CLEAN DEVELOPMENT MECHANISM
PROJECT DESIGN DOCUMENT FORM (CDM-PDD)
Version 03 - in effect as of: 28 July 2006

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ANNEXES

SECTION A. General description of project activity

A.1 Title of the project activity:

Bionersis Project Thailand 1
Version 01
PDD completed on 20/05/2008

A.2. Description of the project activity:

The project activity is to build, operate and maintain a landfill gas (LFG) collection and flaring system on the Kamphaeng Saen landfill ("KPS") in Nakhon Pathom, Thailand. It is an anaerobic managed landfill, operated by Group 79, opened in 1991 and closed in 2005. The location details of the landfill are provided in section A.4.
Possible uses for LFG include electricity generation for use at the landfill site and/or supply to the local grid. The feasibility of electricity generation will be revisited once the project is fully operational.

It is estimated that the project will achieve emissions reductions of more than 717,217 tCO_2e over the period 2009 – 2018.

Besides climate change mitigation, the project would have important local environmental benefits. Currently, most of the landfill gas is released into the atmosphere without any treatment or control. This implies a potential fire and explosion risk as well as bad odours. Moreover, landfill gas contains trace amounts of volatile organic compounds, which are air pollutants. The capture and flaring of landfill gas would greatly reduce all these risks and thereby contribute to sustainable development.

The project will have very little or no negative impact on the environment: it does not use any scarce resources (like fuel or water), nor does it produce any waste or emissions to water and soil. The only noticeable impact will be the noise generated by the compressors and flare in operation, but the noise level is low, and will not be a nuisance for the local population.

The project will also have a small, but positive impact on employment in the local area as a number of staff will need to be recruited to manage the landfill gas capture operations.

More generally, on site, the project will greatly enhance the awareness to the benefits of a proper management of waste, and demonstrate that environment preservation can also create jobs and wealth for the local community. Moreover, the local stakeholders will participate in improving their own environment, and being better informed of the key environmental issues the solutions that landfill gas techniques can bring, and how they can use them.

The project will also have several positive effects on the regional economic situation, by way of:
- Financial contribution to local communities,
- Hiring and training of local employees,
- Transfers of know-how, directly by training, or indirectly through the visibility of the project and its interest as a successful local environmental initiative,
- Increased awareness to environmental issues (e.g. by organizing site visits by academics and students) and how they can create economic opportunities,

- Emergence of local suppliers of equipment and local competitors launching their own business, using the project as a benchmark.

A.3. Project participants:

Name of Party involved	Private and/or public entities Project Participants	Does the Party involved wish to be considered as a Project Participant
Thailand (Host country)	Bionersis (Thailand) Ltd (private entity)	No
France	Bionersis S.A. (private entity) GF Global Carbon Trading Co Ltd (private entity)	No

Please refer to Annex 1 for detailed information on project participants.

A.4. Technical description of the project activity:

A.4.1. Location of the project activity:

A.4.1.1. Host Party(ies):

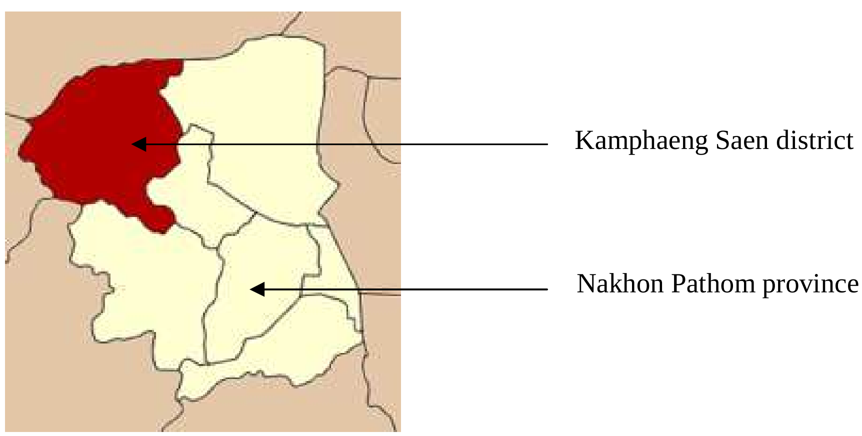
Thailand.

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

The Kamphaeng Saen landfill ("KPS") is located in the Nakhon Pathom province, as shown on the map below:

A.4.1.3.	City/Town/Community etc:

Province of Nakhon Pathom, district of Kamphaeng Saen, city of Kamphaeng Saen:



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

This landfill is designated locally as: “The landfill of Kamphaeng Saen”.
It is an anaerobic managed landfill of 34 hectares, operated by Group 79, opened in 1991 and closed in 2005, which has received approximately 10.5 million tons of waste. Project operations will take place on 20 hectares, considering topographical constraints of the landfill and waste disposition.
This landfill is located at T. Sasimhum, A. Kamphaeng Saen, Nakhon Pathom, 73140.
Its geographic coordinates are 14°03’36.35” North, 99°58’01.19” East.

A.4.2. Categories of project activity:

The project belongs to Category 13- Waste handling and disposal, and Category 1- Energy industries (renewable sources).

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

The project activity is based on a landfill gas (“LFG”) collection and flaring system, compliant with EU and local regulations. The equipment which will be used in this project activity on each site includes, inter alia:

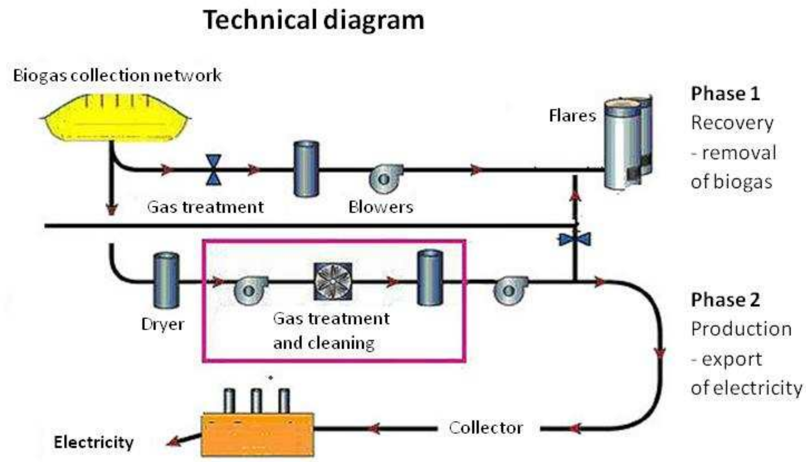
- a gas collection network, permeable pipes, and vertical gas wells and/or horizontal trenches
- a high temperature enclosed flare (Temperature = 1000°- 1200°C, retention time> 0.3s)
- monitoring and control systems to measure the actual flow and composition of the LFG
- civil works

LFG collection systems will be installed over an area of 20 hectares of the landfill.

The project design engineering reflects current good practices for leachate infiltration: the rain will be drained and collected in order to reduce the volumes of leachate generated.

The drainage of the leachate will be maximised, according to the site conditions, through profiling of the site or if necessary through pumping excess volumes. The aim is to direct leachate to leachate ponds for treatment.

Bionersis design will use good practices for the drainage of leachate. The pumping, exploitation and treatment of leachate remain in the scope of the landfill operator’s responsibility.



The LFG collection system is composed of a network of vertical wells and/or horizontal trenches and interconnected pipes, and a low pressure is created in the system producing suction for the extraction of the LFG. The LFG extracted is fed into a high temperature flare which enables the methane contained in the LFG to be completely oxidized by the flaring process. The sites are equipped with a monitoring system to measure the flow, the pressure and the temperature. The equipments are connected to the public electricity grid to satisfy their energy needs.

The operators will be qualified to carry out maintenance and control activities and they will have the support of an aid telephone line and experts will be in charge of maintenance whenever necessary.

We will use the HOF*GAS*® extracting and flaring station that has been developed by the Swiss Hofstetter Umwelttechnik company, which is regarded commonly as one of the world's leading companies in landfill gas flaring solutions. It has the following characteristics:

- the complete degassing unit is built in a ventilated container, providing securities against any weather or burglary risks and which would prove beneficial for noise reduction;
- safe and low emission combustion is guaranteed by a high temperature flare;
- safety devices are as follows:
  - EEX motor;
  - flame arrester;
  - slam shut valve;
  - burner control with UV detector.
- gas flow rate could be anything between 40 and 2,500 Nm^3/h, with associated burners between 200 and 12,500 kW.

The project activity will be first limited to the destruction of the LFG collected (project phase 1), the possibility of generating electricity and delivering it to the local grid will be considered at a future stage (project phase 2) and as soon as it will be economically viable.

The energy plant will consist of a pretreatment system, in order to dry and clean the landfill gas, and 2 electricity generators.
The gas pretreatment system will dry the LFG and compress it. The cleaning system will be adapted to the quality of LFG.
The electricity generators will be installed in different stages of the project, with maximum 2MW capacity during the crediting period.

A.4.4 Estimated amount of emission reductions over the chosen crediting period:

The capture and combustion of the CH_4 component of the LFG in the project activity is estimated to prevent emissions of 717,217 tons of CO_2e over the fixed crediting period of 10 years.

Year	Emission reductions from methane destruction (tCO_2e)	Emission reductions from energy displacement (tCO_2e)	Estimation of overall emission reductions (tCO_2e)
2009	84,636	0	84,636
2010	83,539	10,658	94,197
2011	75,407	10,658	86,065
2012	68,890	10,579	79,469
2013	63,518	9,756	73,274
2014	58,975	9,060	68,034
2015	55,042	8,457	63,499
2016	51,570	7,925	59,495
2017	48,457	7,448	55,905
2018	45,630	7,015	52,644
2019	0	0	0
Total	**635,662**	**81,555**	**717,217**
Yearly Av	63,566	8,155	71,722

A.4.5. Public funding of the project activity:

There is no public funding from Parties included in Annex I of the UNFCCC involved in this project activity. Please refer to annex 2 for further details.

SECTION B. Application of a baseline and monitoring methodology

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

Methodology ACM0001 version 08, "*Consolidated baseline and monitoring methodology for landfill gas project activities*", has been applied to this project.
In addition, methodology AMS I.D version 13 "*Grid connected renewable energy generation*" has been applied considering the possibility to use the captured gas for energy production in the future.
The other methodological tools used are:
Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site
Tool to determine project emissions from flaring gases containing methane
Tool for the demonstration and assessment of additionality
Tool to calculate project emissions from electricity consumption
Tool to calculate the emission factor for an electricity system

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

The *"Consolidated baseline and monitoring methodology for landfill gas project activities"* ACM0001 version 08 is applicable because the current situation on the project site (baseline scenario) is the partial or total atmospheric release of the gas and the project activities include situations such as:

a) The captured gas is flared; and/or

b) The captured gas is used to produce energy (e.g. electricity/thermal energy);

c) The captured gas is used to supply consumers through natural gas distribution network. If emission reductions are claimed for displacing natural gas, project activities may use approved methodologies AM0053.

The project activity corresponds to situations a) and b): the collected landfill gas will be flared at a first stage, and may be used to produce electricity at a second stage.

The small-scale methodology AMS I.D. version 13 *"Grid connected renewable electricity generation"* is applicable to the second stage of the project activity due to the fact that the installed generated capacity would be less than 15 MW in case we produce energy in the future.

The other methodological tools used are:

Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site

Tool to determine project emissions from flaring gases containing methane

Tool for the demonstration and assessment of additionality

Tool to calculate project emissions from electricity consumption

Tool to calculate the emission factor for an electricity system

B.3. Description of the sources and gases included in the project boundary

The project boundary is the physical, geographical site of the landfill where the gas is captured and destroyed/used.

In this project, the following sources and gases are included in the project boundary:

	Source	Gas	Included	Justification/Explanation
Baseline	Emissions from decomposition of waste at the landfill site	**CH_4**	**Yes**	**Main source of GHG on the landfill**
		CO_2	No	Not accounted
	Emissions from electricity consumption	CH_4	No	Excluded for simplification. This is conservative
		CO_2	**Yes**	**Electricity may be consumed or generated offsite in the baseline scenario**
	Emissions from thermal energy generation	CH_4	No	Excluded for simplification. This is conservative
		CO_2	No	No thermal energy generation happens in the project activity
Project	On site fossil fuel consumption due to the	CH_4	No	Excluded for simplification. Assumed to be very small

	project activity, other than electricity generation	CO_2	No	No fossil fuel consumption other than for electricity
	Emissions from on-site electricity use	CH_4	No	Excluded for simplification. Assumed to be very small
		CO_2	**Yes**	**This project uses grid electricity**

- We estimate that most of LFG generated at the site will be captured (see Recovery Rate below), which means that the remaining LFG will be released as fugitive emissions.
- CO_2 from the combustion of landfill gas in the flare and electricity generator: when combusted, methane is converted into CO_2. As the methane is organic in nature these emissions are not counted as project emissions. The CO_2 released during the combustion process was originally fixed via biomass so that the life cycle CO_2 emissions of LFG are zero.
- Electricity required for the operation of the project activity will be accounted for in the project emissions and will be monitored.

B.4. Description of how the baseline scenario is identified and description of the identified baseline scenario:

The baseline scenario has been identified through the *Tool for the demonstration and assessment of additionality* as the atmospheric release of the landfill gas and the existing and/or new grid-connected power plants.

STEP 1: Identification of alternative scenario

Sub-step 1a): Define alternatives to the project activity

Alternatives for the disposal/treatment of the waste in the absence of the project activity, i.e. the relevant scenario for estimating baseline methane emissions, to be analysed include:

<u>LFG1: Capture of landfill gas and its flaring undertaken without being registered as a CDM project activity.</u>
This scenario involves significant investment and additional costs of landfill operations with no associated revenues.

<u>LFG2: Atmospheric release of the landfill gas or partial capture of landfill gas and destruction to comply with regulations or contractual requirements, or to address safety and odour concerns.</u>
This scenario corresponds to the continuation of the current situation. Since there is currently no controlled capture and destruction of methane at the landfill, and no regulation will require such capture and destruction in the foreseeable future, the release of the landfill gas directly into the atmosphere would continue.

The project activity also includes the use of LFG for generation of electricity for export to a grid and/or to a nearby industry or used on-site, realistic and credible alternatives should also be separately determined for power generation in the absence of the project activity, and include:

<u>P1</u>. Power generated from landfill gas undertaken without being registered as CDM project activity
<u>P2</u>. Existing or construction of a new on-site or off-site fossil fuel fired cogeneration plant
<u>P3</u>. Existing or construction of a new on-site or off-site renewable based cogeneration plant

P4. Existing or construction of a new on-site or off-site fossil fuel fired captive power plant
P5. Existing or construction of a new on-site or off-site renewable based captive power plant
P6. Existing and/or new grid-connected power plants

As the project activity does not aim at producing heat for nearby industries or on-site use, existing or construction of a cogeneration plant is not part of the baseline scenario. Hence alternatives P2 and P3 are not taken into consideration in the present demonstration of additionality.

Sub-step 1b): Consistency with mandatory laws and regulations

Currently, in Thailand, there are no national or sector policies[1] or regulations governing the release of LFG into the atmosphere. Hence alternative LFG2 is in compliance with national laws and regulations.

In Thailand, national laws regulating electricity generation do not interfere with the construction of power plants, either producing electricity for internal use or providing power to the grid, hence alternatives P1, P4, P5 and P6 are in compliance with mandatory laws and regulations.

STEP 2: Identify the fuel for the baseline choice of energy source taking into account the national and/or sectoral policies as applicable.

As renewable resources and fossil fuel are not available in abundance on the site of the project activity, alternatives P4 and P5 will not be taken into consideration furthermore in the baseline scenario identification.

Outcome of step 2: alternatives LFG1, LFG2, P1 and P6 are feasible baseline scenarios of the project activity. We will now demonstrate that LFG1 and P1 are not economically attractive enough to be realistic.

