WASTEWATER TREATMENT
WITH BIOGAS SYSTEM
IN PALM OIL MILL
AT SAWI, CHUMPORN, THAILAND

Document Prepared By South Pole Carbon Asset Management Ltd.

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Project Title	Wastewater Treatment with Biogas System in Palm Oil Mill at Sawi , Chumporn , Thailand
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1 PROJECT DETAILS

1.1 Summary Description of the Project

The project activity was the wastewater treatment plant implemented at the Natural Palm Group in Chumporn province, operated by the Natural Energy Harvesting Co., Ltd.[1], which was founded in 2013 and has been operating a biogas plant in palm oil factory since then.

The proposed project activity entails the installation of an anaerobic wastewater treatment facility, based on Complete Stirred Tank Reactor (CSTR) biogas reactor technology and anaerobic covered lagoon which is a newly built lagoon, at the existing crude palm mill that used to discharge to the open anaerobic lagoons before discharge to existing system.

The mill first installed a 4800 m^3 capacity CSTR digester in 2005 together with a 1.064 MW gas engine (GE Jenbacher) and started to operate and exported electricity to the national grid in 2006. Later in 2007, the second gas engine (GE Jenbacher) was installed in order to support the production of electricity to the grid. In 2008, 1800 m^3 capacity CSTR was installed together with one covered lagoon receiving treated wastewater from both CSTRs in order to treat more efficiently. At the end of 2008, some biogas is sent to replace heavy fuel oil in existing dual fuel fired boiler.

Later in 2013, the CSTR no.3 and generator no.3 , followed by the CSTR no.4 in 2016 , have been added to serve the capacity extension of palm oil mill. All these additional components are not considered for the calculation of emission reductions from this project activity.

The methane produced from CSTRs and the covered lagoon is delivered to gas engines which generate electricity to serve the internal consumption and will be delivered to grid under the Power Purchasing Agreement (PPA) for Very Small Power Plant (VSPP). Any surplus biogas is sent to boiler or flare, which is an open flare.

In the absence of the project activity, the baseline wastewater treatment facility – a series of cascading open lagoon ponds - is able to treat the wastewater and meet the current environmental standards. The treated wastewater is not discharged into any body of water resource, but sent to the nearby plantation and serves as fertilizer. After implementing the project, the quality of the treated water, which is subject to effluent standards regulated by the environmental authorities, will improve substantially due to higher efficiency and improved process control of the biogas reactor as compared to open lagoons. The project will also avoid odour emissions, contributing significantly to an improved quality of life around the project site, as compared to an anaerobic lagoon. Moreover, the treated water will still be utilized as fertilizer for the plantation.

The proposed project activity helps reduce the emission of methane, which is otherwise released uncontrolled to the atmosphere from open lagoons. The proposed project activity is expected to reduce 35,028 tCO_2e annually or total of 350,280 tCO_2e during 10-years of the second crediting period.

1.2 Sectoral Scope and Project Type

The project activity involves recovery of fugitive methane emissions using Complete Stirred Tank Reactor (CSTR) system together with anaerobic covered lagoon and utilizing the biogas produced to generate electricity.

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[1] This new company is set up for the operation of biogas generation and utilization , from the wastewater discharged from palm oil mill which is owned by Natural Palm Group.

The project has an electricity generation capacity less than 15 MW and will generate emission reductions less than 60 ktCO$_2$e per year. The type/category of the project is thus according to Appendix B, *Simplified Modalities and Procedures for Small-Scale CDM Project Activities*, as follows:

Methane avoidance component:

Type III:	Other Project Activities
Category III.H:	Methane Recovery in Wastewater Treatment
Sectoral Scope 13:	Waste Handling and Disposal
Version	18

Electricity energy generation component:

Type I :	Renewable energy projects
Category I.D:	Grid connected renewable electricity generation
Sectoral Scope 01:	Energy Industries
Version	18

This project activity is not a grouped project and not AFOLU project.

1.3 Project Proponent

Organization name	Natural Energy Harvesting Co.,Ltd.[2]
Contact person	Kowit Khuansongtham
Title	Mr.
Address	250 Moo.12 Khron , Sawi , Chumporn Thailand 86130
Telephone	+66 77 557 170
Email	kowit@naturalpalm.com

1.4 Other Entities Involved in the Project

Organization name	South Pole Carbon Asset Management Ltd.
Role in the project	Emission Reduction project developer/consultant
Contact person	Santosh Kumar Singh
Title	Mr.

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[2] Refer to the 1st Monitoring report , the project owner changed its company name from *Natural Palm Oil (Chumporn) Co.,Ltd.* to *The Natural Palm Group Co.Ltd.*. This new company is a combination of Natural Refinery Co.,Ltd. , Natural Palm Oil (Chumporn) Co.,Ltd. and Natural Electric (Chumporn) Co.,Ltd.. This new company was registered on 30th December 2009 with the cancellation of the old company in the same day.
Later on in 2013 , the new company *Natural Energy Harvesting Co.,Ltd* has been registered on 25th April 2013. This company has the operating license for the biogas production and selling , issued on 8th March 2017. And another operating license issued on 30th November 2016 for the electricity generation from biogas , which the PPA will be issued in 2018.

Address	Technoparkstrasse 1, Zurich, Switzerland 8005
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1.5 Project Start Date

Project start date is 15/05/2006, the date of first usage of biogas in gas engine to generate power i.e. destruction of captured biogas starts.

1.6 Project Crediting Period

The second crediting period is ten years, from 01/06/2016 to 31/05/2026.

1.7 Project Scale and Estimated GHG Emission Reductions or Removals

Project Scale	
Project	X
Large project	

Year	Estimated GHG emission reductions or removals (tCO_2e)
Year 2016	20,433
Year 2017	35,028
Year 2018	35,028
Year 2019	35,028
Year 2020	35,028
Year 2021	35,028
Year 2022	35,028
Year 2023	35,028
Year 2024	35,028
Year 2025	35,028
Year 2026	14,595
Total estimated ERs	350,280
Total number of crediting years	10
Average annual ERs	35,028

1.8 Description of the Project Activity

Wastewater treatment:

The proposed project activity entails the installation of an anaerobic wastewater treatment facility, based on Complete Stirred Tank Reactor (CSTR) and anaerobic covered lagoon technologies, at the existing palm oil mill, replacing the open anaerobic lagoon based system.

From the operation of the digester system, biogas will be produced and used for generation of electricity. There are 2 gas engines (GE Jenbacher) included in project boundary, with a capacity of 1.064 MW and 1.415 MW respectively.

Technology Description

The system comprises five major components: equalization pond, CSTR reactor tank, covered lagoon, gas storage and gas engine set.

Continuous Stirred Tank Reactor, CSTR technology is used in the project for methane biogas generation from wastewater with a high concentration of organic content by anaerobic digestion. The CSTR reactor consists of a well-stirred tank, incorporating a mechanical stirrer. The wastewater is continuously pumped into the reactor at the same time as the treated water is removed. The CSTR is a versatile reactor, which allows simple catalyst charging and replacement. Its well-mixed nature (due to stirring) permits straightforward control over the temperature and pH of the reaction and the supply or removal of gas. The two CSTRs are implemented at a gap of two years and have a volumetric capacity of 4800 m^3 and 1800 m^3 respectively.

Anaerobic covered lagoon is a simple, effective and reliable technology to capture anaerobic lagoon-produced biogas. Material, used to cover the anaerobic pond, is synthetic high density polyethylene (HDPE) which is sealed by means of strip-to-strip welding and a peripheral anchor trenched around the perimeter of the existing lagoon.

