex 2

INFORMATION REGARDING PUBLIC FUNDING

No public funding is used for the project.

Annex 3

BASELINE INFORMATION

Parameters for Methane and N_2O emission

Table 1: Food intake and manure production for swine

Region	Livestock Category	Mass	Feed Digestibility	Energy intake	Category population	Manure	VS	Bo
		kg	%	MJ/d	kg/d	kg/h/d-dm	kg/h/d	m^3_{CH4}/kg-VS
Developing contries	Swine	28	50	13.0	0.7	0.35	0.34	0.29
Developed contries	Swine	82	75	38.0	2.1	0.51	0.50	0.45

Source: Table B-2, Appencix B, chapter4-2, IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

Parameters for Methane emission

Table 2: MCF values for manure management systems

SYSTEM		CLIMATE			
		Cool	Temperate	Warm	
Liquid	%	39	45	72	
Anaerobic Lagoon	%	39	45	72	0-100
Anaerobic Digester	%	0	0	0	0-100
Aerobic Lagoon	%	0.1	0.1	0.1	

MCF caluculation

MCF＝(CH_4prod －CH_4used CH_4flared ＋MCFstorage×(Bo－CH_4prod))／Bo×100

	CH4prod	CH4used	C H4flared	MCFstorage			MCF		
				Cool	Temperate	Warm	Cool	Temperate	Warm
Anaerobic Lagoon	0	0	0	39	45	72	39	45	72
Anaerobic Digester	0.29	0.29		39	45	72	0	0	0

Source: Table 4-10 and 4-11, IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories

Table 3: VS and TN values

	VS	TN
One-cel lagoon	75-85	60-80

Source: Table 8-10, US EPA (2001)

	VS	TN
Complete-mix	40-70	0

Source: Table 8-11, US EPA (2001)

Parameters for N_2O emission

Table 4: Default emission factors for N_2O from manure management

		EF
SYSTEM		kg/kg-N
Liquid	%	0.001
Anaerobic Lagoon	%	0.001
Anaerobic Digester	%	0.001
Aerobic Treatment	%	0.02

Source: Table 4-12 and 4-13, IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories

Table 5: Default values for nitrogen excretion head

		NEX
		kg/head/year
Swine	Asia & far east	16

Source: Table 4-20, chapter4-5, IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

Table 6: Anaerobic unit process performance

	VS	TN
Complete-mix	40-70	0
Covered First cell of two cell lagoon	80-90	25-35

Source: Table 8-11, US EPA (2001)

Parameters for CO_2 emission from displaced grid electricity

Table7: Power development plan in Thailand

Power Development Plan 2004 (2004-2015)
Forcast of Power Generation in Thailand by Fuel
Primary Plan

Type of Fuel	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015
Hydroelectricity	GWh	7,359	7,274	7,216	11,736	12,057	12,072	12,116	12,018	11,981
	%	4.7	4.3	4.0	6.1	5.8	5.5	5.2	4.8	4.5
Natural Gas	GWh	116,596	125,960	137,913	145,410	145,648	141,173	139,561	135,732	131,295
	%	73.7	74.4	76.2	75.1	70.5	64.1	59.5	54.3	49.4
	MCFD	2,370	2,532	2,758	2,911	2,910	2,794	2,771	2,689	2,598
Heavy Oil	GWh	3,027	2,925	2,880	2,899	2,756	2,161	1,959	1,943	1,613
	%	1.9	1.7	1.6	1.5	1.3	1.0	0.8	0.8	0.6
	MLitre	711	681	666	669	637	508	468	463	379
Diesel Oil	GWh	1,115	971	722	624	673	477	592	536	618
	%	0.7	0.6	0.4	0.3	0.3	0.2	0.3	0.2	0.2
	MLitre	370	330	259	233	245	197	225	211	232
Lignite	GWh	16,798	16,973	17,063	17,176	17,315	17,370	17,282	17,320	17,251
	%	10.6	10.0	9.4	8.9	8.4	7.9	7.4	6.9	6.5
	MTon	15.90	15.94	15.90	15.90	15.90	15.94	15.90	15.90	15.90
Imported Coal	GWh	10,556	12,408	12,378	12,378	12,378	12,408	12,378	12,378	12,378
	%	6.7	7.3	6.8	6.4	6.0	5.6	5.3	5.0	4.6
	MTon	2.77	3.41	3.40	3.40	3.40	3.41	3.40	3.40	3.40
Other Purchases										
Renewable SPP	GWh	1,242	1,251	1,251	1,788	1,788	1,788	1,788	1,788	1,788
	%	0.8	0.7	0.7	0.9	0.9	0.8	0.8	0.7	0.7
Lao PDR **(Hydro)**	GWh	1,517	1,517	1,517	1,517	1,517	1,517	1,517	1,517	1,517
	%	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6
Renewables RPS	GWh	-	-	-	-	812	1,441	1,993	2,652	3,388
	%	-	-	-	-	0.4	0.7	0.8	1.1	1.3
New Plants **(NG)**	GWh	-	-	-	-	11,728	29,845	45,486	63,958	83,958
	%	-	-	-	-	5.7	13.6	19.4	25.6	31.6
Total	GWh	158,211	169,279	180,941	193,529	206,673	220,252	234,671	249,842	265,787