STEP 3: Investment analysis (i.e. step 2 of *Tool for the demonstration and assessment of additionality*)

Sub-step 3a. Determine appropriate analysis method

As the proposed project activity may generate financial or economic benefits other than CDM related income through the sale of electricity, we apply the investment comparison analysis (Option II).

Sub-step 3b. Option II. Apply investment comparison analysis

Since alternative LFG1 involves additional costs with no associated revenues, it is not a realistic scenario and we can discard this option as a possible baseline scenario.

The revenues from generating electricity without CDM registration (P1) are insufficient to cover the costs for installation of the landfill gas collection system, gas treatment and electricity generation system.

We determine the economic feasibility of a LFG-based power generation in the absence of the CDM. Our analysis is based on the assumptions stated in sub-step 3c.

Sub-step 3c. Calculation and comparison of financial indicators

Main assumptions of the P1 scenario: electricity generation in the absence of CDM registration

[1] Legal report from Thai lawyer Dej-Udom & Associates Ltd.

1. Investment costs

1.1. The investments required to capture LFG remain basically the same as for the proposed project investments. These include the construction of the capture network, landfill cover, blowers, etc. to collect the LFG and feed it to the generators.
To be conservative, we excluded the investment required for a flare: we assume that when the power plant is not operating, the collected LFG would be vented, since there would be no reason to destroy the methane in the absence of the CDM. This improves the economic feasibility of this alternative scenario.

1.2. Two 1000 kW LFG generators would be purchased.

1.3. The site would also require a gas treatment unit, to clean the LFG before it is fed into the generators, and a connection to the grid, to deliver the electricity generated, as well as engineering and installation costs.

1.4. The total investment would be 3,094,000 € (based on a 2 MW power generation). This equipment would be operational from July 2009, after a verification period regarding the gas characteristics (quantity and quality), for a period of 15 years (maximum expected life time for such LFG generation units).

Table 1. Investment costs associated with electricity generation

CAPEX KPS - THAILAND, ELECTRICITY GENERATION

Gas collecting system

Landfill area (ha)	20
Average depth (m)	26
Wells per ha (unit)	5
Price of wells (€/m) Std cost	245 €
Total wells cost	509,600 €
Red Flag: calculated average depth	
Main collector (€ / ha)	12,500 €
Total collector cost	250,000 €
Contingency	308,996 €
Total cost gas collecting system	**759,600 €**

Landfill cover

Thickness (m)	0.00
% covered	0%
Volume (m3)	0
Average price of soil (€/m3)	5.0 €
Total cost landfill cover	**0 €**

Energy plant

Dryer	150,000 €
Active coal	120,000 €
Electric set	400,000 €
Supervision system	30,000 €
Adaptation to local grid	120,000 €
Engineering study and cooordination	100,000 €

Generators

Type	Units	Generator cost per kWe	Generator cost	Transportation cost per unit
500 kW	0	600 €	0 €	18,000 €
1000 kW	2	600 €	1,200,000 €	28,000 €

Total generators		**1,200,000 €**
Duties (% of engines cost)	9%	**108,000 €**
Transport		**56,000 €**
Civil works - platform (200 euro/m2)		**40,000 €**
Total cost energy plant		**2,324,000 €**

Other costs

Exceptional items	*enter details*	0 €
Training		10,000 €
Total other costs		**10,000 €**

Total CAPEX	**3,093,600 €**

2. Operation and maintenance costs

Maintenance costs of generators are estimated at 0.019 € per kWh (depending on the gas quality), which represents on average 240,000 € per year over the period. Small, internal combustion engines have high operation and maintenance costs. Equipment will be imported from Europe.

Other O&M costs for the rest of the energy plant equipment would be approximately 190,000 € per year.

Table 2. Operation and maintenance costs associated with electricity generation

OPEX		
Direct manpower		25,200 €
Maintenance gas collecting system (7% cost)		53,172 €
Maintenance energy plant (7% cost w/o generators)		64,400 €
Insurance		10,000 €
Filtration consumables	20 EUR/kW	40,000 €
Exceptional items	*enter details*	0 €
Total fixed OPEX		**192,772 €**
Maintenance generators	0.019 EUR/kWh	239,617 €
Total variable OPEX		**239,617 €**
Total OPEX		**432,389 €**
Average OPEX per kWh produced		**0.034 €**

3. Electricity sale

In Thailand, Very Small Power Producers (VSPP) regulations are determined by the Thai Energy Policy Committee (EPC) under the National Energy Policy Council (NEPC). In December 2006, VSPP regulations have been upgraded: "If a net surplus of electricity is generated, the VSPP regulations stipulated that Thai utilities must purchase this electricity at the same tariff that they purchase electricity from the state-owned generation company, EGAT. In autumn 2006 this rate (including FT charge) worked out to be about 3.8 baht per kWh during for on-peak hours (weekdays 9 am to 10 pm) and about 2.0 baht/kWh for off-peak hours (weekends, holidays and nighttime)[2]."

Hence, the average peak and off-peak hours electricity sale price is 2.7 THB per kWh, which corresponds to 0.054 € per kWh at prevailing exchange rate[3].

4. Benchmark

Discount rate: 12%. Note that banks prime lending in Thailand offered a 6.5% interest rate in 2006[4]. For a small or medium-sized company borrowing a relatively small amount of money, the applicable interest rate is likely to be about 5% higher. Considering the risks of this new technology as well as the risks in effective biodegradation of waste and effective methane capture, another 2% may be added. Thus an appropriate benchmark rate for this type of investment would be 13.5%. The chosen benchmark discount rate of 12% is therefore conservative.

5. Calculation

For the assumptions stated above, the IRR for LFG capture and electricity generation is -1.0%, in the absence of the CDM.

Even if electricity sale prices were 20% higher, the IRR would be 9.9%, far below discount rate. Similarly, if investment requirements or O&M costs were 20% lower, the IRR would be 4.3% or 5.9%.

Table 3. Sensitivity analysis for electricity generation without CDM registration

Parameter	Variation	Electricity price	Investment Cost	Operating Costs
IRR	-20%	-15.8%	4.3%	5.9%

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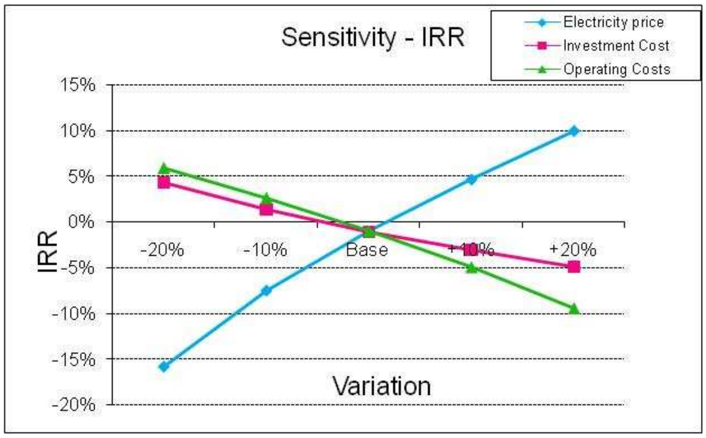
[2] http://www.netmeter.org/en/regs

[3] Exchange rate (2008 average): 50 THB = 1 EUR

[4] http://unstats.un.org/unsd/cdb/cdb_years_on_top.asp?srID=6000&Ct1ID=&crID=764&yrID=2006

	-10%	-7.5%	1.4%	2.6%
	Base	-1.0%	-1.0%	-1.0%
	+10%	4.6%	-3.1%	-5.0%
	+20%	9.9%	-4.9%	-9.5%



Overall, this alternative is not realistic for financial/economic reasons.

STEP 4: Conclusion

Based on this analysis, LFG2 (atmospheric release of the landfill gas) and P6 (existing and/or new grid-connected power plants) are the only remaining credible and plausible scenarios, and have been identified as the baseline scenario.

B.5. 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 (assessment and demonstration of additionality):

Additionality determination is done by using the CDM *Tool for the demonstration and assessment of additionality* version 04. For implementation of steps 1 and 2, please see section B.4.
We do not apply step 3 (barrier analysis), since step 2 (investment analysis) shows a clear conclusion.
We can now proceed to Step 4 (common practice analysis).

Step 4. Common practice analysis

Sub-step 4a. Analyze other activities similar to the proposed project activity:

The current Thai national legislation does not require landfills to collect and destroy the gas generated. So far, only a few landfills in the country have incorporated technical devices to collect and partially flare the gas generated[5]. Only 6% of the Thai disposal sites in Provincial capital are sanitary landfills. These few landfills are compliant with environmental practices including gas ventilation for safety

[5] Thailand Environmental Monitor 2003
http://www.worldbank.or.th/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/THAILANDEXTN/0,,contentMDK:20206649~menuPK:333323~pagePK:141137~piPK:217854~theSitePK:333296,00.html

reasons, to avoid explosions and fires. Still, gas ventilation is passive and the volumes effectively collected and destroyed are insignificant.
The World Bank environment report on Thailand highlights the fact that common practices on disposal sites in Thailand lack environmental controls.
Currently, only one similar project has been implemented, in the belief of the coming CDM registration which has just occurred, the CDM project no. 1413, registered in March 2008 (source: publicly available information displayed on the UNFCCC website):

Registered	Title	Host Parties	Other Parties	Methodology	Reductions	Ref
14 Mar 08	Jaroensompong Corporation Rachathewa Landfill Gas to Energy Project	Thailand	Japan	ACM0001 ver. 5	47185	1413

This shows that without carbon revenue, development of these projects would not take place, and they are therefore not relevant to the common practice analysis.

Sub-step 4b. Discuss any similar options that are occurring:

Where other similar projects are planned, these are all to be developed under the CDM. This does not call into question the claim that the proposed Project activity is financially unattractive without the CDM.

Outcome of step 4a and 4b*:*

Activities similar to the proposed Project activity can be observed only on a very minor scale, for different purpose (avoiding explosions and fires) using low level technology with insignificant results in terms of GHG emission reductions. These are essential differences with the proposed project activity.

The proposed project activity is therefore additional.

B.6. Emission reductions

B.6.1. Explanation of methodological choices:

As specified in section B.2, ACM0001 Version 8 is used, including the following methodological tools:
Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site
Tool to determine project emissions from flaring gases containing methane
Tool to calculate project emissions from electricity consumption
Tool to calculate the emission factor for an electricity system

I. Formula used for calculation of Emissions Reduction

As specified by the methodology the emission reduction shall be calculated as follows:

$$\textbf{(0) } ER_y = BE_y - PE_y$$

Where:

ER_y	Emission reduction in a given year y, in tonnes of CO_2 equivalent (tCO_2e)
BE_y	Baseline emissions in a given year y, in tonnes of CO_2 equivalent (tCO_2e)
ER_y	Project emissions in a given year y, in tonnes of CO_2 equivalent (tCO_2e)

II. Formula used for calculation of Baseline Emissions

$$\textbf{(1) } BE_y = (MD_{project,y} - MD_{BL\ y}) * GW_{CH4} + EL_{LFG,y} * CEF_{elec,BL,y} + ET_{LFG,y} * CEF_{ther,BL,y}$$

Where:

BE_y	Baseline emissions in year y (tCO_2e)
$MD_{project,y}$	Amount of methane that would have been destroyed/combusted during the year, in tons of methane (tCH_4) in project scenario
$MD_{BL,y}$	Amount of methane that would have been destroyed/combusted during the year in the absence of the project due to regulatory and/or contractual requirement, in tons of methane (tCH_4)
GWP_{CH4}	Global Warming Potential value for methane for the first commitment period is $21tCO_2e/tCH_4$
$EL_{LFG,y}$	Net quantity of electricity produced using LFG, which in the absence of the project activity would have been produced by power plants connected to the grid or by an onsite/ off-site fossil fuel based captive power generation, during year y, in megawatt hours (MWh).
$CEF_{elecy,BL,y}$	CO_2 emissions intensity of the baseline source of electricity displaced, in tCO2e/MWh.
$ET_{LFG,y}$	Quantity of thermal energy produced utilizing the landfill gas, which in the absence of the project activity would have been produced from onsite/offsite fossil fuel fired boiler, during the year y in TJ.
$CEF_{ther,BL,y}$	CO_2 emissions intensity of the fuel used by boiler to generate thermal energy which is displaced by LFG based thermal energy generation, in tCO_2e/TJ.

The formula specified in ACM 0001 will be used, with the following specific applications:

In this project there will be no thermal energy utilization from LFG: $\mathbf{ET_{LFG,y} = 0}$

As a result, baseline calculation can be simplified as:

$$\textbf{(1b) } BE_y = (MD_{project,y} - MD_{BL\ y}) * GW_{CH4} + EL_{LFG,y} * CEF_{elec,BL,y}$$

III. Formula used for calculation of Adjustment Factor

On this landfill, there are no regulatory or contractual requirements specifying $MD_{BL,y}$, the amount of methane that would have been destroyed/combusted during the year in the absence of the project, therefore an "Adjustment Factor"(AF) will be used, taking into account the project context, as required by the methodology.

Hence: $$\textit{(2) } MD_{BL,y} = MD_{project,y} * AF$$

Where:

AF is the adjustment factor (in %)

As there are no regulatory requirements to capture and flare landfill gas, and that there is no existing LFG collection system at the landfill, an AF of 0 can be applied.

IV. Formula used for Ex-Ante calculation of $MD_{project}$

The ex-ante estimation of the amount of methane that would have been destroyed/combusted during the year, in tonnes of methane ($MD_{project,y}$) is done with the latest version of the approved *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site*, considering the following additional equation

$$(3a)\ MD_{project,y} = BE_{CH4,SWDS,y} / GWP_{CH4}$$

Where:
$BE_{CH4,SWDS,y}$ is the methane generation from the landfill in the absence of the project activity at year y (tCO2e), calculated as per the *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site* (see Annex 3).
The waste composition is obtained from the IPCC standards for the region.

V. Formula used for Ex-Post calculation of $MD_{project}$

According to the methodology, $MD_{project,y}$ will be determined *ex post* by metering the actual quantity of methane captured and destroyed once the project activity is operational.
The methane destroyed by the project activity ($MD_{project,y}$) during a year is determined by monitoring the quantity of methane actually flared and gas used to generate electricity and/or produce thermal energy and/or sent to a pipeline for distribution, and the total quantity of methane captured
On the project activity, all the methane captured will be initially destroyed by flaring and may be destroyed for electricity generation at a second stage. There is no methane destroyed for thermal energy generation, and no methane is sent to a pipeline for distribution:

$$(3b)\ MD_{project\,y} = MD_{flare,y} + MD_{electricity,y}$$

Where:
$MD_{flare,y}$ is the quantity of methane destroyed by flaring in year y (tCH_4)
$MD_{electricity,y}$ is the quantity of methane destroyed by generation of electricity (tCH_4)

$$\textbf{(4)}\ MD_{flare,y} = (LFG_{flare,y} * w_{CH4,y} * D_{CH4}) - \left(\frac{PE_{flare,y}}{GWP_{CH4}}\right)$$

Where:

$LFG_{flare,y}$	Quantity of landfill gas flared during the year measured in cubic meters (m^3)
$W_{CH4,y}$	Average methane fraction of the landfill gas
D_{CH4}	Methane density expressed in t_{CH4}/m^3_{CH4}

$PE_{flare,y}$	Emissions from flaring of the residual gas stream in year y
GWP_{CH4}	Global Warming potential of CH_4

$$(5)\ \mathbf{MD}_{electricity,y} = \mathbf{LFG}_{\mathbf{electricity,y}} * \mathbf{w}_{\mathbf{CH4,y}} * \mathbf{D}_{\mathbf{CH4}}$$

Where:
$\mathbf{LFG}_{\mathbf{electricity,y}}$ is the quantity of landfill gas fed into electricity generator (m^3)

VI. Formula used for calculation of the emissions from the flare

$PE_{flare,y}$ is calculated according to “the tool to determine project emissions from flaring gases containing methane”, according to the following steps:
STEP 1: Determination of the mass flow rate of the residual gas that is flared
STEP 2: Determination of the mass fraction of carbon, hydrogen, oxygen and nitrogen in the residual gas
STEP 3: Determination of the volumetric flow rate of the exhaust gas on a dry basis
STEP 4: Determination of methane mass flow rate of the exhaust gas on a dry basis
STEP 5: Determination of methane mass flow rate of the residual gas on a dry basis
STEP 6: Determination of the hourly flare efficiency
STEP 7: Calculation of annual project emissions from flaring based on measured hourly values or based on default flare efficiency.