Biogas handling and storage

The project has a gas scrubbing system installed to cleanse the gas to finally use in the gas engines and two gas storages of capacity 5000 Nm^3 and 2000Nm^3 are available at project site. The gas storage sends the gas to gas cleansing system i.e. scrubber and then the blower delivers the gas to gas engines for electricity generation.

Secondary treatment system and final wastewater

The effluent from the wastewater treatment system will flow into the existing system of 8 cascading lagoons. It must be mentioned that there is no wastewater discharge outside the factory at all. The method of final discharge remains the same before and after the project activity. A relatively small amount of sludge will be removed infrequently and will be treated aerobically by land application.

After the installation of CSTRs and covered lagoon, the wastewater will first be treated in the biogas digesters before discharge to existing lagoons so the improving quality of wastewater and odour quality will be the priority expectation. The methane capture will be used as fuel for gas engines which will also reduce the emission from methane avoidance which causes global warming.

Table 1 : Description of main equipments in the project activity

Project/Baseline Component	Brief Description
Lagoon System	There are 8 open anaerobic lagoons at the baseline. The starting date of open anaerobic lagoon is July 2003.
CSTR (2 units)	The primary digesters, which are used in the project, have the capacity of 4800 m^3 for the CSTR1 and 1800 m^3 for CSTR2. The commissioning date for those are on February 2006 and February 2007
Covered lagoon	The covered lagoon is the anaerobic digester which is having the capacity of 25,168 m^3. It was commissioned together with CSTR2
Gas storage	There are two gas storages in the project site. The capacities are 5,000 and 2,000 m^3.
Gas engine	There are 2 gas engines (GE Jenbacher) have a capacity of 1.064 MW and 1.415 MW respectively. The first one was installed in 2005 and the second one later in 2007.
Flare (open flare type)	Flare has a maximum operation capacity of 500 Nm^3/hr as per the technology description in the proposal. This is higher than maximum gas generation capacity of anaerobic wastewater treatment plant. Commissioning date of flare is March 2006.
Capacity of Auxiliary drive	Total capacity of the auxiliary drives amount to 181.3 kW; the same can be referred in the GHG calculation sheet as well as in the document submitted during validation.

1.9 Project Location

The project site is located on the site of the Natural Palm Group (Chumporn) factory, located at address: 250 M. 12 Petchkasem Rd, Khron, Sawi, Chumporn, about 530 km south of Bangkok.

The project site is located at Lat 10°17"34'N and Long 99°5"27'E .

Figure 1 : Project Location

1.10 Conditions Prior to Project Initiation

Wastewater treatment:

Prior to project implementation, the waste water from the palm oil mill is treated in a system of 8 cascading lagoons. In project activity the baseline system is still in use, and functions as a secondary treatment system.

Over the past 3 years, 2005-2007, the factory has processed an average of 43,875 tons of palm oil per year. Prior to implementation of the project activity, the wastewater from the plant was treated through a system of 8 cascading lagoons. The average volume of waste water is about 450 m^3/day which gives a retention time of approximately 289 days. The ponds are minimum 2 meters in depth measured from the water surface. The deepest pond is 5 m deep. The average atmospheric temperature in the region is 27 degree Celsius[3]. These conditions result in an anaerobic environment within the ponds, resulting in methane generation from the organic content (characterized by chemical oxygen demand or COD) of the wastewater.

Prior to project implementation, the sludge removal from lagoons is an irregular mechanism as anaerobic process does not lead to excessive sludge formation. The sludge removal from lagoons is a need based mechanism and observed interval of sludge removal is once a year during the past. The sludge removed is used for soil application as a fertilizer in the plant premises. Under the post-project scenario, any sludge removed from lagoons or anaerobic digester system is planned to be used for soil application.

Electricity Generation:

Fossil fuels based grid electricity by the Provincial Electricity Authority (PEA), is displaced by power generated in project activity. Additionally , the electricity supplied from the internal biomass power plant is the preferable as a secondary source for electricity supply to project activity.

Prior to project implementation, the sludge removal from lagoons is an irregular mechanism as anaerobic process does not lead to excessive sludge formation. The sludge removal from lagoons is a need based mechanism and observed interval of sludge removal is once a year during the past. The sludge removed is used for soil application as a fertilizer in the plant premises. Under the post-project scenario, any sludge removed from lagoons or anaerobic digester system is planned to be used for soil application.

1.11 Compliance with Laws, Statutes and Other Regulatory Frameworks

The proposed project activity is in compliance with factory of Act, local laws and regulations such as the operation permit from the local government section and the Ministry of Industry, Thailand. The plant has the necessary legal documents including property deed, construction permit and operation permit. Moreover, the project activity needs to be get acceptance from the local stakeholders since any stakeholders' bad comment can be effect to the operation permit approval from Industrial Work Department (DIW).

The project's compliance to the local laws and regulations is confirmed by applicable operation license. For no discharge of wastewater outside the plant operational boundary the wastewater discharge regulations are not application in host country.

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[3] Source: http://www.tmd.go.th/agromet_report.php

Laws and regulations	Control on	Demonstration of the compliance
Regulation on the limitation of discharge wastewater	Limit on COD of 400 mg/l of wastewater from all type of industry[4].	This project did not discharge wastewater to outside of the factory, instead the wastewater is used in the plantation area.

A valid operation permit ensures the compliance to applicable laws and regulations.

1.12 Ownership and Other Programs

1.12.1 Project Ownership

The ownership of project proponent can be verified through following documents;

- Operation license of Natural Energy Harvesting Co.,Ltd.

1.12.2 Emissions Trading Programs and Other Binding Limits

The net GHG emission reductions or removals generated by the project will not be used for compliance with an emissions trading program or to meet binding limits on GHG emissions.

1.12.3 Other Forms of Environmental Credit

The project neither has nor intends to generate any other form of GHG-related environmental credit for GHG emission reductions or removals claimed under the VCS Program.

1.12.4 Participation under Other GHG Programs

The project has not been or will be registered under other GHG programs.

1.12.5 Projects Rejected by Other GHG Programs

The project has not been rejected by any other GHG programs.

1.13 Additional Information Relevant to the Project

Eligibility Criteria

As this project is not a grouped project activity, the eligibility criteria is not applicable.

Leakage Management

Not Applicable.

Commercially Sensitive Information

Not Applicable.

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[4] Notification by the Ministry of Industry, No. 2, B.E. 2539 (1996) issued under the Factory Act B.E. 2535 (1992); Re: Standard of Discharging Effluent from Factories. As well, the maximum permissible COD content of wastewater discharge is 400 mg/l for all types of industry.

Sustainable Development

The project activity is certified with Roundtable on Sustainable Palm Oil[5] (RSPO) , to reduce the negative impact of palm oil cultivation on the environment and communities. The project activity can contribute the sustainable development in more than one way as described below.

1. Technical:

The advanced biogas reactor systems, CSTR and covered lagoon, are implemented for using biogas as fuel for electricity generators. As compared to the baseline scenario, the installed wastewater treatment system consists of an efficient process for wastewater treatment based on state of the art technology. The usage of reactor allows reducing the water losses due to evaporation and achieving the same efficiency of COD removal in a reduced period of time.

The anaerobic digester requires special training of skilled staff to operate and maintain the biogas plant, creating employment and leading to knowledge transfer to the host country and especially to rural region of the country. The use of this technology in wastewater treatment by the project owner will popularize the technological knowhow in the nearby areas and in plants looking for similar technologies in the country.

Also, the locally produced equipment may be put to use in other parts of Thailand for similar purposes. Geographically, transfer of technology and know-how has occurred mainly from urban to rural areas.