Note:

MCFD	Million Cubic Feet per Day
MLitre	Million Litres
MTon	Million Tonnes
NG	Natural Gas
Lao PDR	Lao People's Democratic Republic

Source: Appendix 7, Thailand PDP 2004, EGAT, p.77

Table 8: Input Variables for grid electricity generation

Variable	Value		Reference
Net calorific value (TJ/kt)	Natural gas	52.3	Table 1-2,1-3*
	Heavy oil	40.19(residual fuel oil)	
	Diesel oil	43.33	
	Lignite	12.14(Thailand)	
	Imported coal	26.38(Imported hard coal, Thailand	
Carbon emission factor (tC/TJ)	Natural gas	15.3(dry)	Table 1-1*
	Heavy oil	21.1(residual fuel oil)	
	Diesel oil	20.2	
	Lignite	27.6	
	Imported coal	26.8 (anthracite)	
Fraction of C oxidized	Gas	0.995	Table 1-6*
	Oil and oil products	0.99	
	Coal (default)	0.98	
Grid fuel consumption	Refer to table above		EGAT PDP
Grid electricity generation	Refer to table above		EGAT PDP
Electricity exported by project (MWh/yr)		132,864	Calculated

* Revised IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

Other data

Table 9: GWP and MCF

GWP CH_4	21
GWP N_2O	310
Mass conversion factor (tCO_2/tC)	44/12
Mass conversion factor (tCH_4/tC)	16/12

In converting volume-based fuel consumption to mass-based, the following densities were used:

Natural gas = 0.774kg/m^3
Specific gravity is typically around 0.6 (density of natural gas = density of air (1.29 kg/m^3) x 0.6 = 0.774)

Heavy oil = 0.89kg/l
Heavy oil densities are between 0.9 and 1.0 kg/m^3 at 15℃. For a conservative calculation of baseline emissions, the lower limit was used, adjusted for higher temperatures (30℃).

Annex 4

MONITORING PLAN

The following table represents the monitoring plan followed by KHF for validation and verification.

ID	Data variable	Uncertainty level	Data unit	Data origin
D.2-1	Animal population	Low	Heads	Daily animal stock. Information managed by KHF.
D.2-2	Average weight of Animals	Low	kg	Sampling measurement by KHF
D.2-3	Volatile solid excretion per animal and day	Low	kg dry matter /animal /day	
D.2-4	Nitrogen excretion per animal and day	Low	kg dry matter /animal / day	
D.2-5	Manure flow between each treatment stage	Low	m^3/day	This parameter is monitored by a flow meter installed before the activated sludge.
D.2-6	5 days Biochemical Oxygen Demand (BOD) in manure between each treatment stage	Low	mg/l	Activated sludge monitoring
D.2-7	Total nitrogen content in manure between each treatment stage	Low	mg/l	Activated sludge monitoring
D.2-8	Temperature of manure between each treatment stage	Low	℃	Activated sludge monitoring
D.2-9	Biogas flow extracted by digester	Low	Nm^3/h	A Flow meter installed
D.2-10	CH_4 concentration in gas flow	Low	%	A Flow meter installed
D.2-11	Exhaust gas flow	Low	Nm^3/h	A Flow meter installed
D.2-12	CH_4 concentration in exhaust gas flow	Low	%	A Flow meter installed
D.2-13	N_2O concentration in exhaust gas flow	Low	%	A Flow meter installed
D.2-14	Electricity generated	Low	kWh	A meter installed
D.2-15	Electricity consumed in the digester	Low	kWh	Meters installed. Double-checked by the receipt of electricity export and metered in-house use.
D.2-16	CO_2 emission factor for grid	Low	tCO_2/MWh	Official publication from EGAT will be obtained.

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