The calculation procedure in this tool determines the flow rate of methane before and after the destruction in the flare, taking into account the amount of air supplied to the combustion reaction and the exhaust gas composition (oxygen and methane). The flare efficiency is calculated for each hour of a year based either on measurements or default values plus operational parameters. Project emissions are determined by multiplying the methane flow rate in the residual gas with the flare efficiency for each hour of the year.

We will used the simplified approach, measuring only the volumetric fraction of methane in the residual gas and considering the difference to 100% as being nitrogen (N_2).

The following data are continuously monitored to use this calculation methodology:

$fv_{CH4,RG,h}$	-	Volumetric fraction of methane in the residual gas in the hour *h*
$FV_{RG,h}$	m^3/h	Volumetric flow rate of the residual gas in dry basis at normal conditions (NTP) in the hour *h*
$t_{O2,h}$	-	Volumetric fraction of O2 in the exhaust gas of the flare in the hour *h*
$fv_{CH4,FG,h}$	mg/m^3	Concentration of methane in the exhaust gas of the flare in dry basis at normal conditions in the hour *h*
T_{flare}	°C	Temperature in the exhaust gas of the enclosed flare

The detail of the calculation steps is as follows:

<u>STEP 1: Determination of the mass flow rate of the residual gas that is flared</u>

$$FM_{RG,h} = \rho_{RG,n,h} * FV_{RG,h}$$

Where:

Variable	**SI Unit**	**Description**
$FM_{RG,h}$	kg/h	Mass flow rate of the residual gas in hour *h*
$\rho_{RG,n,h}$	kg/m^3	Density of the residual gas at normal conditions in hour *h*
$FV_{RG,h}$	m^3/h	Volumetric flow rate of the residual gas in dry basis at normal conditions in the hour *h*

and:

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

Where:

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

and:

$$MM_{RG,h} = \sum \left(fv_{i,RG,h} * MM_i \right)$$

Where:

Variable	SI Unit	Description
$MM_{RG,h}$	kg/kmol	Molecular mass of the residual gas in hour *h*
$fv_{i,RG,h}$	-	Volumetric fraction of component *i* in the residual gas in the hour *h*
MM_i	kg/kmol	Molecular mass of residual gas component *i*
i	The components CH_4, N_2	

and:

$$fv_{N2,RG,h} = 1 - fv_{CH4,RG,h}$$

STEP 2: Determination of the mass fraction of carbon, hydrogen and nitrogen in the residual gas

$$\text{fm}_{\text{j,h}} = \frac{\sum_i fv_{i,RG,h} * AM_j * NA_{j,i}}{MM_{RG,h}}$$

Where:

Variable	SI Unit	Description
$fm_{j,h}$	-	Mass fraction of element *j* in the residual gas in hour *h*
$fv_{i,RG,h}$	-	Volumetric fraction of component *i* in the residual gas in the hour *h*
AM_j	kg/kmol	Atomic mass of element *j*
$NA_{j,i}$	-	Number of atoms of element *j* in component *i*
$MM_{RG,h}$	kg/kmol	Molecular mass of the residual gas in hour *h*
j	The elements carbon, hydrogen and nitrogen	
i	The components CH_4, N_2	

<u>STEP 3: Determination of the volumetric flow rate of the exhaust gas on a dry basis</u>

$$TV_{n,FG,h} = V_{n,FG,h} * FM_{RG,h}$$

Where:

Variable	SI Unit	Description
$TV_{n,FG,h}$	m^3/h	Volumetric flow rate of the exhaust gas in dry basis at normal conditions in hour *h*
$V_{n,FG,h}$	m^3/kg residual gas	Volume of the exhaust gas of the flare in dry basis at normal conditions per kg of residual gas in hour *h*
$FM_{RG,h}$	kg residual gas/h	Mass flow rate of the residual gas in the hour *h*

$$V_{n,FG,h} = V_{n,CO_2,h} + V_{n,O_2,h} + V_{n,N_2,h}$$

Where:

Variable	SI Unit	Description
$V_{n,FG,h}$	m^3/kg residual gas	Volume of the exhaust gas of the flare in dry basis at normal conditions per kg of residual gas in the hour *h*
$V_{n,CO2,h}$	m^3/kg residual gas	Quantity of CO_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
$V_{n,N2,h}$	m^3/kg residual gas	Quantity of N_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
$V_{n,O2,h}$	m^3/kg residual gas	Quantity of O_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour h

$$V_{nCO2,h} = \frac{fm_{C,h}}{AM_c} * MV_n$$

Where:

Variable	SI Unit	Description
$V_{n,CO2,h}$	m^3/kg residual gas	Quantity of CO_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
$fm_{C,h}$	-	Mass fraction of carbon in the residual gas in the hour *h*
AM_C	kg/kmol	Atomic mass of carbon
MV_n	m^3/kmol	Volume of one mole of any ideal gas at normal temperature and pressure (22.4 m^3/Kmol)

$$V_{n,0_2,h} = n_{0_2,h} * MV_n$$

Where:

Variable	SI Unit	Description
$V_{n,O2,h}$	m^3/kg residual gas	Quantity of O_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
$n_{O2,h}$	kmol/kg residual gas	Quantity of moles of O_2 in the exhaust gas of the flare per kg of residual gas flared in hour *h*
MV_n	m^3/kmol	Volume of one mole of any ideal gas at normal temperature and pressure (22.4 L/mol)

$$V_{n,N2,h} = MV_n * \left\{ \frac{fm_{N,h}}{200 AM_N} + \left(\frac{1 - MF_{O_2}}{MF_{O_2}} \right) * \left[F_h + n_{O_2,h} \right] \right\}$$

Where:

Variable	SI Unit	Description
$V_{n,N2,h}$	m^3/kg residual gas	Quantity of N_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
MV_n	m^3/kmol	Volume of one mole of any ideal gas at normal temperature and pressure (22.4 m^3/Kmol)
$fm_{N,h}$	-	Mass fraction of nitrogen in the residual gas in the hour *h*
AM_n	kg/kmol	Atomic mass of nitrogen
MF_{O2}	-	O_2 volumetric fraction of air
Fh	kmol/kg residual gas	Stoichiometric quantity of moles of O_2 required for a complete oxidation of one kg residual gas in hour *h*
$n_{O2,h}$	kmol/kg residual gas	Quantity of moles O_2 in the exhaust gas of the flare per kg residual gas flared in hour *h*

$$n_{0_2,h} = \frac{t_{O_2,h}}{\left(1 - (t_{O_2,h} / MF_{O_2})\right)} * \left[\frac{fm_{C,h}}{AM_C} + \frac{fm_{N,h}}{2 AM_N} + \left(\frac{1 - MF_{O_2}}{MF_{O_2}} \right) * F_h \right]$$

Where:

Variable	SI Unit	Description

$n_{O2,h}$	kmol/kg residual gas	Quantity of moles of O_2 in the exhaust gas of the flare per kg of residual gas flared in hour *h*
$t_{O2,h}$	-	Volumetric fraction of O_2 in the exhaust gas in the hour *h*
MF_{O2}	-	Volumetric fraction of O_2 in the air (0.21)
Fh	kmol/kg residual gas	Stochiometric quantity of moles of O_2 required for a complete oxidation of one kg of residual gas in hour *h*
$fm_{j,h}$	-	Mass fraction of element *j* in the residual gas in hour *h*
AM_j	kg/kmol	Atomic mass of element *j*
j		The elements carbon (index C) and nitrogen (index N)

$$F_h = \frac{fm_{C,h}}{AM_C} + \frac{fm_{H,h}}{4AM_H}$$

Where:

Variable	**SI Unit**	**Description**
F_h	kmol O_2/kg residual gas	Stoichiometric quantity of moles of O_2 required for a complete oxidation of one kg residual gas in hour *h*
$fm_{j,h}$	-	Mass fraction of element *j* in the residual gas in hour *h*
AM_j	kg/kmol	Atomic mass of element *j*
j		The elements carbon (index C) and hydrogen (index H)

STEP 4: Determination of methane mass flow rate of the exhaust gas on a dry basis

$$TM_{FG,h} = \frac{TV_{n,FG,h} * fv_{CH_4,FG,h}}{1000000}$$

Where:

$TM_{FG,h}$	kg/h	Mass flow rate of methane in the exhaust gas of the flare in dry basis at normal conditions in the hour *h*
$TV_{n,FG,h}$	m^3/h exhaust gas	Volumetric flow rate of the exhaust gas in dry basis at normal conditions in hour *h*
$fv_{CH4,FG,h}$	mg/m^3	Concentration of methane in the exhaust gas of the flare in dry basis at normal conditions in the hour *h*

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

$$TM_{RG,h} = FV_{RG,h} * fv_{CH_4,RG,h} * \rho_{CH_4,n}$$

Where:

$TM_{RG,h}$	kg/h	Mass flow rate of methane in the residual gas in the hour *h*
$FV_{RG,h}$	m^3/h	Volumetric flow rate of the residual gas in dry basis at normal conditions in the hour *h*

$fv_{CH4,RG,h}$	-	Volumetric fraction of methane in the residual gas on dry basis in hour *h* (NB: this corresponds to $fv_{i,RG,h}$ where *i* refers to methane).
$\rho_{CH4,n}$	kg/m^3	Density of methane at normal conditions (0.716)

STEP 6: Determination of the hourly flare efficiency

$\eta_{flare,h}$ is the hourly efficiency of the flare. Since the project activity will use an enclosed flare and continuous monitoring the flare efficiency will be monitored as follows:

- 0% if the temperature of the exhaust gas of the flare (T_{flare}) is below 500 °C during more than 20 minutes during the hour *h*.
- determined as follows in cases where the temperature of the exhaust gas of the flare (T_{flare}) is above 500 °C for more than 40 minutes during the hour *h* :

$$\eta_{flare,h} = 1 - \frac{TM_{FG,h}}{TM_{RG,h}}$$

Where:

Variable	SI Unit	Description
$\eta_{flare,h}$	-	Flare efficiency in the hour *h*
$TM_{FG,h}$	kg/h	Methane mass flow rate in exhaust gas averaged in the hour *h*
$TM_{RG,h}$	kg/h	Mass flow rate of methane in the residual gas in the hour *h*

In case of the continuous system is unavailable for maintenance, or failure, the following methods will be used:

- 0% if the temperature in the exhaust gas of the flare (T_{flare}) is below 500 °C for more than 20 minutes during the hour *h* .
- 50%, if the temperature in the exhaust gas of the flare (T_{flare}) is above 500 °C for more than 40 minutes during the hour *h*, but the manufacturer's specifications on proper operation of the flare are not met at any point in time during the hour *h*.
- 90%, if the temperature in the exhaust gas of the flare (T_{flare}) is above 500 °C for more than 40 minutes during the hour *h* and the manufacturer's specifications on proper operation of the flare are met continuously during the hour *h*.

STEP 7: Calculation of annual project emissions from flaring based on measured hourly values or based on default flare efficiency.

$$PE_{flare,y} = \sum TM_{RG,h} * (1 - \eta_{flare,h}) * \frac{GWP_{CH4}}{1000}$$

Where:

$PE_{flare,y}$	t_{CO2e}	Project emissions from flaring of the residual gas stream in year y
$TM_{RG,h}$	Kg/h	Mass flow rate of methane in the residual gas in the hour h
GWP_{CH4}	t_{CO2e}/t_{CH4}	Global Warming Potential

The following fixed constants will be used for the calculation

Parameter	SI Unit	Description	Value
MM_{ch4}	kg/kmol	Molecular mass of methane	16.04
MM_{CO}	kg/kmol	Molecular mass of carbon monoxide	28.01
MM_{co2}	kg/kmol	Molecular mass of carbon dioxide	44.01
MM_{O2}	kg/kmol	Molecular mass of oxygen	32.00
MM_{H2}	kg/kmol	Molecular mass of hydrogen	2.02
MM_{N2}	kg/kmol	Molecular mass of nitrogen	28.02
AM_c	kg/kmol (g/mol)	Atomic mass of carbon	12.00
AM_h	kg/kmol (g/mol)	Atomic mass of hydrogen	1.01
AM_o	kg/kmol (g/mol)	Atomic mass of oxygen	16.00
AM_n	kg/kmol (g/mol)	Atomic mass of nitrogen	14.01
Pn	Pa	Atmospheric pressure at normal conditions	101,325
R_u	Pa.m3/kmol.K	Universal ideal gas constant	8,314.472
T_n	K	Temperature at normal conditions	273.15
GWP_{CH4}	tCO2/tCH4	Global warming potential of methane	21
$D_{CH4,n,h}$	t/m3	Density of methane gas at normal conditions	0.0007168
$NA_{i,j}$	Dimensionless	Number of atoms of element j in component i, depending on molecular structure	

VII. Formula used for calculation of the emissions from project electricity consumption

$$\textit{(6)}\ \mathbf{PE_{y} = PE_{EC,y} + PE_{FC,y}}$$

Where :

PE_y project emissions by the project activity during the year *y* (tCO_2 / yr)

$PE_{EC,y}$ project emissions from electricity consumption by the project activity during the year *y* (tCO_2 / yr)

$PE_{FC,y}$ project emissions from heat consumption by the project activity during the year *y* (tCO_2 / yr)

On the project activity, there is no heat consumption: $PE_{FC,y} = 0$

We use the *Tool to calculate project emissions from electricity consumption* to calculate $PE_{EC,y}$

The project will use electricity from the grid, as a result, we will use Case A of the *Tool to calculate project emissions from electricity consumption.* However, at the time of writing the PDD, it is not clear whether the project may use a diesel generator as a back-up. In this case we would use option B2 of the same tool.
Using option A of the tool, project emissions are calculated based on the power consumed by the project activity and the emission factor of the grid and taking into account transmission and distribution losses, using the following formula:

$$PE_{EC,y} = EC_{PJ,y} * EF_{grid,y} * (1+ TDL)$$

Where:

$PE_{EC,y}$	project emissions from electricity consumption by the project activity during the year y (tCO_2 / yr);
$EC_{PJ,y}$	quantity of electricity consumed by the project activity during the year y (MWh);
$EF_{grid,y}$	emission factor of the grid (tCO_2/MWh), set to 0.62 tCO_2/MWh using the *Tool to calculate the emission factor for an electric system* (see Annex 3);
TDL_y	average technical transmission and distribution losses in the grid in year y for the voltage level at which electricity is obtained from the grid at the project site. We use the default value of 20%, as specified in the “tool to calculate project emissions from electricity consumption”

The equation (6) above can be simplified as:

$$\textit{(6b)}\ PE_{y} = EC_{PJ,y} * 0.62 * (1+20\%)$$

VIII. Formula used for determination of $CEF_{elec,BL,y}$

Captured landfill gas will be initially flared, and may be used for electricity generation at a later stage, as long as it is economically viable. In the perspective of producing electricity, we will calculate the carbon emission factor $\mathbf{CEF_{grid,y}}$ for the grid electricity displaced by the project. The carbon emission factor for the displacement of electricity generated by power plants connected to the grid $\mathbf{CEF_{elec,BL,y}}$ (baseline source) will be determined according to the *Tool to calculate the emission factor for an electricity system*. Calculations are presented in Annex 3.