2. Economic:

New jobs will be created during the construction and operation phrases of biogas reactor systems. As well, regional economic development can foster through contracts to local firms. In addition, not only that partial reimbursement on the vast investment cost can be made through utilization of the captured biogas, the additional revenue from the sale of VERs will also make the project financially feasible.

3. Sectoral:

The project is a good example of an effective waste to energy project which in turn improve the long-term sustainability of the Thai Palm oil industry.

4. Social:

The project activity provides direct and indirect employment to the local community during construction of the project activity and as well as during operation. During construction, employment was offered for lot of local unskilled labors contributing to social well being and economic well being. The involvement of local employees in the project activity will help to enhance the skills of the labor in the region by training them in different technical areas. In addition, the close collaboration between external experts and local counterparts is expected to promote long-term sustainable partnerships, benefiting the local stakeholders.

The substitution of fuel oil with biogas from the project activity will result in energy security improvement of region. The noise, arising from pumps and blowers operating in the biogas plant, is insignificant. There are no other occupational health issues identified. The safety aspects of operating the biogas plant will be sufficiently addressed.

HDPE piping is used for transporting the generated gas, which avoids all possibilities of corrosion, leakage and fire hazard.

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[5] https://www.rspo.org/members/794/The-Natural-Palm-Group-Co.Ltd

5. Environmental:

The proposed project activity captures the methane which otherwise would have been let into the atmosphere, and uses the biogas generated for energy purposes, thereby achieving better local air quality.

The project activity has zero discharge to the river or other natural sources such as soils and groundwater. The treated water which contains plant nutrients such as Nitrogen, Phosphorus and Potassium will be stored in the holding pond, the last pond in the wastewater treatment series. The project owner aims to use the final treated water for recycling water in the cleaning the raw material (tapioca root and for irrigation on the company's plantations. The benefits of this are water and fertilizer savings.

Since the project owner uses wastewater and stores water from precipitation for utilization in the manufacturing process should not be a problem for the local community. Thus, wastewater leakage is unlikely.

Further, the project avoids odour emissions as compared to an anaerobic lagoon, which contributes significantly to improved health and quality of life and around the project site.

Note that wastewater overflow might happen during the rainy season if the precipitation rate is higher than the outflow rate of the final pond for a sustained period of time. The palm oil mill and the pond systems are surrounded by agricultural land. Wastewater overflow can lead to a variety of problems that have significant environmental impacts. Excess nutrients in the wastewater will stimulate excessive plant growth which can disrupt normal functioning of the ecosystem, known as Eutrophication. Such problem could lead to social conflicts within the community. While wastewater can overflow from any ponds in the old anaerobic lagoon, the overflow can only happen from the post-treatment ponds in the closed anaerobic system.

Since the average water quality at the outlet of the project activity is better than that in the anaerobic lagoon ponds, the environmental impacts from overflow of wastewater is significantly reduced. Overall, the project has positive impacts on the local environment by improving air quality through reduction in odour and cleaner emissions. This can in turn improve the standard of living of the local population.

6. Geographic/site specific:

The project can be uniquely identified with no barriers regarding logistic. In addition, it is not located in sensitive area such as protected area or where there is any fragile or vulnerable habitats close by. Thus, there are no issues preventing the eligibility of the project in this regard.

Further Information

Not Applicable.

2 APPLICATION OF METHODOLOGY

2.1 Title and Reference of Methodology

Baseline & Monitoring Methodology for the project activity is defined:

- AMS III.H : Methane Recovery in Wastewater Treatment, version 18.0;
- AMS I.D : Grid connected renewal electricity generation, version 18.0.

The above selected methodologies also refer to the latest approved versions of the following approved methodologies and methodological tools:

- Project emissions from flaring, version 02.0.0;
- Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation" , version 03.0.
- Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion, version 03.0;
- Tool to calculate the emission factor for an electricity system, version 06.0.

2.2 Applicability of Methodology

Applicability Criteria from AMS III.H	Project Status
2. This methodology comprises measures that recover biogas from biogenic organic matter in wastewater by means of one, or a combination, of the following options: (a) Substitution of aerobic wastewater or sludge treatment systems with anaerobic systems with biogas recovery and combustion; (b) Introduction of anaerobic sludge treatment system with biogas recovery and combustion to a wastewater treatment plant without sludge treatment; (c) Introduction of biogas recovery and combustion to a sludge treatment system; (d) Introduction of biogas recovery and combustion to an anaerobic wastewater treatment system such as anaerobic reactor, lagoon, septic tank or an on-site industrial plant; (e) Introduction of anaerobic wastewater treatment with biogas recovery and combustion, with or without anaerobic sludge treatment, to an untreated wastewater stream; (f) Introduction of a sequential stage of wastewater treatment with biogas recovery and combustion, with or without sludge treatment, to an anaerobic wastewater	In the absence of the project activity the wastewater would have been treated in existing open lagoons (all with depth greater than 2 meters) under anaerobic condition without biogas recovery. The project activity involves the installation of CSTR and covered lagoon system to treat high COD concentration of wastewater generated and to capture biogas. Therefore, the project activity can fulfil the applicability condition (f).

Applicability Criteria from AMS III.H	Project Status
treatment system without biogas recovery (e.g. introduction of treatment in an anaerobic reactor with biogas recovery as a sequential treatment step for the wastewater that is presently being treated in an anaerobic lagoon without methane recovery).	
3. In cases where baseline system is anaerobic lagoon the methodology is applicable if: a) The lagoons are ponds with a depth greater than two meters, without aeration. The value for depth is obtained from engineering design documents, or through direct measurement, or by dividing the surface area by the total volume. If the lagoon filling level varies seasonally, the average of the highest and lowest levels may be taken; b) Ambient temperature above 15°C, at least during part of the year, on a monthly average basis; c) The minimum interval between two consecutive sludge removal events shall be 30 days.	The wastewater would have been treated in an open anaerobic lagoon in the absence of the project. a) The baseline system is anaerobic lagoons with the minimum depth of 2 m.; b) The average atmospheric temperature in the region is 27 degree Celsius[6]; c) There was no any sludge removal before the implementation of project activity. The minimum interval is definitely more than 30 days. Therefore, the project activity is applicable for this criterion.
4. The recovered biogas from the above measures may also be utilised for the following applications instead of combustion/flaring: a) Thermal or mechanical, electrical energy generation directly; b) Thermal or mechanical, electrical energy generation after bottling of upgraded biogas, in this case additional guidance provided in the appendix shall be followed; or c) Thermal or mechanical, electrical energy generation after upgrading and distribution, in this case additional guidance provided in the appendix shall be followed: i. Upgrading and injection of biogas into a natural gas distribution grid with no significant transmission constraints; ii. Upgrading and transportation of biogas via a dedicated piped network to a group of end users; or iii. Upgrading and transportation of biogas (e.g. by trucks) to distribution points for end users; d) Hydrogen production;	The captured biogas from the project activity will be utilized for thermal and electricity energy generation directly which falls under condition a).