B.6.2. Data and parameters that are available at validation:

Data / Parameter:	**Regulatory requirements relating to landfill gas projects**
Data unit:	Text
Description:	Regulatory requirements relating to landfill gas projects
Source of data:	Laws and Regulations
Value applied:	N/A
Justification of the choice of data or description of measurement methods and procedures actually applied :	- We will follow-up the evolution of the national and local environmental laws & regulations through a review with our lawyers every 6 months. - All the data will be recorded yearly, on an electronic database.
Any comment:	

Data / Parameter:	$\mathbf{GWP_{CH4}}$

Data unit:	tCO_2e/tCH_4
Description:	Global Warming Potential of CH_4
Source of data:	Defined by the IPCC methodology
Value applied:	21
Justification of the choice of data or description of measurement methods and procedures actually applied :	21 for the first commitment period. Shall be updated according to future COP/MOP decisions.
Any comment:	

Data / Parameter:	**D_{CH4}**
Data unit:	t_{CH4}/m^3_{CH4}
Description:	Methane density
Source of data:	Defined by the methodology
Value applied:	0.0007168
Justification of the choice of data or description of measurement methods and procedures actually applied :	0.0007168 $t_{CH4}/m3_{CH4}$ at standard temperature and pressure (0ºC and 1,013 bar)
Any comment:	

Data / Parameter:	**$BE_{CH4,SWDS,y}$**
Data unit:	tCO2e
Description:	Methane generation from the landfill in the absence of project activity, in year y
Source of data:	Calculated as per *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site*
Value applied:	See calculation spreadsheets
Justification of the choice of data or description of measurement methods and procedures actually applied :	As per *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal sit*e
Any comment:	Used for ex-ante estimation of the amount of methane that would have been destroyed/combusted during year y.

Data / Parameter:	**AF**
Data unit:	%
Description:	Adjustment factor
Source of data:	
Value applied:	0
Justification of the choice of data or description of measurement methods and procedures actually applied :	There are no enforced regulatory or contractual requirements for LFG collection/utilization in Thailand. There is no existing LFG collection system at the landfill.
Any comment:	See annex 3

Data / Parameter:	**TDL_y**
Data unit:	-

Description:	Average technical transmission and distribution losses in the grid
Source of data used:	Default values
Value applied:	20%
Justification of the choice of data or description of measurement methods and procedures actually applied :	The value is a conservative default value specified by the "tool to calculate project emissions from electricity consumption"
Any comment:	Applicable for Case C2 of the tool above

Data / Parameter:	$\mathbf{CEF_{elec,BL}}$
Data unit:	tCO_2e/MWh
Description:	CO_2 emission factor of the Thai grid
Source of data used:	DEDE (Department of Alternative Energy Development and Efficiency), Ministry of Energy of Thailand
Value applied:	0.62 (combined margin)
Justification of the choice of data or description of measurement methods and procedures actually applied :	Calculated as specified by the *Tool to calculate the emissions factor for an electric system*, using official relevant data.
Any comment:	See details in Annex 3

B.6.3 Ex-ante calculation of emission reductions:

According to ACM0001 v08 "No leakage effects need to be accounted for this methodology"

A. Baseline Emissions

According to ACM 0001 v08, the ex-ante estimation of the amount of methane that would have been destroyed/combusted during the year, in tonnes of methane ($MD_{project,y}$) will be done with the latest version of the approved *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site*, considering the following additional equation:

$$\mathbf{MD_{project,y} = BE_{CH4,SWDS,y}/GWP_{CH4}}$$

Where:
$BE_{CH4,SWDS,y}$ is the methane generation from the landfill in the absence of the project activity at year y (tCO_2e), calculated as per the *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site.*

$$\mathbf{BE_{CH4,SWDS,y} = \varphi\ (1-f) * GWP_{CH4} * (1-OX) * 16/12 * F * DOC_f * MCF * \Sigma\Sigma\ w_{j,x} * DOC_j * e^{-kj(y-x)} * (1-e^{-kj})}$$

Where:
φ = Model correction factor to account for model uncertainties (90%)
f = Fraction of methane captured at the SWDS and flared, combusted or used in another manner
GWP_{CH4} = Global Warming Potential (GWP) of methane
OX = Oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste)

F = Fraction of methane in the SWDS gas (volume fraction) (50%)
DOC_f = Fraction of degradable organic carbon (DOC) that can decompose
MCF = Methane correction factor
$W_{j,x}$ = Amount of organic waste type j prevented from disposal in the SWDS in the year x (tons)
DOC_j = Fraction of degradable organic carbon (by weight) in the waste type j
k_j = Decay rate for the waste type j
j = Waste type category (index)
x = Year during the landfill lifetime: x runs from the first year of the landfill opening (x = 1) to the year y for which avoided emissions are calculated (x = y)
y = Year for which methane emissions are calculated

The parameters used for the calculations are presented in Annex 3.

B. Ex-Ante estimation of the amount of methane captured

$$MD_{collected,y} = BE_{CH4,SWDS,y} * Rr * 363/365$$

Where:

- $BE_{CH4,SWDS,y}$ is the methane generation from the landfill in the absence of the project activity at year y (tCO_2e), calculated as per the *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site* (the waste composition is obtained from the IPCC standards for the region).

- **Recovery rate Rr = 40%.** The expected capture efficiency is set to 40% in the absence of cover on the landfill.

- The equipment will be shut down for scheduled maintenance, as prescribed by the manufacturer, a maximum of 2 days per year or 48 hours. We will thus consider, in ex-ante calculations that the plant will be in operation 363 days upon 365, i.e. 8 712 hours per year.

C. Ex-Ante estimation of the amount of methane destroyed $MD_{project}$

$$MD_{project,y} = MD_{flared,y} + MD_{elec,y}$$

The project activity considers only flaring at a first stage, but aims at using the landfill gas for energy production at a later stage and as long as it is economically viable.
Therefore, we state that 100% of the collected LFG will be flared during the first year, and in the future 100% will be used for energy production. The flare would then be used only in case of technical incident on the energy plant. For instance, the energy plant will require a 3-days maintenance per year, the flare would then operate during these 3 days.

The flare is limited to a 90% flare efficiency (FE), given by the *Tool to determine project emissions from flaring gases containing methane.* The site will be equipped with a high performance enclosed flare. If possible, the flare efficiency will be monitored and we expect a proven FE of 99.99%. For ex-ante calculation, a 90% default value will be used.
The energy plant is not capped by any efficiency ratio.

Hence, during the first year:

$$MD_{project,y} = \mathbf{MD_{flared,y} = BE_y * Rr *363/365 * FE}$$

And for the rest of the period:

$$MD_{project,y} = \mathbf{MD_{elec,y} + MD_{flared,y} =(BE_y * Rr *360/365) + (BE_y * Rr *3/365 * FE)}$$

Year	**Estimation of methane PRODUCED** (tCO_2e)	**Estimation of $MD_{project,y}$** (tCO_2e)
	$BE_y = \varphi$ (1-f) * GWP_{CH4} * (1-OX) * 16/12 * F * DOC_f * MCF * ΣΣ $w_{j,x}$ * DOC_j * $e^{-kj(y-x)}$ * (1-e^{-kj})	$MD_{project,y}$= (BE_y * Rr) * (360/365 + 3/365 * FE)
2009	236,809	84,784
2010	210,544	83,687
2011	190,086	75,555
2012	173,690	69,038
2013	160,176	63,667
2014	148,745	59,123
2015	138,850	55,190
2016	130,116	51,718
2017	122,283	48,605
2018	115,171	45,778
2019	0	0
Total	**1,626,469**	**637,145**
Yearly Av	162,647	63,715

D. Estimation of the project emissions from electricity consumption $PE_{EC,y}$

$$PE_{EC,y} = EC_{PJ,y} * 0.62 * (1 + TDL)$$

Where :

$PE_{EC,y}$ project emissions from electricity consumption by the project activity during the year *y* (tCO_2 / yr)

$EC_{PJ,y}$ Amount of electricity imported from the grid, as a result of the project activity, in MWh, estimated as 200 MWh/year for the site

CEF_{grid} Thai carbon emission factor: 0.62 tCO_2/MWh

TDL is set to 20% (conservative default value)

Therefore, $PE_{EC,y}$ = 148 tCO_2e/yr

An excel calculation spreadsheet is given with this document explaining in detail the calculation of the ex-ante emission reductions:

E. Ex Ante estimation of the Project Emission Reductions resulting of methane reduction

Year	**Estimation of $MD_{project}$** (tCO_2e)	**Estimation of PE_{EC}** (tCO_2e)	**Estimation of leakage** (tCO_2e)	**Emission reductions from methane destruction** (tCO_2e)
	$MD_{project,y}$= (BE_y * Rr) * (360/365 + 3/365 * FE)	$PE_{EC,y} = EC_{PJ,y}$ * EF_{grid} * (1+TDL)	N/A	$MD_{project,y}$ - $MD_{BL,y}$ - $PE_{EC,y}$
2009	84,784	148		84,636
2010	83,687	148		83,539
2011	75,555	148		75,407
2012	69,038	148		68,890
2013	63,667	148		63,518
2014	59,123	148		58,975
2015	55,190	148		55,042
2016	51,718	148		51,570
2017	48,605	148		48,457
2018	45,778	148		45,630
2019	0	0		0
Total	637,145	1,483	0	635,662
Yearly Av	63,715	148	0	63,566

F. Project Emissions Reductions resulting of energy displacement

- **Grid emission factor: CEF_{grid} = 0.62 tCO_2/MWh**
  The emission factor for Thai national grid is determined in Annex 3 using the *Tool to calculate the emission factor for an electricity system.*

- Net electricity supplied by the project to the grid (**EL_{LFG}**) is calculated based on the flow of methane captured and the installed energy capacity, expected to 2 MWh:

Year	**Estimation of EF_{LFG}** (MWh)	**Emission reductions from energy displacement** (tCO_2e)
2009	0	0
2010	17,280	10,658
2011	17,280	10,658
2012	17,152	10,579
2013	15,818	9,756
2014	14,689	9,060
2015	13,712	8,457

2016	12,849	7,925
2017	12,076	7,448
2018	11,373	7,015
2019	0	0
Total	132,228	81,555
Yearly Av	13,223	8,155

B.6.4 Summary of the ex-ante estimation of emission reductions:

Ex-ante estimation of overall Project Emission Reductions

Year	Emission reductions from methane destruction (tCO_2e)	Emission reductions from energy displacement (tCO_2e)	Estimation of overall emission reductions (tCO_2e)
2009	84,636	0	84,636
2010	83,539	10,658	94,197
2011	75,407	10,658	86,065
2012	68,890	10,579	79,469
2013	63,518	9,756	73,274
2014	58,975	9,060	68,034
2015	55,042	8,457	63,499
2016	51,570	7,925	59,495
2017	48,457	7,448	55,905
2018	45,630	7,015	52,644
2019	0	0	0
Total	**635,662**	**81,555**	**717,217**
Yearly Av	63,566	8,155	71,722

B.7 Application of the monitoring methodology and description of the monitoring plan:

B.7.1 Data and parameters monitored:

Data and parameters monitored for all sites:

Data / Parameter:	**$LFG_{flare,y}$**
Data unit:	Normalised m^3
Description:	Total amount of landfill gas captured and flared
Source of data:	Flow meter
Measurement procedures (if any):	Measuring principle: turbine-based measure of the volume by electric signal from 4 to 20 mA Accuracy: from 99.5% at 50 m^3/h to 100% at 400 m^3/h and above
Monitoring frequency:	Continuously
QA/QC procedures:	The flow meter will be subject to a regular maintenance and

	testing regime to ensure its accuracy. The manufacturer technician or manufacturer accredited agent in the host country will perform an independent verification onsite, according to the manufacturer specifications. The outcome of the independent verification is a certificate of good order and accuracy of the flow meter. Maintenance: yearly
Any comment:	No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and Pressure, expressing LFG volumes in normalized cubic meters

Data / Parameter:	**$LFG_{electricty,y}$**
Data unit:	Normalised m^3
Description:	Total amount of landfill gas captured and used for electricity production (phase II of the project only)
Source of data:	Flow meter
Measurement procedures (if any):	Measuring principle: turbine-based measure of the volume by electric signal from 4 to 20 mA Accuracy: from 99.5% at 50 m^3/h to 100% at 400 m^3/h and above
Monitoring frequency:	Continuously
QA/QC procedures:	The flow meter will be subject to a regular maintenance and testing regime to ensure its accuracy. The manufacturer technician or manufacturer accredited agent in the host country will perform an independent verification onsite, according to the manufacturer specifications. The outcome of the independent verification is a certificate of good order and accuracy of the flow meter. Maintenance: yearly
Any comment:	No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and Pressure, expressing LFG volumes in normalized cubic meters

Data / Parameter:	**$LFG_{total,y}$**
Data unit:	Normalised m^3
Description:	Total amount of landfill gas captured (phase II of the project only)
Source of data:	Flow meter
Measurement procedures (if any):	Measuring principle: turbine-based measure of the volume by electric signal from 4 to 20 mA Accuracy: from 99.5% at 50 m^3/h to 100% at 400 m^3/h and above
Monitoring frequency:	Continuously
QA/QC procedures:	The flow meter will be subject to a regular maintenance and testing regime to ensure its accuracy. The manufacturer technician or manufacturer accredited agent in the host country will perform an independent verification

	onsite, according to the manufacturer specifications. The outcome of the independent verification is a certificate of good order and accuracy of the flow meter. Maintenance: yearly
Any comment:	No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and Pressure, expressing LFG volumes in normalized cubic meters

Data / Parameter:	**$W_{CH4,y}$**
Data unit:	%
Description:	Average fraction of methane in the LFG
Source of data:	Analysis device
Measurement procedures (if any):	Measuring principle: is infra- red for CH_4 Accuracy: 2% (according to manufacturer documentation) There is a low level of uncertainty on this type of equipment. Even so, the gas analyzer will be calibrated once a year. All the data will be recorded continuously, on an electronic database
Monitoring frequency:	The methane fraction on the LFG gas will be measured continuously.
QA/QC procedures to be applied:	Calibration interval: monthly maintenance and testing regime (by comparison with a bottle of sample CH_4 gas obtained from certified provider such as AGA SA - Paseo Pdte. Errázuriz Echaurren 2631, Providencia, Santiago, Chile) to ensure accuracy
Any comment:	

Data / Parameter:	**T**
Data unit:	^{o}C (Celsius)
Description:	Temperature of the landfill gas
Source of data:	Thermometers
Measurement procedures (if any):	There is a low level of uncertainty on this type of equipment. Even so, the thermometer will be calibrated once a year. All the data will be recorded continuously, on an electronic database.
Monitoring frequency:	The temperature of the LFG gas will be measured continuously.
QA/QC procedures:	Thermocouples will be replaced or calibrated every year
Any comment:	Measured to determine the density of methane Dch4. No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and pressure, expressing LFG volumes in normalized cubic meters.

Data / Parameter:	**P**
Data unit:	Pa (Pascal)
Description:	Pressure of the landfill gas
Source of data:	Manometer
Measurement procedures (if any):	There is a low level of uncertainty on this type of equipment. Even so, the manometer will be calibrated once a year. All the data will be recorded continuously, on an electronic database.

Monitoring frequency:	The pressure of the LFG gas will be measured continuously.
QA/QC procedures:	Manometer will be subjected to a regular maintenance and testing regime to ensure accuracy.
Any comment:	Measured to determine the density of methane Dch4. No separate monitoring of pressure is necessary when using flow meters that automatically measure temperature and pressure, expressing LFG volumes in normalized cubic meters.

Data / Parameter:	**$EL_{LFG,y}$**
Data unit:	MWh
Description:	Net amount of electricity generated using LFG
Source of data:	Project participant
Measurement procedures (if any):	Electricity meter (outflow)
Monitoring frequency:	Continuous
QA/QC procedures:	Electricity meter will be subject to regular (in accordance with stipulation of the meter supplier) maintenance and testing to ensure accuracy
Any comment:	Required to estimate the emission reductions from electricity generation from LFG, if credits are claimed

Data / Parameter:	**Operation of the energy plant**
Data unit:	hours
Description:	Operation of the energy plant
Source of data:	Project participant
Measurement procedures (if any):	An hour-counter records the operating hours of the energy plant (when the plant is working, it powers an electronic watch)
Monitoring frequency:	Annually
QA/QC procedures:	Hour-counter will be subject to regular maintenance
Any comment:	This is monitored to ensure methane destruction is claimed for methane used in electricity plant when it is operational.

The ACM0001 parameter PEflare,y (Project Emissions from flaring the residual gas stream in the year y) need to be calculated from the following parameters that will be monitored, according to “Tool to determine project emissions from flaring gases containing methane”

Data / Parameter:	**$PE_{flare,y}$**
Data unit	tCO_2e
Description:	Project emissions from flaring of the residual gas stream in the year y
Source of data:	Calculated according to *Tool to determine project emissions from flaring gases containing methane*
Measurement procedures (if any):	The following parameter will be monitored, so $PE_{flare,y}$ can be calculated according to *Tool to determine project emissions from flaring gases containing methane*.
Monitoring frequency:	The flare efficiency will be continuously monitored.
QA/QC procedures:	See parameters $FV_{i,h}$, tO_2,h, $fvCH_4$,FG,h and T_{flare}.

Any comment:	As a simplified approach, project participants will only measure the methane content of the residual gas and consider the remaining part as N_2.

Data / Parameter:	$\mathbf{FV_{fi,h}}$
Data unit:	-
Description:	Volumetric fraction of component I in the residual gas in the hour h where i= CO_2, O_2, N_2 and CH_4 (already considered as $_{WCH4,y}$ above)
Source of data:	Measurements by project participants using a continuous gas analyzer.
Measurement procedures (if any):	Ensure that the same basis (dry or wet) is considered for this measurement and the measurement of the volumetric flow rate of the residual gas ($FV_{RG,h}$) when the residual gas temperature exceeds 60 ºC
Monitoring frequency:	Continuously. Values to be averaged hourly or at a shorter time interval
QA/QC procedures:	Analyzers will be periodically (monthly) calibrated according to the manufacturer's recommendation. A zero check and a typical value check will be performed by comparison with a standard certified gas.
Any comment:	As a simplified approach, project participants will only measure the methane content of the residual gas and consider the remaining part as N2.

Data / Parameter:	$\mathbf{t_{O2,h}}$
Data unit:	-
Description:	Volumetric fraction of O_2 in the exhaust gas of the flare in the hour h
Source of data:	Measurements by project participants using a continuous gas analyzer
Measurement procedures (if any):	Extractive sampling analyzers with water and particulates removal devices or in situ analyzer for wet basis determination. Measurement principle: electrochemical + signal 4-20 mA Accuracy:0.25% of volume The point of measurement (sampling point) shall be in the upper section of the flare (80% of total flare height). Sampling shall be conducted with appropriate sampling probes adequate to high temperatures level (e.g. inconel probes).
Monitoring frequency:	Continuously. Values will be averaged hourly or at a shorter time interval.
QA/QC procedures:	Analyzers will be periodically (monthly) calibrated according to manufacturer's recommendation. A zero check and a typical value check will be performed by comparison with a standard gas.
Any comments	

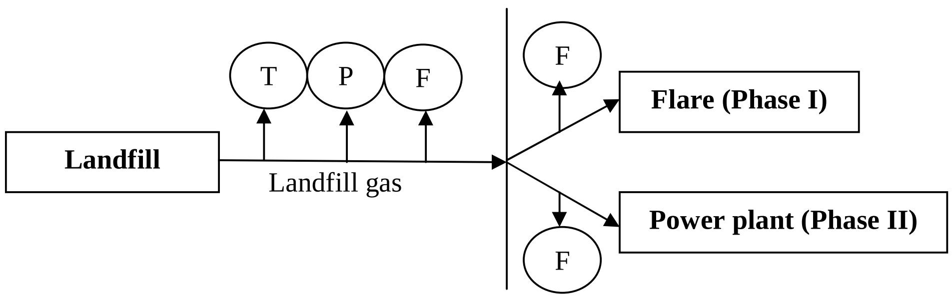
Data / Parameter:	**$fv_{CH4,FG,h}$**
Data unit:	mg/m3
Description:	Concentration of methane in the exhaust gas of the flare in dry basis at normal conditions in the hour h
Source of data:	Measurements by project participants using a continuous gas analyzer
Measurement procedures (if any):	Extractive sampling analyzers with water and particulates removal devices or in situ analyzer for wet basis determination. Measurement principle: Binos NDIR + signal 4-20 mA The point of measurement (sampling point) shall be in the upper section of the flare (80% of total flare height). Sampling shall be conducted with appropriate sampling probes adequate to high temperatures level (e.g. inconel probes).
Monitoring frequency:	Continuously. Values will be averaged hourly or at a shorter time interval.
QA/QC procedures:	Analyzers will be periodically calibrated according to manufacturer's recommendation. A zero check and a typical value check will be performed by comparison with a standard gas.
Any comment:	Measurement instruments may read ppmv or % values. To convert from ppmv to mg/m^3 simply multiply by 0.7168. 1% equals 10 000 ppmv.

Data / Parameter:	**T_{flare}**
Data unit:	°C
Description:	Combustion temperature
Source of data:	Analysis device
Measurement procedures (if any):	Measure the temperature in the flare by a Type N thermocouple
Monitoring frequency:	Continuously.
QA/QC procedures:	Thermocouples will be replaced or calibrated every year
Any comment:	

Data / Parameter:	**$EC_{PJ,y}$**
Data unit:	MWh
Description:	Quantity of electricity consumed by the project activity during the year y
Source of data:	Onsite measurement
Measurement procedures (if any):	Use electricity meters. The meter is a General Electric induction meter, owned and controlled by the state electricity company. - accuracy: < 2% , measured at 25%, 50%, 75% and 100% of the maximum electric capacity - calibration frequency: every 5 years
Monitoring frequency:	Continuously, aggregated manually by the electricity supplier, via onsite meter checking.
QA/QC procedures:	Cross check measurement results with electricity invoices
Any comment:	

B.7.2 Description of the monitoring plan:

The monitoring plan specifies the generic approach to monitoring, the equipment to be used, the process of data generation, processing and transmission, calibration and maintenance as well as managerial responsibilities.



GENERIC MONITORING APPROACH

The parameters used for determining the project emissions from flaring (**$PE_{flare,y}$**) will be monitored as per the *Tool to determine project emissions from flaring gases containing methane*:

- $Fv_{i,h}$: Volumetric fraction of component *I* in the residual gas in the hour *h* where *i*= CH_4 (already considered as $W_{CH4,y}$, above – as a simplified approach the CH_4 will be measured and the remaining part will be considered N_2);
- $t_{O2,h}$: Volumetric fraction of O_2 in the exhaust gas of the flare in the hour h, continuous measurements will be made, if economically viable;
- $fv_{CH4,FG,h}$: Concentration of methane in the exhaust gas of the flare in dry basis at normal conditions in the hour h, continuous measurements will be made, if economically viable.

If it proves technically or financially not possible to monitor flare efficiency, a default Flare Efficiency (FE) of 90% will be used when the compliance with manufacturer’s specification will be achieved and a Flare efficiency of 50% will be used if the flare temperature is out of the specified limits. In order to monitor the compliance with the manufacturer’s specifications the combustion temperature of the flare will be measured continuously.

MONITORING EQUIPMENT

The flare unit is equipped with the following instruments to capture the required monitoring data:

No	Instrument	Data monitored
1	Flowmeter	**$LFG_{flare,y}$** Volume of gas sent to the flare during phase 1 of the project **$LFG_{electricity,y}$** Volume of gas sent to the energy plant during phase 2 **$LFG_{total,y}$** Volume of gas captured **T** Temperature of the LFG **P** Pressure of the LFG
2	LFG Gas analyser	**$W_{CH4,y}$** Fraction of methane in LFG

3	Thermocouple	**T_{flare}** Temperature of the flare
4	Electricity meter	**$EC_{PR,y}$** Electricity consumed by the equipment
5	Exhaust gas analyser (when feasible)	**$fv_{CH_4,FG}$** concentration of methane in the exhaust gas
6	Electricity meter	**EL_{LFG}** net amount of electricity generated using LFG
7	Hour-counter	Operating hours of the generators

One flowmeter will be used to measure LFG sent to the flare during phase 1 and two flowmeters will be added to measure LFG sent to energy plant during phase 2, LFG sent to the flare and total LFG captured. The different instruments send their data to the data logging device (the MemoGraph).

DATA LOGGING TECHNOLOGY

The data from the instruments will be collected in MemoGraph (type: Visual Data Manager, Provider: Endress+Hauser), equipped with a Compact Flash card of 256 MB for the archive. The unit comes also with a preinstalled copy of software ReadWin2000 (from Endress+Hauser), that is used for the configuration and display of the MemoGraph.
The system also offers 2 different ways of communication for output:

- USB Interface
- Modem transmission, using either protocol RS232, protocol RS485 or Ethernet Interface

The MemoGraph is secured by means of a seal so the displayed value is true and protected against manipulation.

The Monitoring unit collects the following parameters from the flare unit every minute: (see Figure 1 - Example of Monitoring Output)

- Date & Hour:Min of the measure
- Status validity of the measure
- Average Gas Pressure in degree in mbar.
- Average Gas concentration in Methane (CH_4).
- Normalised gas Flow in nM^3/h.
- Gas concentration in Oxygen (O_2).
- Average Gas Temperature in degree Celsius.
- Average Flare Temperature in degree Celsius.

Date/Time	2 Status	Pression Average mbar	CH4 Average %	FLUJO Average NM3/h	O2 Average VOL%	T Antorcha Average °C	T Gas Average °C
17/12/2007 13:32	OK	80	49	500.1	2.5	1223	37
17/12/2007 13:33	OK	80	49	499.8	2.5	1196	37
17/12/2007 13:34	OK	80	49	499.6	2.5	1165	38
17/12/2007 13:35	OK	80	49.1	499.5	2.5	1114	38
17/12/2007 13:36	OK	80	49	499.5	2.5	1170	38
17/12/2007 13:37	OK	80	49	499.5	2.5	1137	38
17/12/2007 13:38	OK	80	49	499.4	2.5	1141	38
17/12/2007 13:39	OK	80	48.9	499.3	2.5	1129	38

Figure 1 - Example of Monitoring Output

The data are recorded on spreadsheet file with a predefined format. The file will then be directly used for the verification report.

DATA TRANSMISSION, PROCESSING AND STORAGE

All parameters mentioned above will be processed according to the following methodology:

a) Automatic Transmission:

The MemoGraph is configured to communicate data by modem once a day. The results are sent using a direct dedicated phone line to a dedicated server machine that is physically installed in the office of Bionersis Chile in Santiago. The Monitoring Director is controlling that process is functional.

b) Manual Logging:

If Automatic Transmission failed, the Monitoring Director will contact directly the monitoring unit from the server to collect the data.

c) Physical Logging:

If Physical Logging Failed, the Monitoring Director will send a technician physically at site location to output data using the USB interface. These data will be then be sent back to the office and recorded on the server.

d) If all options above do not work, the following procedures will be used:
    1. If data can be retrieved subsequently, they will be reintegrated on the server.
    2. If data cannot be retrieved, no emissions reductions will be claimed for the period of data failure.

- All data will be stored physically on the disk of the server machine.
- A daily backup of the server will be done.
- A copy of the backup on a portable electronic storage device will be held securely at the Bionersis office in Santiago.

Copies of the files will be stored up to two years after termination of the project.

CALIBRATION AND MAINTENANCE PROCEDURES

Instrumentation will be calibrated as recommended by manufacturers.
The critical calibration frequency and procedures are detailed below:

A) Flow Meter
The flow meter will be calibrated once a year by an external certified company, recommended by the meter manufacturer.

B) Gas Analyser
The gas analyser is calibrated every month according to its calibration protocol by a qualified operator. The calibration gases will be purchased from certified gas suppliers. All gas cylinders will be provided with a quality certificate.

C) Temperature and Pressure of the LFG
The temperature and pressure meters will be calibrated annually by an independent third-party.

D) Temperature of the flare
The thermocouple will be checked annually by an independent third-party

E) Electricity meters
The reading from electricity meters will be cross-checked annually with the invoices from and to the national grid company. Electricity meter will measure inflow from the grid (energy imported for the plant consumption) and outflow to the grid (electricity delivered to the grid)

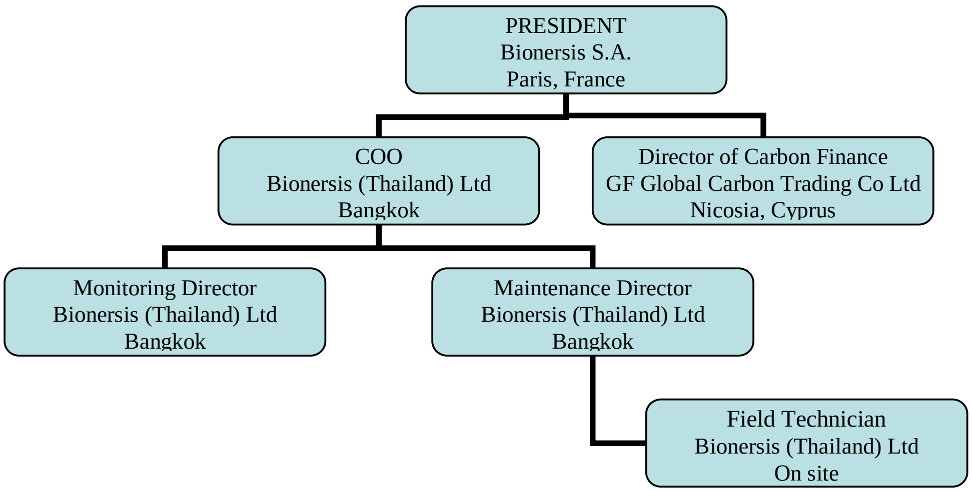
F) Hour-counter
The hour-counter will be checked annually.

G) General malfunction of equipment
If the equipment (flow meter, gas analyser, gauge, controller, MemoGraph, etc.) fails, the equipment supplier will be immediately notified. If possible, repairs will be carried out. If the damaged equipment cannot be repaired, it will be replaced at the earliest by the same or an equivalent unit. In some cases, portable tools will be used in order to carry out daily monitoring of the missing parameter(s). This data will be recorded on paper.

ID Number	Data Variable	Source of Data	Data Unit	Recording Frequency	Calibration Method and Frequency	Alternative procedure in case of failure
LFG flare,y	Total amount of landfill gas flared	Flowmeter	m3	every minute	Annualy by external expert	N/A (data lost)
LFG elec,y	Total amount of landfill gas sent to energy plant	Flowmeter	m3	every minute	Annualy by external expert	N/A (data lost)
LFG total,y	Total amount of landfill gas captured	Flowmeter	m3	every minute	Annualy by external expert	N/A (data lost)
Wch4,y and Fvi,y	Fraction of the component I in measured gas	Gas Analyser	m3 of i / m3 of gas	every minute	Monthly	Manual measurements will be taken using and infrared portable device
T	Temperature of the landfill gas	Temperature Gauge	Celcius	every minute	Annualy	N/A (data lost)
P	Pressure of the landfil gas	Pressure Gauge	Pa	every minute	Annually	N/A (data lost)
Tflare	Temperature of the flare	Thermocouple	Celcius	every minute	Annually	N/A (data lost)
EC	Electricity consumed	Electricity meter	MWh	daily	Annually	Manual reading and logging

MANAGERIAL RESPONSIBILITIES

The CDM aspects of the project are managed by the Director of Carbon Finance of GF Global Carbon Trading Company Limited, based in Cyprus.
The monitoring plan is the responsibility of the Monitoring Director of the project.
The Maintenance Director supervises the calibration procedure under the supervision of the Monitoring Director.