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[6] Source: METEOROLOGICAL DEPARTMENT, website http://www.tmd.go.th/agromet_report.php

Applicability Criteria from AMS III.H	Project Status
e) Use as fuel in transportation applications after upgrading.	
5. If the recovered biogas is used for project activities covered under paragraph 4(a), that component of the project activity can use a corresponding methodology under Type I.	The project activity also applies AMS I.D for electricity generation component.
6. For project activities covered under paragraph 4(b), if bottles with upgraded biogas are sold outside the project boundary, the end-use of the biogas shall be ensured via a contract between the bottled biogas vendor and the end-user. No emission reductions may be claimed from the displacement of fuels from the end use of bottled biogas in such situations. If, however, the end use of the bottled biogas is included in the project boundary and is monitored during the crediting period CO_2 emissions avoided by the displacement of fossil fuel can be claimed under the corresponding Type I methodology, e.g. “AMS-I.C.: Thermal energy production with or without electricity”.	This condition is not relevant to the project activity.
7. For project activities covered under paragraph 4(c)(i), emission reductions from the displacement of the use of natural gas are eligible under this methodology, provided the geographical extent of the natural gas distribution grid is within the host country boundaries.	This condition is not relevant to the project activity.
8. For project activities covered under paragraph 4(c)(ii), emission reductions for the displacement of the use of fuels can be claimed following the provision in the corresponding Type I methodology, e.g. AMS-I.C.	This condition is not relevant to the project activity.
9. In particular, for the case of paragraph 4(b) and (c)(iii), the physical leakage during storage and transportation of upgraded biogas, as well as the emissions from fossil fuel consumed by vehicles for transporting biogas shall be considered. Relevant procedures in paragraph 18 of the appendix of “AMS-III.H.: Methane recovery in wastewater treatment” shall be followed in this regard.	This condition is not relevant to the project activity.
10. For project activities covered under paragraph 4(b) and (c), this methodology is applicable if the upgraded methane content of the biogas is in accordance with relevant national regulations (where these exist) or, in the absence of national regulations, a minimum of 96 per cent (by volume).	This condition is not relevant to the project activity.

Applicability Criteria from AMS III.H	Project Status
11. If the recovered is utilized for the production of hydrogen (project activities covered under paragraph 3(d)), that component of the project activity shall use the corresponding methodology "AMS III.O.: Hydrogen production using methane extracted from biogas".	This condition is not relevant to the project activity.
12. If the recovered biogas is used for project activities covered under paragraph 4(e), that component of the project activity shall use corresponding methodology "AMS-III.AQ.: Introduction of Bio-CNG in transportation applications".	This condition is not relevant to the project activity.
13. New facilities (Greenfield projects) and project activities involving a change of equipment resulting in a capacity addition of the wastewater or sludge treatment system compared to the designed capacity of the baseline treatment system are only eligible to apply this methodology if they comply with the relevant requirements in the "General guidelines for SSC CDM methodologies". In addition the requirements for demonstrating the remaining lifetime of the equipment replaced, as described in the general guidelines shall be followed.	The project activity is not a greenfield project. Hence this condition is not relevant to the project activity.
14. The location of the wastewater treatment plant as well as the source generating the wastewater shall be uniquely defined and described in the PDD.	The location of project activity is clearly identified in section 1.9 above.
15. Measures are limited to those that result in aggregate emissions reductions of less than or equal to 60 kt CO_2 equivalent annually from all Type III components of the project activity.	The emission reductions achieved by this project activity is 35,028 tCO_2e per year which is much less than the limit.

Applicability Criteria from AMS I.D	Project Status
2. This methodology comprises renewable energy generation units, such as photovoltaics, hydro, tidal/wave, wind, geothermal and renewable biomass: (a) Supplying electricity to a national or a regional grid; or (b) Supplying electricity to an identified consumer facility via national/regional grid through a contractual arrangement such as wheeling.	The project involves the installation of generators that will use biogas as fuel to produce electricity. The total capacity of the generators is 2.479 MW. Hence, the project activity is satisfied with this applicability criterion.
3. Illustration of respective situations under which each of the methodology (i.e. "AMS-I.D.: Grid	The project activity will use a part of biogas (a renewable fuel) which is

connected renewable electricity generation", "AMS-I.F.: Renewable electricity generation for captive use and mini-grid" and "AMS-I.A.: Electricity generation by the user) applies is included in the appendix.	captured from the methane avoidance component of the project activity to generate electricity by the gas engines. The electricity generated will be firstly served the internal consumption and then exported to the national grid. Hence, it can be concluded that AMS I.D is applicable for this project activity.
4. This methodology is applicable to project activities that (a) Install a Greenfield plan; (b) Involve a capacity addition in (an) existing plant(s); (c) Involve a retrofit of (an) existing plant(s); (d) Involve a rehabilitation of (an) existing plant(s)/unit(s); or (e) Involve a replacement of (an) existing plant(s).	The project activity will install a gas engine set at the project site where there was no renewable energy power plant operating prior to the implementation of the project.
5. Hydro power plants with reservoirs that satisfy at least one of the following conditions are eligible to this methodology: (a) The project activity is implemented in an existing reservoir with no change in the volume of reservoir; (b) The project activity is implemented in an existing reservoir, where the volume of reservoir is increased and the power density of the project activity, as per definitions given in the project emissions section, is greater than 4 W/m_2; (c) The project activity results in new reservoirs and the power density of the power plant, as per definitions given in the project emissions section, is greater than 4 W/m^2.	This condition is not relevant to the project activity.
6. If the new unit has both renewable and non-renewable components (e.g. a wind/diesel unit), the eligibility limit of 15MW for a small-scale CDM project activity applies only to the renewable component. If the unit added co-fires fossil fuel, the capacity of the entire unit shall not exceed the limit of 15 MW.	The total capacity of the generators for producing electricity is 2.479 MW which does not use the co-fired fossil fuel. Therefore, the project activity is applicable for this criterion.
7. Combined heat and power (co-generation) systems are not eligible under this category.	This condition is not relevant to the project activity
8. In the case of project activities that involve the capacity addition of renewable energy generation units at an existing renewable power generation facility, the added capacity of the units added by the project should be lower than 15 MW and should be physically distinct from the existing units.	This condition is not relevant to the project activity

9. In the case of retrofit, rehabilitation or replacement, to qualify as a small-scale project, the total output of the retrofitted, rehabilitated or replacement power plant/unit shall not exceed the limit of 15 MW.	This condition is not relevant to the project activity
10. In the case of landfill gas, waste gas, wastewater treatment and agro-industries projects, recovered methane emissions are eligible under a relevant Type III category. If the recovered methane is used for electricity generation for supply to a grid then the baseline for the electricity component shall be in accordance with procedure prescribed under this methodology. If the recovered methane is used for heat generation or cogeneration other applicable Type-I methodologies such as “AMS-I.C.: Thermal energy production with or without electricity” shall be explored.	The approved baseline and monitoring methodologies. AMS-I.D. is used for the electricity generation components of the project activity.
11. In case biomass is sourced from dedicated plantations, the applicability criteria in the tool “Project emissions from cultivation of biomass” shall apply.	This condition is not relevant to the project activity

2.3 Project Boundary

The project boundary is the physical, geographical site where the wastewater and sludge treatment takes place, in the baseline and project situations. It covers all facilities affected by the project activity including sites where processing, transportation and application or disposal of waste products as well as biogas takes place.

The following emission sources and gases are considered in the emission reduction calculation of this project activity.

Source		Gas	Included?	Justification/Explanation
Baseline	Emission from the existing wastewater treatment system, i.e., open lagoon system	CH_4	Included	Emission from decomposition of organic matter in anaerobic conditions.
		CO_2	Excluded	CO_2 emissions from the decomposition of organic matter are not accounted for because biogenic in nature.
		N_2O	Excluded	Excluded for simplification.
	Electricity energy Generation	CH_4	Excluded	Excluded for simplification. This is conservative
		CO_2	Included	Emission from electricity generation in the grid displaced by the project activity.
		N_2O	Excluded	Excluded for simplification. This is conservative
Pr oje		CH_4	Included	The treatment of wastewater under the project activity are from:

Source		Gas	Included?	Justification/Explanation
	Wastewater treatment system			- Decomposition of the organic matter in the open anaerobic lagoons - Physical leakage from the bio-digester - Incomplete flaring
		CO_2	Excluded	CO_2 emissions from the decomposition of organic matter are not accounted for because biogenic in nature.
		N_2O	Excluded	Excluded for simplification. This is conservative.
	On-site electricity use	CH_4	Excluded	Excluded for simplification. This emission source is assumed to be very small.
		CO_2	Included	On-site electricity consumed by project activity which is imported from grid will be accounted for.
		N_2O	Excluded	Excluded for simplification. This emission source is assumed to be very small.