QUALITY ASSURANCE

- The monitoring director of the project will be in charge of and accountable for the generation of the monitoring, logging and record keeping of all monitoring data.
- The monitoring director will officially sign off on all worksheets used for the recording of monitoring data.
- The director of carbon finance will be in charge of compiling the monitoring report.
- Proper management processes and systems records will be kept by the monitoring director. The auditors can require copies of such records to judge compliance with the required management systems.

TRAINING OF MONITORING PERSONNEL

Employees involved in the monitoring will be trained internally and/or externally at least once a year. Training will include:

a) Review of equipment and captors
b) Calibration requirement
c) Configuration of monitoring equipment
d) Maintenance requirement

B.8 Date of completion of the application of the baseline study and monitoring methodology and the name of the responsible person(s)/entity(ies)

The baseline study was completed on 20/05/2008 by GF Global Carbon Trading Company Ltd which is a project participant (see contact information in Annex 1).

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:

The starting date of the project activity is 29/04/2008.

The starting date chosen is the date when the contract with landfill operator was signed.

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

The expected operational lifetime of the project activity will be approximately 15 years, from the starting date of the project activity mentioned above.

The expected operational lifetime of the project is longer than 10 years, since:

- the period of significant LFG production for a closed landfill is about 15 years
- the lifetime of the equipment purchased is about 15 years, according to the information from the equipment provider (Hofstetter)

C.2 Choice of crediting period and related information:

C.2.1. Renewable crediting period

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

Not applicable

C.2.1.2. Length of the first crediting period:

Not applicable

C.2.2. Fixed crediting period:

C.2.2.1. Starting date:

The starting date of the fixed crediting period is the final validation date, which is expected by 01/01/2009.

C.2.2.2. Length:

The length of the fixed crediting period is 10 years, from 01/01/2009 to 31/12/2018

SECTION D. Environmental impacts

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

Based on the information obtained from the Office of Environmental Policy and Planning (OEPP), an Environmental Impact Assessment (EIA) is not required for LFG collection and utilization projects that have a capacity of less than 10MW.
An EIA was also not required for the development of the landfill site. The Pollution Control Department of MOSTE (MOSTE PCD) is responsible for approving solid and hazardous waste management facilities. This approval process does not have any requirements or constraints relating to the development of the landfill site.

We list hereafter the environmental impacts to demonstrate that no significant negative impacts are to be expected.

Impact on the landscape
The project activity will allow the closing of the landfill site and accelerate the remodelling process of the site. The implementation of techniques of compaction of waste as part of the remodelling will reduce the risks of fire on the landfill. The reshaping of the waste body is favourable for biogas production and also allows it to fit better in the landscape.

Impact on Fauna and Flora
The project will have a positive influence on the local ecosystem by remodelling the landscape and allowing the development of grass and trees on the covered landfill. Additionally, the destruction of gases like H_2S and derivatives of methane, which constitutes a substantial nuisance in the neighbouring zones (because of their scents), will also contribute to the development of the local ecosystem.

Impact on air and climate
The flaring and destruction of the methane contained in landfill gas will contribute to the reduction of greenhouse gas emissions, which are proved to increase global warming. This is why the project activity can be considered as a CDM project.

The project activity will prevent all nuisance created by the total release of the landfill gas to the atmosphere, such as the release of H_2S, mercaptenes and other chemical compounds that result in bad odours and sanitary risks in the neighbouring populations, such as diseases and asthma due to the air pollution.
The improved management of waste, engendered by the project activity, will reduce the presence of rodents (rats or similar) or birds, thus reducing the sanitary risks for the neighbouring population.

Impact on safety
The collection and destruction of the landfill gas will reduce risks of explosion in the landfill sites and the neighbourhood. Indeed, for a specific content, in the presence of oxygen, the methane contained in the landfill gas can become explosive. The project activity implies continuous monitoring and control of the oxygen content of the landfill gas, thus continuously controlling the risk of explosions.

Noise
The installed equipment (flare) can produce some noise, however the noise level will always be below 69dB(A). This noise level will not result in any significant nuisance to the neighbouring population due to the distance between the flare and population dwellings (if any in the vicinity).

D.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:

Hence, there are no negative environmental impacts due to the project activity. All the impacts of the project activity listed above will contribute to improve both local and global environment.

SECTION E. Stakeholders' comments

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

I. Stakeholders invitation

The identified stakeholders were invited by means of fax and formal letter sent one week before the scheduled meeting. In addition, general public was informed through posters.

II. Meeting

The public consultation took place on May 15, 2008 at Sa Si Mum sub-district administration office, city of Kamphaeng Saen, province of Nakhon Pathom. The meeting was conducted by representatives of Bionersis (Thailand) Ltd, which is a project participant.

III. Agenda

The agenda of the meeting consisted of:

9.30-10.15am:	Reception of the attendees with the movie "The Inconvenient Truth"
10.15am:	Presentation of the speakers and the company
10.20am:	Presentation 1: Bionersis – Greenhouse gas Effect and Global Warming (case study in Thailand)
10.40am:	Presentation 2: DNA in Thailand – What are the Kyoto Protocol and the CDM? Thailand Overview
11.00am:	Break
11.10am:	Presentation 3: Landfill gas project and CDM – Kamphaeng Saen project
11.40am:	Q&A session
12.30pm:	Lunch

IV. Participants

The following stakeholders attended the meeting:

- Governmental organizations:
  - representatives of central government
  - representatives of the Department of Alternative Energy Development & Efficiency (DEDE)
  - representatives of the Office of National Resources and Environmental Policy and Planning (ONEP) – Thailand Greenhouse Gas Organization
  - representatives of local government:
    - Kamphaeng Saen Administration Office
    - Provincial Environmental Office. (PCD)
    - Sa Si Mum Sub-Administration Office

- Public and private entities
  - representatives of EGAT (Electricity Generating Authority of Thailand)

  - representatives of PEA (Provincial Electricity Authority)
  - representatives of Mahidol University
  - representatives of Kasetsart University

- Community
  - residents of KPS city
  - representatives of landfill workers
  - Group 79 Co. Ltd
  - Group 15 Co. Ltd
  - Wasaduphan Turakit Co., Ltd.
  - Jaroensompong Co., Ltd.

E.2. Summary of the comments received:

During the meeting, stakeholders raised questions on the following topics:

- Past experience of the project participants
  - "Where are the 4 Bionersis' projects (already running) located?"

- Operational matters
  - "How much might be the expected capacity for power generation?"
  - "When will the power generation be set up?"
  - "What is the area of the landfill which can be suitable for LFG extraction and electricity generation?"
  - "What are the specifications of the gas engine?"

- Waste decomposition process
  - "Do the quantities of LFG generation depend on the type of waste?"
  - "Isn't it better if organic waste is used for biogas fermentation system?"

- Carbon credits
  - "How many Carbon Credits do you expect to sell per year and at what unit price?"
  - "Does Carbon Credit price have a standard price?"
  - "When can you start the sale of Carbon Credits?"
  - "How long can you sell the Carbon Credits for?"

- Economic aspects of the project
  - "What is the CAPEX of the project and what IRR will you get?"
  - "How long this LFG purchase contract has been signed for?"

- Relation with DNA/Environmental Authority
  - "How long will it take to carry out the IEE report?"
  - "Does Thai DNA have any support to this kind of project? [biogas fermentation systems]"

- Benefits of the project for the local communities
  - Environmental benefits
  - Social benefits
  - Economic benefits

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

All questions have been duly answered by representatives of Bionersis (Thailand) Ltd TBD. In particular, the following answers have been provided on the last issues – benefits of the project for the local communities:

- Environmental benefits:
    - Reduction of methane emissions which is a potent GHG that contributes to global climate change;
    - Reduction of odours;
    - Emissions of Volatile Organic Compounds (VOC) contribute to ground-level ozone (O3) formation (smog);
    - Reduction of subsurface migration (risks of explosion and fire)
    - Reduction of GHGs emission from grid replacement (when phase II would be implemented).

- Social benefits:
    - Exposure of landfill workers and local communities to HAP will drop significantly reducing the health hazards caused by such substances;
    - Reduction of odours dissemination which will have a great impact on quality of life improvements for individuals that live within the landfill compound (workers) and near the landfill. The reduction of odours will also have a significant economical improvement because usually odours reduce local property values.

- Economic benefits:
    - Landfill gas projects involve engineers, construction firms, equipment vendors, and utilities or end-users of the power produced. Much of this cost is spent locally for drilling, piping, construction, and operational personnel, helping communities to realize economic benefits from increased employment and local sales. Thailand will also benefit from the cost savings associated with using LFG as a replacement for more expensive fossil fuels, such as natural gas and fuel oil.

Annex 1

CONTACT INFORMATION ON PARTICIPANTS IN THE PROJECT ACTIVITY

Organization:	Bionersis SA
Street/P.O.Box:	176 avenue Charles de Gaulle
City:	Neuilly sur Seine
State/Region:	
Postfix/ZIP:	92200
Country:	France
Telephone:	+331 53 02 90 80
Fax:	+331 43 42 48 30
E-Mail:	
URL:	www.bionersis.com
Represented by:	Frederic Pastre
Title:	President
Salutation:	Mr
Last Name:	Pastre
Middle Name:	-
First Name:	Frédéric
Department:	Head Office
Mobile:	+336 21 11 83 79
Direct FAX:	+331 43 42 48 30
Direct tel:	+331 53 02 90 03
Personal E-Mail:	Frederic.pastre@bionersis.com

Organization:	GF Global Carbon Trading Company Limited
Street/P.O.Box:	2-4 Arch. Makarios III Ave
Building:	Capital Center, 7^{th} floor, office 703
City:	Nicosia
State/Region:	
Postfix/ZIP:	
Country:	Cyprus
Telephone:	+357-22-676 126
Fax:	+357-22-674201
E-Mail:	stephane.vidaillet@bionersis.com
URL:	
Represented by:	Stephane Vidaillet
Title:	General Manager
Salutation:	Mr
Last Name:	Vidaillet
First Name:	Stephane
Department:	-
Mobile:	+33 6 5911 5600
Direct FAX:	+33 1 4342 4830
Direct tel:	+33 1 5302 9007

Organization:	Bionersis (Thailand) Ltd
Street/P.O.Box:	153/3 Goldenland Building, Soi Mahardlekluang 1, Rajdamri Road, Lumpini, Phathuwan
Building:	Goldenland Building, 4th floor, Room A4
City:	Bangkok
State/Region:	
Postfix/ZIP:	10330
Country:	Thailand
Telephone:	+66 23 05 66 21
Fax:	
E-Mail:	
URL:	
Represented by:	Alban Casimir
Title:	Director
Salutation:	Mr
Last Name:	Alban
First Name:	Casimir
Department:	Head office
Mobile:	
Direct FAX:	
Direct tel:	

Annex 2

INFORMATION REGARDING PUBLIC FUNDING

There will be no public funding, under any form, for the proposed CDM project. It will be financed exclusively by private capital that is being raised from investments funds and/or banks, either locally or in the European Union.

Annex 3

BASELINE INFORMATION

A. SUPPORTING INFORMATION FOR BASELINE AND PROJECT EMISSIONS CALCULATION

A spreadsheet detailing the calculation is provided for validation.

$BE_{CH4,SWDS,y}$ is the methane generation from the landfill in the absence of the project activity at year y (tCO_2e), calculated as per the *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site.*

$$BE_{CH4,SWDS,y} = \varphi\ (1-f) * GWP_{CH4} * (1-OX) * 16/12 * F * DOC_f * MCF * \Sigma\Sigma\ w_{j,x} * DOC_j * e^{-kj(y-x)} * (1-e^{-kj})$$

Where:

φ = Model correction factor to account for model uncertainties (90%)
f = Fraction of methane captured at the SWDS and flared, combusted or used in another manner
GWP_{CH4} = Global Warming Potential (GWP) of methane
OX = Oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste)
F = Fraction of methane in the SWDS gas (volume fraction) (50%)
DOC_f = Fraction of degradable organic carbon (DOC) that can decompose
MCF = Methane correction factor
$W_{j,x}$ = Amount of organic waste type j prevented from disposal in the SWDS in the year x (tons)
DOC_j = Fraction of degradable organic carbon (by weight) in the waste type j
k_j = Decay rate for the waste type j
j = Waste type category (index)
x = Year during the landfill lifetime: x runs from the first year of the landfill opening (x = 1) to the year y for which avoided emissions are calculated (x = y)
y = Year for which methane emissions are calculated

The parameters used are shown in the table below:

1. Fixed parameters

	Variable	Value
Model correction factor	φ	**90%**
Model adjustment factor, set to 0 by ACM0001 v08	f	**0**
Global Warming Potential of LFG	GWP_{CH4}	**21**
Oxidation factor: there is NO soil or compost cover	OX	**0**
Fraction of methane in the LFG	F	**50%**
Fraction of degradable organic content (DOC) that can decompose	DOC_f	**50%**
Anaerobic managed site	MCF	**1**

The equation used and the result of the calculation is thus:

$$\varphi\ (1-f) * GWP_{CH4} * (1-OX) * 16/12 * F * DOC_f * MCF = \quad \mathbf{6.3}$$

2. Waste composition ($W_{j,x}$) and Degradable Organic Content (DOC_j)

According to the *Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site*, we can apply IPCC 2006 Guidelines for National Greenhouse Inventories default values for the site waste composition and the value of DOC_j:

South East Asia	Food	Paper Cardboard	Wood	Textile	Rubber Leather	Plastic	Metal	Glass	Other
SITE WASTE COMPOSITION (IPCC 2006 default values)	**43.50%**	**12.90%**	**9.90%**	**2.70%**	**0.90%**	**7.20%**	**3.30%**	**4.00%**	**16.30%**

DOCj (IPCC 2006 default values)	**15%**	**40%**	**43%**	**24%**	**0%**	**0%**	**0%**	**0%**	**0%**

3. k-factor

The decay rate is taken from the tool, and based on

- the waste composition,
- the site MAT, MAP and aridity index (MAT/PET) taken from the online database of WorldClimate.org,

Waste type	Food	Paper Cardboard	Wood	Textile	Rubber Leather	Plastic	Metal	Glass	Other
MAT ≤ 20ºC and MAP/PET < 1	0.06	0.04	0.02	0.04	0	0	0	0	0
MAT ≤ 20ºC and MAP/PET > 1	0.185	0.06	0.03	0.06	0	0	0	0	0
MAT > 20ºC and MAP ≤ 1000 mm	0.085	0.045	0.025	0.045	0	0	0	0	0
MAT > 20ºC and MAP > 1000 mm	0.4	0.07	0.035	0.07	0	0	0	0	0

MAT Mean Average Temperature (www.worldclimate.org)	27
MAP Mean Average Precipitation (www.worldclimate.org)	1500
MAP/PET = aridity index	5

Decay Rate - K_j (from Tool to determine methane ...)	**0.400**	**0.070**	**0.035**	**0.070**	-	-	-	-	-

4. Waste volumes per year

The requested input information has been submitted to us directly by the municipality. It has been cross checked by our on-site inspections and topographical study.