The system boundaries for calculation of project and baseline emissions is illustrated in the following figures.

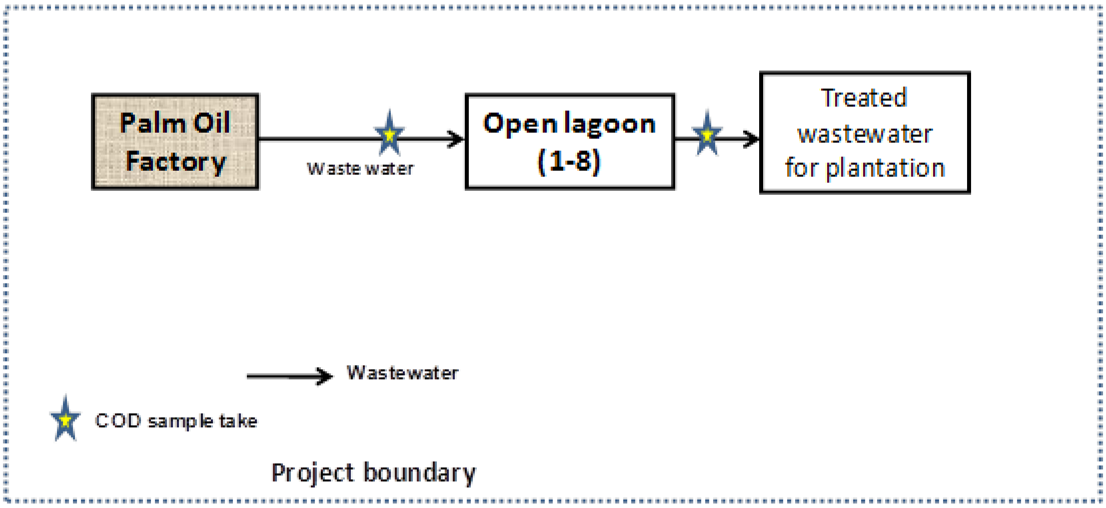

Figure 2 : The baseline system boundary

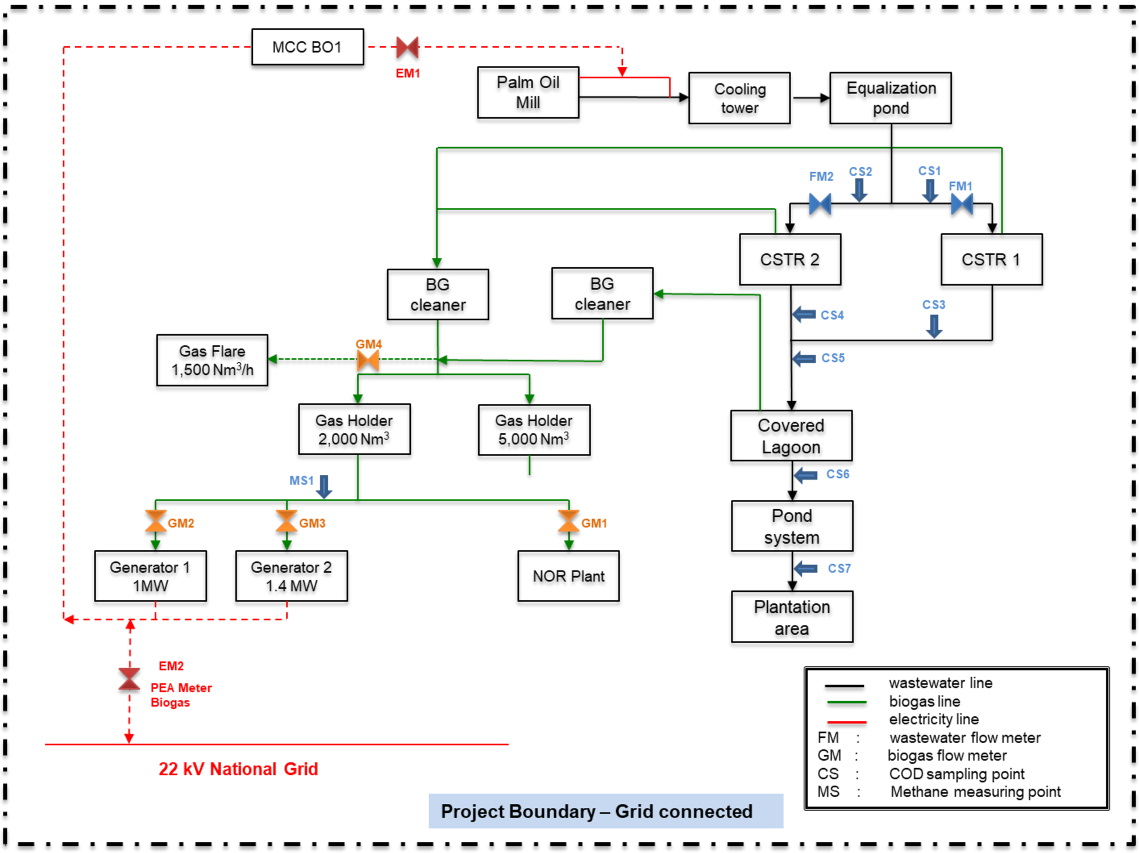

Figure 3 : The project system boundary

2.4 Baseline Scenario

Demonstration the validity of baseline scenario

As per reference from the VCS standard (version 3 v.3.7), section 3.8.5: Renewal of Project Crediting Period, *2) The validity of the original baseline scenario shall be demonstrated, or where invalid a new baseline scenario shall be determined, when renewing the project crediting period, as follows:*

Assessment as per VCS standard	Justification
(a) The validity of the original baseline scenario shall be assessed. Such assessment shall include an evaluation of the impact of new relevant national and/or sectoral policies and circumstances on the validity of the baseline scenario.	Refer to section 1.11 of this PD, *The proposed project activity is in compliance with all local laws and regulations*[7]. Therefore, there is no impact to the original baseline of project activity.
(b) Where it is determined that the original baseline is still valid, the GHG emissions associated with the original baseline scenario shall be reassessed using the latest version of the CDM Tool to assess the validity of the	The assessment is provided in Table 3 and Table 4.

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[7] https://www.jetro.go.jp/thailand/e_survey/factoryact.html
https://www.jetro.go.jp/ext_images/thailand/pdf/MOIEffluentStandards2560.pdf

Assessment as per VCS standard	**Justification**
original/current baseline and to update the baseline at the renewable of a crediting period.	
(c) Where it is determined that the original baseline scenario is no longer valid, the current baseline scenario shall be established in accordance with the VCS rues.	According to assessment result presented in Table 3 and Table 4 , the original baseline scenario is still valid. This section is not applicable.
(d) The project description, containing updated information with respect to the baseline, the estimated GHG emission reductions or removals and the monitoring plan, shall be submitted for validation.	The project description is updated and revised according to the latest approved version of AMS III.H and AMS I.D including the relevant tools to the applied methodologies.

Methane avoidance component:

At the project location, open anaerobic lagoons without methane recovery represent the existing wastewater treatment system and the biogas reactor system is being introduced as a sequential stage with methane recovery to the existing lagoon system (as defined under applicability conditions for project activity measures under the applied methodology, see Section 2.2 above).

Therefore, the baseline scenario to the project activity is defined as follows:

"The existing anaerobic wastewater treatment system without methane recovery for the case of introduction of a sequential anaerobic wastewater treatment system with methane recovery"

The baseline scenario consists of 8 anaerobic lagoons, which were used to treat wastewater prior to project implementation. The lagoons has a minimum depth of 2 m. The following table gives the description of lagoons at the starch facility.

Table 2: Characteristics of the baseline open anaerobic lagoons

pond number	Depth (m)	Storage Volume(m3)
1	5	3250
2	5	36566
3	5	24245
4	5	21512
5	3	13171
6	2	12888
7	2	18602
8	2	6840
Total Volume		137074

According to the principle design of the anaerobic pond, the average volume of waste water is about 450 $m^{3/}$day which gives a retention time of approximately 289 days. The ponds are minimum 2 meters in depth measured from the water surface. Therefore, the open lagoons of starch factory are under anaerobic process because the retention time and depth of ponds are higher than principle design value.

Table 3 : Validity of original baseline for methane avoidance component

Assessment as per CDM Tool	Justification
Step 1: Assess the validity of the current baseline for the next crediting period	
Step 1.1: Assess compliance of the current baseline with relevant mandatory national and/or sectoral polices	The project complies with the national policies as the justification is provided in the previous section.
Step 1.2: Assess the impact of circumstances	There is no change in the circumstance that would impact the continuation of existing open lagoon system as a baseline scenario of the project.
Step 1.3: Assess whether the continuation of use of current baseline equipment(s) or an investment is the most likely scenario for the crediting period for which renewal is requested.	The identified baseline scenario at the first validation of this project was the continuous using of the existing anaerobic open lagoons without any investment. This system requires extremely limited operation and maintenance due to the self-regulatory nature of the systems. Hence, lagoons are a very cost-effective solution, do not require advanced technology and are easy to operate and maintain[8]. The technical lifetime of baseline system exceeds the crediting period for which renewal is requested.
Step 1.4: Assessment of the validity of the data and parameters	All data and parameters that were determined at the start of the crediting period are updated accordingly.

The justification provided above shows that the current baseline scenario for methane avoidance component is still valid for subsequent crediting period. Therefore, all data and parameters can be used for the renewed crediting period.

Electricity generation component:

According to clause 19 of AMS.I.D , the baseline scenario for Greenfield power plant , *The baseline scenario is that the electricity delivered to the grid by the project activity would have otherwise been generated by the operation of grid-connected power plants and by the addition of new generation sources into the grid.*

In absence of the project activity, the project would use electricity supplied from grid.

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[8] Cinara, 2004 “Waste stabilization ponds for wastewater treatment, International Water and Sanitation Centre”
http://www.irc.nl/page/8237
https://bioenergyinternational.com/feedstock/asia-biogas-turning-pome-to-power

Table 4 : Validity of original baseline for electric energy generation component

Assessment as per CDM tool	Justification
Step 1: Assess the validity of the current baseline for the next crediting period	
Step 1.1: Assess compliance of the current baseline with relevant mandatory national and/or sectoral polices	The project complies the national policies as the justification is provided in the previous section.
Step 1.2: Assess the impact of circumstances	There is no change in the circumstance that would impact the continuation of using electricity from grid system as a baseline scenario of the project.
Step 1.3: Assess whether the continuation of use of current baseline equipment(s) or an investment is the most likely scenario for the crediting period for which renewal is requested.	The continuation to use the electricity imported from grid as a most likely scenario for source of electricity supplied to project activity is still applicable for this crediting period.
Step 1.4: Assessment of the validity of the data and parameters	All data and parameters that were determined at the start of the crediting period are updated accordingly.

The justification provided above shows that the current baseline scenario for thermal generation component is still valid for subsequent crediting period. Therefore, all data and parameters can be used for the renewed crediting period.

2.5 Additionality

As per the VCS standard v3.7 for the renewal of crediting period, a full reassessment of additionality is not required when renewing the project crediting period. However, regulatory surplus shall be demonstrated in accordance with Section 4.6.3) and the project description shall be updated accordingly.

Step 1: Regulatory surplus

The project shall not be mandated by any law, statute or other regulatory framework. For UNFCCC non-Annex I countries, laws, statutes, regulatory frameworks or policies implemented[9] since 11 November 2001 that give comparative advantage to less emissions intensive technologies or activities relative to more emissions-intensive technologies or activities need not be taken into account. For all countries, laws, statutes, regulatory frameworks or policies implemented since 11 December 1997 that give comparative advantage to more emissions intensive technologies or activities relative to less emissions-intensive technologies or activities shall not be taken into account.

There is no other regulatory requirement for the implementation of a specific wastewater treatment technology such as anaerobic digester or aerobic treatment system to palm oil mill for wastewater treatment[10]. The current law in Thailand, which allows the use of open lagoon

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[9] Implemented in the context of this paragraph means enacted or introduced, consistent with use of the term under the CDM rules on so-called Type E+ and Type E- policies.

[10] https://www.jetro.go.jp/thailand/e_survey/factoryact.html
https://www.jetro.go.jp/ext_images/thailand/pdf/MOIEffluentStandards2560.pdf

systems and other waste treatment technologies that meet effluent standards for the discharge of treated wastewater into the environment (COD ≤ 400 mg/l)[11]. Therefore, the proposed project activity is a regulatory surplus as it is not being implemented to respond to laws or regulations.

The assessment of additionality from the prior PD is provided as follow.

Additionality assessment

It is stated in the VCS website that *projects using existing methodologies are required to follow the additionality requirements set out in the methodology they are using*[12]. As such, the project proponents shall follow attachment A of Appendix B of the *Simplified Modalities and Procedures for Small-Scale CDM Project Activities*, to demonstrate that the project activity would not have occurred anyway due to at least one of the following barriers: (a) investment barrier, (b) technological barrier, and (c) barrier due to prevailing practice.

- **Investment Barriers:**

Open anaerobic pond systems are less sophisticated and require no upfront investments or high operation and maintenance cost. Although there are many benefits from power generation, but the benefits are much reduced due to high investment cost[13].

"On the other hand, the analysis on systems harnessing biogas for electric energy generation, as shown in Table 6, reveals that the benefits acquired from the treatment systems are very much reduced, although the annual operating revenue derived from the electricity generation systems is still comparable to that of the heat generation systems. This is due mainly to the considerably higher capital costs of the equipment involved in the former, resulting in substantially increased capital charges and depreciation cost."

A recent publication by UNDP on the Palm Oil Energy Sector demonstrates the barriers to investment and reluctance of palm oil industry to invest in Energy projects[14].

"Whilst the concept of biomass based CHP generation for sale to the grid or other consumer is well accepted, lack of experience and a number of barriers have hindered its development. Key barriers to the development …… a belief that investors view the generation and sale of electricity as marginal to the core business of the industry…... financing of projects based on renewable energy technologies is an unfamiliar investment and perceived as high risk."

For many biomass projects in South East Asia, financing has become one of the most important factors for their successful implementation. Project developers, many of which are small to medium size, are finding it difficult to provide the equity needed for the projects. Not so many of such projects are implemented compared to what can be potentially achieved[15]. Projects that have been soundly

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[11] Notification by the Ministry of Industry, No. 2, B.E. 2539 (1996) issued under the Factory Act B.E. 2535 (1992); Re: Standard of Discharging Effluent from Factories. As well, the maximum permissible COD content of wastewater discharge is 400 mg/l for all types of industry.

[12] This is again confirmed by an email communication with VCS staff.

[13] B.G. Yeoh A Technical and Economic Analysis of Heat and Power Generation from Biomethanation of Palm Oil Mill Effluent, published at Electricity Supply Industry in Transition: Issues and Prospect for Asia.