Year	Metric Tons Disposed	Cumulative Metric Tons
1991	666,378	666,378
1992	686,987	1,353,365
1993	708,234	2,061,599
1994	730,138	2,791,737
1995	752,720	3,544,457
1996	776,000	4,320,457
1997	800,000	5,120,457
1998	824,000	5,944,457
1999	848,720	6,793,177
2000	874,182	7,667,359
2001	900,407	8,567,766
2002	485,000	9,052,766
2003	500,000	9,552,766
2004	500,000	10,052,766
2005	515,000	10,567,766
2006	0	10,567,766
2007	0	10,567,766
2008	0	10,567,766
2009	0	10,567,766
2010	0	10,567,766

B. ADJUSTMENT FACTOR

In Thailand, the technical, legal, economic and financial conditions are such that generally no LFG collection and destruction is occurring, even though some landfills are equipped of passive ventilation wells for the purpose of preventing potentially dangerous LFG concentration inside the landfill.
A specialized consultant[6] has conducted an inspection on Bionersis'behalf, and issued a report describing the current status of the landfill.

According to the report, most landfill gas that is currently generated is freely and totally released into the atmosphere either through the existing (and mostly collapsed) passive venting system or by migrating directly to the landfill surface or borders. As a result, it has been estimated that the methane flared was negligible and that no reliable historical data existed to precisely determine it.

Hence, an adjustment factor of 0 has been applied.

C. DETERMINATION GRID EMISSION FACTOR IN THAILAND ($CEF_{elec,BL}$)

The methodological *Tool to calculate the emission factor for an electricity system* is applied to determine the CO_2 emission factor for the displacement of electricity generated by power plants in an electricity

[6]CEFT - Inspection Report

system, by calculating the "operating margin" (OM) and "build margin" (BM) as well as the "combined margin" (CM).
Therefore, we apply the baseline methodology procedure according to the tool:

STEP 1 Identify the relevant electric power system
STEP 2 Select an operating margin (OM) method
STEP 3 Calculate the operating margin emission factor according to the selected method
STEP 4 Identify the cohort of power units to be included in the build margin (BM)
STEP 5 Calculate the build margin emission factor
STEP 6 Calculate the combined margin (CM) emissions factor

STEP 1 Identify the relevant electric power system

The relevant project electricity system and connected electricity system is identified as the national grid. On the one hand, the Thai DNA has not published any delineation of the project electricity system connected electricity system. On the other hand, we did not identify any significant transmission constraints according to criteria set in the *Tool to calculate the emission factor for an electricity system*. Hence we use the default definition of the relevant electric power.

STEP 2 Select an operating margin (OM) method Identify the relevant electric power system

According to the *Tool to calculate the emission factor for an electricity system*, the calculation of the operating margin emission factor ($EF_{grid,OM,y}$) is based on one of the following methods:

(a) Simple OM, or
(b) Simple adjusted OM, or
(c) Dispatch data analysis OM, or
(d) Average OM

The simple OM method (option a) can be applied as low-cost/must-run resources constitute less than 50% of total grid generation in Thailand, in average of the five most recent years[7]. Tables below presents the national grid generation by sources in Thailand for the 2002-2006 period (five most recent years for which data is available):

[7] Source: Electric Power report in Thailand, DEDE (table 17) http://www.dede.go.th/dede/index.php?id=929

TABLE 17 NATIONAL GRID GENERATION BY ENERGY SOURCES[1/ 2/]

ล้านกิโลวัตต์ชั่วโมง - Gwh

พ.ศ.	พลังน้ำ HYDRO	น้ำมันเตา FUEL OIL	น้ำมันดีเซล DIESEL OIL	ถ่านหินและลิกไนต์ COAL & LIGNITE	ก๊าซธรรมชาติ NATURAL GAS	อื่น ๆ [3/] OTHERS [3/]	รวม TOTAL	YEAR
2545	7,471	2,616	168	16,652	69,538	2	**96,447**	**2002**
2546	7,299	2,941	180	16,807	76,332	2	**103,561**	**2003**
2547	6,040	7,138	551	17,993	80,489	2	**112,213**	**2004**
2548	5,798	8,244	414	18,334	85,703	2	**118,495**	**2005**
2549	8,125	8,350	143	22,051	86,339	3	**125,011**	**2006**

ที่มา : พพ. กฟผ. กฟภ. และผู้ผลิตไฟฟ้าเอกชนอิสระ

หมายเหตุ : 1/ ไม่รวมการผลิตพลังงานไฟฟ้าของผู้ผลิตไฟฟ้าเอกชนรายเล็ก และผู้ผลิตไฟฟ้าพลังงานหมุนเวียนขนาดเล็กมากจากแหล่งพลังงานเชิงพาณิชย์และพลังงานหมุนเวียน จำนวน 13,731 ล้านกิโลวัตต์ชั่วโมง

2/ ไม่รวมผู้ผลิตพลังงานควบคุมที่ผลิตไฟฟ้าใช้เอง

3/ รวมโรงไฟฟ้าพลังงานความร้อนใต้พิภพ พลังงานแสงอาทิตย์และพลังงานลม

Sources : DEDE, EGAT, PEA, and IPP.

Notes : 1/ Excluding generation from SPP and VSPP generated from renewable and conventional energy amounting to 13,731 Gwh.

2/ Excluding private generation for own use.

3/ Including geothermal, solar cell and wind turbine, etc.

Year	Hydro	Others including geothermal, solar cell and wind turbine	Total low-cost/must-run resources	Total national grid generation	Generation from SPP and VSPP	Total grid generation in Thailand	% of low-cost resources in total grid generation
2002	7,471	2	7,473	96,447	12,556	109,003	6.9%
2003	7,299	2	7,301	103,561	13,422	116,983	6.2%
2004	6,040	2	6,042	112,213	13,514	125,727	4.8%
2005	5,798	2	5,800	118,495	13,514	132,009	4.4%
2006	8,125	2	8,127	125,011	13,731	138,742	5.9%
Average 5 most recent years for which data is available							5.6%

Low-cost/must-run resources represents only 5.6% of total grid emission in Thailand, hence the simple OM method con be applied.

We have chosen to apply the ex-ante option: a 3-year generation-weighted average, based on the most recent data available at the time of submission of the CDM-PDD to the DOE for validation, without requirement to monitor and recalculate the emission factor during the crediting period.

STEP 3 Calculate the operating margin emission factor according to the selected method

The simple OM emission factor is calculated as the generation-weighted average CO_2 emissions per unit net electricity generation (tCO_2/MWh) of all generating power plants serving the system, not including low-cost / must-run power plants / units. It will be calculated according to Option A, i.e. based on data on fuel consumption and net electricity generation of each power plant / unit, as fuel consumption data for each power plant in Thailand is available.

Hence, the simple OM emission factor is calculated as follows:

$$EF_{grid,OMsimple,y} = \frac{\sum_{i,m} FC_{i,m,y} \cdot NCV_{i,y} \cdot EF_{CO2,i,y}}{\sum_{m} EG_{m,y}}$$

Where:

$EF_{grid,OMsimple,y}$	Simple operating margin CO_2 emission factor in year y (tCO_2/MWh)
$FC_{i,m,y}$	Amount of fossil fuel type i consumed by power plant / unit m in year y (mass or volume unit)
$NCV_{i,y}$	Net calorific value (energy content) of fossil fuel type i in year y (GJ / mass or volume unit)
$EF_{CO2,i,y}$	CO_2 emission factor of fossil fuel type i in year y (tCO_2/GJ)
$EG_{m,y}$	Net electricity generated and delivered to the grid by power plant / unit m in year y (MWh)
m	All power plants / units serving the grid in year y except low-cost / must-run power plants / units
i	All fossil fuel types combusted in power plant / unit m in year y
y	Either the three most recent years for which data is available at the time of submission of the CDM-PDD to the DOE for validation (ex ante option) or the applicable year during monitoring (ex post option), following the guidance on data vintage in step 2

I. Data available for yearly fuel consumption $FC_{i,m,y}$[8]:

TABLE 19 FUEL CONSUMPTION FOR ELECTRIC GENERATION TO NATIONAL GRID 1/2/

พ.ศ.	น้ำมันเตา (ล้านลิตร) FUEL OIL (million litres)	น้ำมันดีเซล (ล้านลิตร) DIESEL OIL (million litres)	ถ่านหินและลิกไนต์ (พันตัน) COAL & LIGNITE (thousand tons)	ก๊าซธรรมชาติ (ล้านลูกบาศก์ฟุต) NATURAL GAS (MMscf)	YEAR
2545	646	47	15,035	667,865	2002
2546	696	51	15,406	698,132	2003
2547	1,697	120	16,537	724,560	2004
2548	1,996	83	16,571	764,118	2005
2549	2,030	41	17,166	857,103	2006

ที่มา : พพ. กฟผ. กฟภ. และผู้ผลิตไฟฟ้าเอกชนอิสระ

หมายเหตุ : 1/ ไม่รวมการใช้เชื้อเพลิงของผู้ผลิตไฟฟ้าเอกชนรายเล็ก และผู้ผลิตไฟฟ้าพลังงานหมุนเวียนขนาดเล็กมาก

2/ ไม่รวมผู้ผลิตพลังงานควบคุมที่ผลิตไฟฟ้าใช้เอง

Sources : DEDE, EGAT, PEA, and IPP.

Notes : 1/ Excluding fuel consumption from SPP and VSPP.

2/ Excluding private generation for own use.

[8] Source: Electric Power report in Thailand, DEDE (tables 19 & 20) http://www.dede.go.th/dede/index.php?id=929

TABLE 20 FUEL CONSUMPTION FOR SPP COGENERATION SELLING TO NATIONAL GRID IN 2006

ประเภทกิจการ	จำนวน No.	ก๊าซธรรมชาติ (ล้านลูกบาศก์ฟุต) NATURAL GAS (MMscf)	น้ำมันเตา (ลิตร) FUEL OIL (litre)	น้ำมันดีเซล (ลิตร) DIESEL OIL (litre)	ถ่านหินและลิกไนต์ (ตัน) COAL & LIGNITE (ton)	พลังงานหมุนเวียน[1] (ตัน) RENEWABLE[1] FUEL (ton)	อื่น ๆ[2] (จิกะจูล) OTHERS[2] (GJ)	TYPES
โรงงานผลิตเส้นใยไฟเบอร์	1	-	-	-	29,553	-	-	FIBRE PRODUCTION
โรงงานผลิตเม็ดพลาสติก	1	1,385	-	-	-	-	-	PETROCHEMICAL
โรงงานผลิตกระดาษ	3	-	559,525	-	19,889	202,923	10,292,963	PULP & PAPER
โรงเผาขยะมูลฝอย	1	-	-	-	-	34,899	-	INCINERATION PLANT
โรงงานน้ำตาล	32	-	-	-	-	1,746,299	-	SUGAR MILL
โรงไฟฟ้า	43	91,503	7,615,005	436,418	866,491	1,921,507	472,895	UTILITY COMPANY
รวม	**81**	**92,888**	**8,174,530**	**436,418**	**915,933**	**3,905,628**	**10,765,858**	**TOTAL**

ที่มา : ผู้ผลิตไฟฟ้าเอกชนรายเล็ก

Source : SPP

หมายเหตุ : 1/ รวมแกลบ กากอ้อย ฟืน ขยะ และวัสดุเหลือใช้ทางการเกษตร

2/ รวมแบล็คลิเคอและก๊าซเหลือใช้จากขบวนการผลิต

Notes : 1/ Including paddy husk, bagasse, fuel wood, garbage, and agricultural waste.

2/ Including black liquor and residual gas from production processes, etc.

TABLE 20 FUEL CONSUMPTION FOR SPP COGENERATION SELLING TO NATIONAL GRID IN 2005

ประเภทกิจการ	จำนวน No.	ก๊าซธรรมชาติ (ล้านลูกบาศก์ฟุต) NATURAL GAS (MMscf)	น้ำมันเตา (ลิตร) FUEL OIL (litre)	น้ำมันดีเซล (ลิตร) DIESEL OIL (litre)	ถ่านหินและลิกไนต์ (ตัน) COAL & LIGNITE (ton)	พลังงานหมุนเวียน[1/] (ตัน) RENEWABLE[1/] FUEL (ton)	อื่น ๆ[2/] (จิกะจูล) OTHERS[2/] (GJ)	TYPES
โรงงานผลิตเส้นใยไฟเบอร์	1	-	-	-	43,783	-	-	FIBRE PRODUCTION
โรงงานผลิตเม็ดพลาสติก	1	2,568	-	-	-	-	-	PETROCHEMICAL
โรงงานผลิตกระดาษ	3	-	3,766,895	-	14,597	295,957	13,538,531	PULP & PAPER
โรงเผาขยะมูลฝอย	1	-	-	-	-	28,691	-	INCINERATION PLANT
โรงสีข้าว	1	-	-	-	-	51,025	-	RICE MILL
โรงงานน้ำตาล	34	-	-	-	-	2,696,775	-	SUGAR MILL
โรงไฟฟ้า	32	92,273	12,804,133	433,563	858,476	767,531	-	UTILITY COMPANY
รวม	73	94,841	16,571,028	433,563	916,856	3,839,979	13,538,531	TOTAL

ที่มา : ผู้ผลิตไฟฟ้าเอกชนรายเล็ก

หมายเหตุ : 1/ รวมแกลบ กากอ้อย ฟืน ขยะ และวัสดุเหลือใช้ทางการเกษตร

2/ รวมแบล็คลิเคอและก๊าซเหลือใช้จากขบวนการผลิต

Source : SPP

Notes : 1/ Including paddy husk, bagasse, fuel wood, garbage, and agricultural waste.

2/ Including black liquor and residual gas from production processes, etc.

TABLE 20 FUEL CONSUMPTION FOR SPP COGENERATION SELLING TO NATIONAL GRID IN 2004

ประเภทกิจการ	จำนวน No.	ก๊าซธรรมชาติ (ล้านลูกบาศก์ฟุต) NATURAL GAS (MMscf)	น้ำมันเตา (ลิตร) FUEL OIL (litre)	น้ำมันดีเซล (ลิตร) DIESEL OIL (litre)	ถ่านหินและลิกไนต์ (ตัน) COAL & LIGNITE (ton)	พลังงานหมุนเวียน 1/ (ตัน) RENEWABLE FUEL 1/ (ton)	อื่น ๆ 2/ (จิกะจูล) OTHERS 2/ (GJ)	TYPES
โรงงานผลิตเส้นใยไฟเบอร์	1	-	-	-	50,033	-	-	FIBRE PRODUCTION
โรงงานผลิตเม็ดพลาสติก	1	2,503	-	-	-	-	-	PETROCHEMICAL
โรงงานผลิตกระดาษ	3	-	3,535,243	-	15,934	324,186	12,776,227	PULP & PAPER
โรงเผาขยะมูลฝอย	1	-	-	-	-	32,457	-	INCINERATION PLANT
โรงสีข้าว	1	-	-	-	-	52,672	-	RICE MILL
โรงงานน้ำตาล	32	-	-	-	-	1,989,589	-	SUGAR MILL
โรงไฟฟ้า	30	91,201	10,947,656	584,388	822,585	672,799	-	UTILITY COMPANY
รวม	69	93,704	14,482,899	584,388	888,552	3,071,703	12,776,227	TOTAL

ที่มา : ผู้ผลิตไฟฟ้าเอกชนรายเล็ก

Source : SPP

หมายเหตุ : 1/ รวมแกลบ กากอ้อย ฟืน ขยะ และวัสดุเหลือใช้ทางการเกษตร

2/ รวมแบล็คลิเคอและก๊าซเหลือใช้จากขบวนการผลิต

Notes : 1/ Including paddy husk, bagasse, fuel wood, garbage, and agricultural waste.

2/ Including black liquor and residual gas from production processes, etc.