[14] United Nations Development Program, 'Generating Renewable Energy from Palm oil wastes', downloaded at http://www.energyandenvironment.undp.org/undp/index.cfm?module=Library&page=Document&DocumentID=6451. Although this report relates to Malaysia, the quotation applies to the palm oil industry as a whole – the key points are: a) not core business; b) unfamiliar investment and c) perceived as high risk, which apply to Palm industry in general. Prior to introduction of CDM, there was only one pilot project implemented in Thaialnd.

[15] Demonstration and market implementation of bio-energy for heat and electricity in South East Asia: Financing issues and CDM potential. A.D. Gonzales, A.J. Mathias.

conceived technically could be delayed or cancelled because of lack of funds to carry on once the decision to invest that had been made.

According to "Biomass and biogas energy in Thailand: Potential, opportunity and barriers[16]", *"most bioenergy projects are relatively young and small, and therefore their transaction costs are high. The projects are considered highly risky by the financiers. Hence, bioenergy project developers face more difficulty in getting finance. Without the subsidy from the ECON Fund, it is almost impossible to produce a bankable document for the loan proposal"*.

The feasibility study carried out before the project implementation stated the high risk involved in investing in the project activity due to performance related risks with complex anaerobic systems. During feasibility project proponent expected a loan up to 40% of investment or some subsidy on project implementation from EPPO (Energy Policy and Planning Office) or DIW (Department of Industrial Works).

The above explanation clearly suggests that investment related barrier is applicable to the palm oil sector and project proponent had a clear picture of risky returns from the project activity.

To study the impact of same on the project activity, analysis of the status of anaerobic systems implemented in palm oil industry is performed.

- **Prevailing Practice Barrier:**

As per Thai Biogas Report 2007[17], there are a total of 76 Palm oil plants, out of which 49 plants use the wet process and have waste water treatment systems. In a field research carried out by project proponent, information on 55 industries in palm oil sector (including project activity) was found on different resources. Another 2 companies, Saraff Biogas[18] and Vitchiban Plantation Co.[19] which are dependent on palm waste and generate renewable energy are left out of analysis as these don't have any palm crushing capacity. These two companies are anyway in the CDM pipeline for the waste water projects. So there is an approximate increase of 5 plants since 2007, in number of plants using wet process for palm oil production.

Out of these 55 palm oil mills, only 51 plants have capacity 10 or more than 10 tonne per hour. The lower capacity plants are too low to be compared with the project activity. A field research usually by means of telephonic conversation and information on internet revealed that 9 plants do not have biogas systems and 1 plant has a composting facility which is CDM project[20].

Out of the remaining 41 palm oil plants, for 8 industries the information is not available in public domain and no information was available over telephonic conversation and in most occasions, the proponent didn't want to share the information. The basic contact details are available on public sources and general company listing websites.

The remaining 33 palm oil industries have anaerobic digester systems at various stages of development or already implemented. 8 palm oil mills are at various stages of conceptualization of the anaerobic system and are also considering CDM benefits by exploring different options as per the information shared over phone.

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[16] Biomass and biogas energy in Thailand: Potential, opportunity and barriers. S. Prasertsana,*, B. Sajjakulnukitb

[17] http://www.thaibiogas.com/book/upload/book%2065%20page.pdf page – 52, 53, 2007 report.

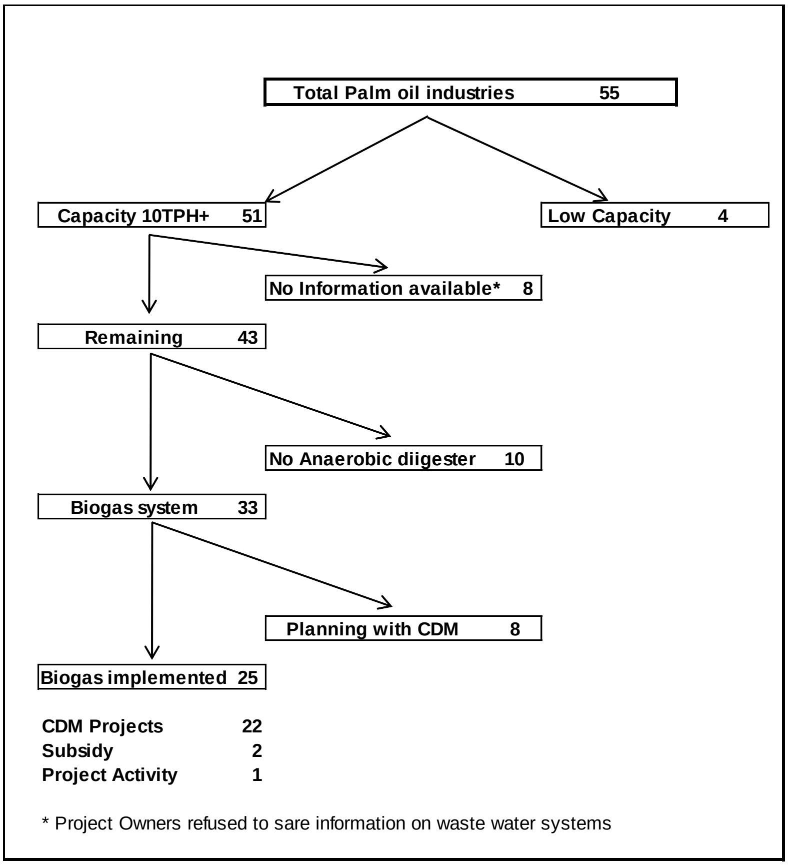
[18] http://cdm.unfccc.int/Projects/Validation/DB/SR7QM88JQ7WDFFTESOFCH9N4Z7IPV2/view.html

[19] Cited at: http://bioenergy.checkbiotech.org/news/thai_palm_oil_group_plans_biomass_energy_businesses

[20] Cited at: http://bioenergy.checkbiotech.org/news/thai_palm_oil_group_plans_biomass_energy_businesses

Remaining 25 have already operational biogas / anaerobic waste water treatment systems implemented at the palm oil facilities. 22 out of these projects are at various stages in CDM pipeline and 2 projects have received soft/loans or subsidy from EPPO.

The remaining project is the project activity i.e. Natural Palm Oil, The above information in detail along with the contact information of the palm oil industries is provided along in an excel sheet. The sample of telephone questionnaire survey is also provided with the excel sheet.



* Project Owners refused to sare information on waste water systems

The above analysis clearly indicates that there is a substantial risk in implementing the project activity without additional income from CDM or special support in form of subsidy.

The above analysis demonstrates that financial barriers are real in palm oil industry and people are not willing to take up this extra investment without the risk being covered by additional flow of money from subsidy or carbon revenues.

- **Technical Barriers:**

The above analysis clearly references and demonstrates the importance of additional income from external sources to support the project activity. These practices and behavior from the palm industry mill owners towards the anaerobic digester technologies is closely related to problems faced during implementation and operation of these technologies. The anaerobic systems are very sensitive system and require a higher level of keenness from operational staff to maintain a smooth operation.

Before the project implementation, the risks from project implementation were studied, apart from the high maintenance and operation cost projected for project activity, the major risk highlighted was related to performance for anaerobic digestion systems. The system being very sensitive to anaerobic loading and quality of effluent from the palm oil mill needs dynamic operation and control on part of operational staff.