II. Data available for yearly net calorific value $NCV_{i,y}$[9]:

[9] Source: DEDE, http://www.dede.go.th/dede/fileadmin/usr/wpd/static/thail_ele_2006/54CONVERS.pdf

ENERGY CONTENT OF FUEL (NET CALORIFIC VALUE)

ประเภท(หน่วย)	กิโลแคลอรี/หน่วย kcal / UNIT	ตันเทียบเท่าน้ำมันดิบ/ล้านหน่วย toe / 10^6 UNIT	เมกะจูล/หน่วย MJ / UNIT	พันบีทียู/หน่วย 10^3 Btu / UNIT	TYPE(UNIT)
พลังงานเชิงพาณิชย์					COMMERCIAL ENERGY
1. น้ำมันดิบ (ลิตร)	8680	860.00	36.33	34.44	1. CRUDE OIL (litre)
2. คอนเดนเสท (ลิตร)	7900	782.72	33.07	31.35	2. CONDENSATE (litre)
3. ก๊าซธรรมชาติ					3. NATURAL GAS
3.1 ชื้น (ลูกบาศก์ฟุต)	248	24.57	1.04	0.98	3.1 WET (scf.)
3.2 แห้ง (ลูกบาศก์ฟุต)	244	24.18	1.02	0.97	3.2 DRY (scf.)
4. ผลิตภัณฑ์ปิโตรเลียม					4. PETROLEUM PRODUCTS
4.1 ก๊าซปิโตรเลียมเหลว (ลิตร)	6360	630.14	26.62	25.24	4.1 LPG (litre)
4.2 น้ำมันเบนซิน (ลิตร)	7520	745.07	31.48	29.84	4.2 GASOLINE (litre)
4.3 น้ำมันเครื่องบิน (ลิตร)	8250	817.40	34.53	32.74	4.3 JET FUEL (litre)
4.4 น้ำมันก๊าด (ลิตร)	8250	817.40	34.53	32.74	4.4 KEROSENE (litre)
4.5 น้ำมันดีเซล (ลิตร)	8700	861.98	36.42	34.52	4.5 DIESEL (litre)
4.6 น้ำมันเตา (ลิตร)	9500	941.24	39.77	37.70	4.6 FUEL OIL (litre)
4.7 ยางมะตอย (ลิตร)	9840	974.93	41.19	39.05	4.7 BITUMEN (litre)
4.8 ปิโตรเลียมโค้ก (กก.)	8400	832.26	35.16	33.33	4.8 PETROLEUM COKE (kg)
5. ไฟฟ้า (กิโลวัตต์ชั่วโมง)	860	85.21	3.60	3.41	5. ELECTRICITY (kWh)
6. ไฟฟ้าพลังน้ำ (กิโลวัตต์ชั่วโมง)	2236	221.54	9.36	8.87	6. HYDROELECTRIC (kWh)
7. พลังงานความร้อนใต้พิภพ (กิโลวัตต์ชั่วโมง)	9500	941.24	39.77	37.70	7. GEOTHERMAL (kWh)
8. ถ่านหินนำเข้า (กก.)	6300	624.19	26.37	25.00	8. COAL IMPORT (kg.)
9. ถ่านโค้ก (กก.)	6600	653.92	27.63	26.19	9. COKE (kg.)
10. แอนทราไซต์ (กก.)	7500	743.09	31.40	29.76	10. ANTHRACITE (kg.)
11. อีเทน (กก.)	11203	1110.05	46.89	44.45	11. ETHANE (kg.)
12. โปรเพน (กก.)	11256	1115.34	47.11	44.67	12. PROPANE (kg.)
13. ลิกไนต์					13. LIGNITE
13.1 ลี้ (กก.)	4400	435.94	18.42	17.46	13.1 LI (kg.)
13.2 กระบี่ (กก.)	2600	257.60	10.88	10.32	13.2 KRABI (kg.)
13.3 แม่เมาะ (กก.)	2500	247.70	10.47	9.92	13.3 MAE MOH (kg.)
13.4 แจ้คอน(กก.)	3610	357.67	15.11	14.32	13.4 CHAE KHON (kg.)
พลังงานใหม่และหมุนเวียน					NEW & RENEWABLE ENERGY
1. ฟืน (กก.)	3820	378.48	15.99	15.16	1. FUEL WOOD (kg.)
2. ถ่าน (กก.)	6900	683.64	28.88	27.38	2. CHARCOAL (kg.)
3. แกลบ (กก.)	3440	340.83	14.40	13.65	3. PADDY HUSK (kg.)
4. กากอ้อย (กก.)	1800	178.34	7.53	7.14	4. BAGASSE (kg.)
5. ขยะ (กก.)	1160	114.93	4.86	4.60	5. GARBAGE (kg.)
6. ขี้เลื่อย(กก.)	2600	257.60	10.88	10.32	6. SAW DUST (kg.)
7. วัสดุเหลือใช้ทางการเกษตร (กก.)	3030	300.21	12.68	12.02	7. AGRICULTURAL WASTE (kg.)
8. ก๊าซชีวภาพ (ลูกบาศก์เมตร)	5000	495.39	20.93	19.84	8. BIOGAS (m^3)

<u>III. Data available for carbon emission factor of fossil fuel type $EF_{CO2i,y}$:</u>

We apply 2006 IPCC Guidelines for National Greenhouse Gas Inventories default values:

Fuel type	EF $_{CO2,i,y}$ (tCO_2/TJ)
Fuel oil	77.4
Diesel oil	74.1
Coal and lignite	101
Natural gas	56.1

IV. Application of the simple OM formula:

Year	Fuel	$FC_{i,m,y}$ (unit)	$NCV_{i,y}$ (TJ/unit)	EF $_{CO2,i,y}$ (tCO_2/TJ)	**Total tCO_2**	**$EG_{m,y}$ (GWh)**	**$EF_{grid,OM,y}$ (tCO_2/MWh)**
2004	Fuel oil (million l)	1,711	39.77	77.4	5,268,284		
	Diesel oil (million l)	121	36.42	74.1	325,423		
	Coal and lignite (Gg)	17,426	13.72	101	24,146,936		
	Natural gas (MMscf)	818,264	1.03	56.1	47,281,749		
	Total				**77,022,391**	**119,685**	**0.64**
2005	Fuel oil (million l)	2,013	39.77	77.4	6,195,092		
	Diesel oil (million l)	83	36.42	74.1	225,162		
	Coal and lignite (Gg)	17,488	13.72	101	24,233,272		
	Natural gas (MMscf)	858,959	1.03	56.1	49,633,228		
	Total				**80,286,754**	**126,209**	**0.64**
2006	Fuel oil (million l)	2,038	39.77	77.4	6,273,905		
	Diesel oil (million l)	41	36.42	74.1	111,824		
	Coal and lignite (Gg)	18,082	13.72	101	25,056,496		
	Natural gas (MMscf)	949,991	1.03	56.1	54,893,330		
	Total				**86,335,555**	**130,615**	**0.66**
$EF_{grid,OM,2004-2006}$ (tCO_2/MWh)							**0.65**

Hence, $\mathbf{EF_{grid,OM,y} = 0.65\ tCO_2/MWh}$

STEP 4 Identify the cohort of power units to be included in the build margin

According to the *Tool to calculate the emission factor for an electricity system*, the sample group of power units m used to calculate the build margin consists of either:
(a) The set of five power units that have been built most recently, or
(b) The set of power capacity additions in the electricity system that comprise 20% of the system generation (in MWh) and that have been built most recently.

The identified power plants that have been built the most recently and comprised more than 20% of the system generation in Thailand in 2006 are listed in the following table:

Name of power plant	Commercial operation date	Generation in 2006[10] (GWh)
Ratchaburi	Apr-2002	15,002

[10] Source: Electric Power report in Thailand, DEDE (table 8) http://www.dede.go.th/dede/index.php?id=929

Glow	Jan-2003	5,425
EPEC	Mar-2003	2,385
Krabi	Aug-2003	1,126
BLCP	Oct-2006	4,024
Total m		27,962
Total grid generation in 2006		125,011
% of the set of power plants *m*		**22.4%**

We have chosen to apply the ex-ante option: BM is calculated according to the most recent data available on unites already built for sample group m at the time of submission of the CDM-PDD to the DOE for validation, without requirement to monitor and recalculate the emission factor during the crediting period.

STEP 5 Calculate the build margin emission factor

The build margin emission factor BM is calculated as follows:

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

Where:

$EF_{grid,BM,y}$	Build margin CO_2 emission factor in year y (tCO_2/MWh)
$EG_{m,y}$	Net electricity generated and delivered to the grid by power unit m in year y (MWh)
$EF_{EL,m,y}$	CO_2 emission factor of power unit *m* in year y (tCO_2/GJ)
m	Power units included in the build margin
y	Most recent year for which power generation is data available

According to the most recent available data on generation and efficiency of the cohort of power units released by the DEDE[11]:

Name of power plant	Generation in 2006 (GWh)	Type of fuel	Efficiency (Btu/kWh)	Energy (TJ)	EF $_{CO2,i,y}$ (tCO_2/TJ)	Emission (tCO_2)	EF $_{EL,m,y}$ (tCO_2/MWh)
Ratchaburi	15,002	natural gas	7,214	114,183	56.1	6,405,657	0.43
Glow	5,425	natural gas	6,979	39,946	56.1	2,240,946	0.41
EPEC	2,385	natural gas	7,020	17,664	56.1	990,978	0.42
Krabi	1,126	fuel oil	8,918	10,595	77.4	820,016	0.73
BLCP	4,024	coal	8,910	37,828	101.0	3,820,609	0.95
Total m	27,962				**$EF_{grid,BM,y}$ (tCO_2/MWh)**		**0.59**

Hence, $\mathbf{EF_{grid,BM,y}}$ = 0.59 tCO_2/MWh

STEP 6 Calculate the combined margin emission factor

[11] Source: Electric Power report in Thailand, DEDE (table 18) http://www.dede.go.th/dede/index.php?id=929

The combined margin emission factor CM is calculated as follows:

$$\mathbf{EF_{grid,CM,y} = EF_{grid,OM,y} * w_{OM} + EF_{grid,BM,y} * w_{BM}}$$

Where:
$\mathbf{EF_{grid,OM,y}}$ = Operating margin CO_2 emission factor in year y (tCO_2/MWh)
$\mathbf{EF_{grid,BM,y}}$ = Build margin CO_2 emission factor in year y (tCO_2/MWh)
$\mathbf{w_{OM}}$ = Weighting of operating margin emission factor (%)
$\mathbf{w_{BM}}$ = Weighting of build margin emission factor (%)

Using default values set in the *Tool to calculate the emission factor for an electricity system:*
$\mathbf{w_{OM} = w_{BM} = 50\%}$ $\mathbf{EF_{grid,OM,y} = 0.59}$ $\mathbf{EF_{grid,BM,y} = 0.65}$

Hence, $\mathbf{\underline{EF_{grid,CM,y} = 0.62\ tCO_2/MWh}}$

Annex 4

SUPPLEMENTARY MONITORING INFORMATION

The degassing system consists in one unit of type HofGas – Ready 600, n° K10015, built in 2007. Provider of the unit is the company Hofstetter Umwelttechnick AG, Munchringgenstrasse 12, 3324 Hindelbank, Switzerland. (www.hofstetter.ch).

This model is a proven technology according to the EU and Chilean requirements. Certificate of Conformity of the unit was signed on 10/08/2007.

The main elements of the unit are: (see Figure 2 - Flare Unit)

- a flare station
- a pump station
- a monitoring unit.

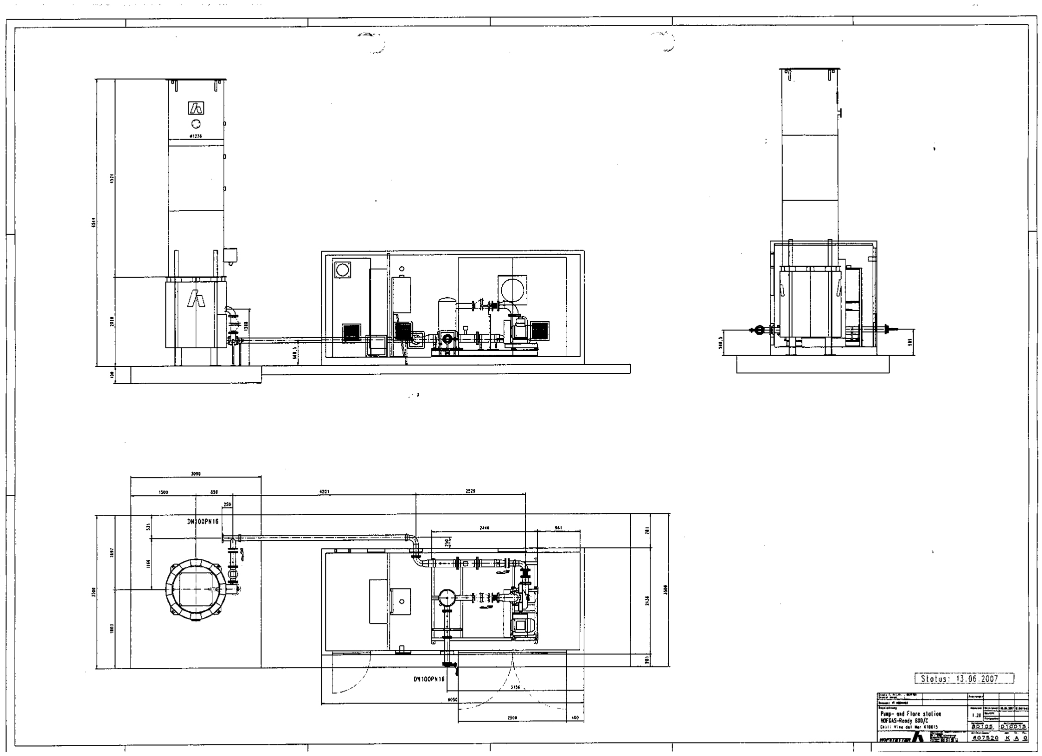
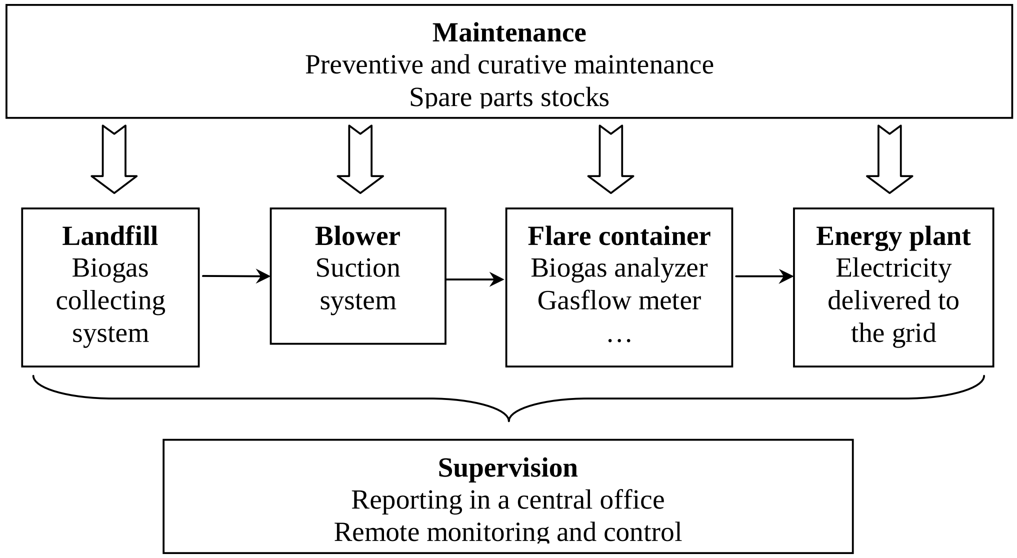


Figure 2 - Flare Unit

The installation will be continuously/permanently controlled thus insuring the safety and accurate data reporting of the emission reductions:


Maintenance
Preventive and curative maintenance
Spare parts stocks
Landfill
Biogas collecting system
Blower
Suction system
Flare container
Biogas analyzer
Gasflow meter
…
Energy plant
Electricity delivered to the grid
Supervision
Reporting in a central office
Remote monitoring and control