The project activity started operation in 2006 and had very few precedents of successful anaerobic treatment systems in palm oil industry. The performance risk related to Palm Oil Mill effluent is also seen as a big risk. According to Yacob[21] et al study on anaerobic digestion of POME that discusses the cause of variable yields from *"the large variation in the chemical properties of POME and the volume discharged to the ponds, resulting in the daily variation of organic loading rate and hydraulic retention time. …. The measured quantity and quality of POME discharge varied from time to time. This in turn will affect the growth and activity of microorganisms especially the methanogens and hence the methane emission rate."*

The project involves utilization of high quality, specialized anaerobic digesters that have been adapted to working with the characteristics of POME wastewater. In Thailand there is however little expertise in this field, since the practice of using large ponds has been prevailing in industries such as tapioca, rubber, starch and palm oil manufacturing for a long time[22].

As per Chavalprit (2006)[22], 93% out of 25 i.e. 23 out of 25 Thai palm oil mills (data from 2002) used open lagoon systems. Only two installations are found to use an anaerobic system. One is a project implemented at Asian Palm Oil Mills in Krabi with support and grant from Thammasat University and EPPO (Office of Energy Policy and Planning) respectively[23] [24]. The other project being was one of the first projects to apply for CDM project[25].

In addition as per studies and interviews carried out by Nuntiya Paepatung[26], "*The performance data of biogas purification system are little or no data available on the efficiency result to trust of user. ….. There is no guideline or standard for the biogas engines. …… Therefore to more motive of biogas production for POME the recommended mechanisms are such as, the government should support the demonstration of each biogas technology, provide financial support or funding for research and develop the suitable technology, support and provide funding for R&D in biogas purification and biogas engine or other utilization.*" This report published in Oct 2007, clearly indicates that these technological risks were still prevalent at the time of project conceptualization in 2005.

Being among the first few plants to conceptualize the anaerobic system for palm oil industry, project proponent was taking a significant risk in this regard. The risks were already in mind of the project owner and the project proponent went ahead with the project keeping in mind the carbon revenues.

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[21] Yacob, S, Hassan, M, Shirai, Y, Wakisaka, M, Subash, S, 2006. 'Baseline study of methane emission from anaerobic ponds of palm oil mill effluent treatment'. Science of the Total Environment 366 (2006) 187– 196. pg 194 provided during validation.

[22] Orathai Chavalparit 2006, "Clean Technology for the Crude Palm Oil Industry in Thailand", Page -7.

[23] http://web.eng.psu.ac.th/enghome/web_Guideline/Treatment%20Web/Puetpaiboon_U.pdf

[24] See Asia-Pacific Environmental Innovation Strategies (APEIS) Research on Innovative and Strategic Policy Options (RISPO) Good Practices Inventory: Waste-to-Energy Project by a Palm Oil Manufacturer, http://www.iges.or.jp/APEIS/RISPO/inventory/db/pdf/0073.pdf , accessed 28 July 2007. For a description of this project and the common practice of wastewater treatment in Thai palm oil industry see also Arul Rajoo: Thailand's Energy And Money From Waste Water, Malaysian National News Agency (Bernama), June 27, 2007, http://www.bernama.com.my/bernama/v3/news.php?id=269835 , accessed July 28, 2007.

[25] See http://www.ambbangkok.um.dk/en/menu/DevelopmentCooperation/ProgrammeComponents/CleanDevelopmentMechanism/DanishCDMProjects/BiogasinPalmOilIndustry/. The other project at Thachana Palm Oil Company has been submitted for validation to JQA and is available at http://www.jqa.jp/service_list/environment/file/thachana_070604.pdf.

[26] ASSESSMENT OF PALM OIL MILL EFFLUENT AS BIOGAS ENERGY SOURCE IN THAILAND - http://www.scisoc.or.th/stt/33/sec_i/paper/stt33_I_I0038.pdf page - 4

Conclusion:

The proposed project activity faces several barriers in that a more financially viable alternative i.e. existing approach and a less technologically advanced technology would result in higher GHG emissions. Thus, the project proponent has a sound justification to conclude that the project activity complies with the additionality test as per *Attachment A of Appendix B of the simplified modalities and procedures for small-scale CDM project activities*.

2.6 Methodology Deviations

There is no methodology deviation proposed for this project activity.

3 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

3.1 Baseline Emissions

Baseline emissions calculation as per AMS III.H

Baseline emissions for the systems affected by the project activity can be calculated as per Equation (1) below.

$$BE_y = \{BE_{power,y} + BE_{ww,treatment,y} + BE_{s,treatment,y} + BE_{ww,discharge,y} + BE_{s,final,y}\} \quad \textbf{Equation (1)}$$

Where:

BE_y = Baseline emissions in year *y* (t CO_2e)

$BE_{power,y}$ = Baseline emissions from electricity or fuel consumption in year *y* (t CO_2e)

$BE_{ww,treatment,y}$ = Baseline emissions of the wastewater treatment systems affected by the project activity in year *y* (t CO_2e)

$BE_{s,treatment,y}$ = Baseline emissions of the sludge treatment systems affected by the project activity in year *y* (t CO_2e)

$BE_{ww,discharge,y}$ = Baseline methane emissions from degradable organic carbon in treated wastewater discharged into sea/river/lake in year y (t CO_2e). The value of this term is zero for the case 1(b)

$BE_{s,final,y}$ = Baseline methane emissions from anaerobic decay of the final sludge produced in year *y* (t CO_2e). If the sludge is controlled combusted, disposed in a landfill with biogas recovery, or used for soil application in the baseline scenario, this term shall be neglected

a) *Emissions on account of electricity or fossil fuel used ($BE_{power,y}$)*

The only electricity consumption devices used in the baseline wastewater treatment systems are pumps for pumping the wastewater from the palm oil mill into the open anaerobic lagoons. There is no consumption of fossil fuels for the operation of the baseline system.

For the sake of simplification and conservativeness, baseline emissions from electricity and fuel consumptions ($BE_{power,\ y}$) are assumed to be zero.

$BE_{power,\ y} = 0$

b) Methane emissions from baseline wastewater treatment systems ($BE_{ww,treatment,y}$);

Methane emissions from the baseline wastewater treatment systems affected by the project ($BE_{ww,treatment,y}$) are determined using the COD removal efficiency of the baseline plant:

$$BE_{ww,treatment,y} = \sum_i (Q_{ww,i,y} \times COD_{inflow,i,y} \times \eta_{COD,BL,i} \times MCF_{ww,treatment,BL,i}) \times B_{o,ww} \times UF_{BL} \times GWP_{CH4}$$

Equation (2)

Where:

$Q_{ww,i,y}$	=	Volume of wastewater treated in baseline wastewater treatment system i in year y (m^3). For ex ante estimation, forecasted wastewater generation volume or the designed capacity of the wastewater treatment facility can be used. However, the ex post emissions reduction calculation shall be based on the actual monitored volume of treated wastewater
$COD_{inflow,i,y}$	=	Chemical oxygen demand of the wastewater inflow to the baseline treatment system *i* in year *y* (t/m^3). Average value may be used through sampling with the confidence/precision level 90/10
$\eta_{COD,BL,i}$	=	COD removal efficiency of the baseline treatment system *i*, determined as per the paragraphs 38, 39 or 40 of the methodology
$MCF_{ww,treatment,BL,i}$	=	Methane correction factor for baseline wastewater treatment systems *i* as per Table 5
i	=	Index for baseline wastewater treatment system
$B_{o,ww}$	=	Methane producing capacity of the wastewater (IPCC value of 0.25 kg CH_4/kg COD)[27]
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)[28]
GWP_{CH4}	=	Global Warming Potential for methane

If the baseline treatment system is different from the treatment system in the project scenario, the monitored values of the COD inflow during crediting period will be used to calculate the baseline emissions ex post.

The Methane Correction Factor (*MCF*) shall be determined based on the following table:

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[27] Project activities may use the default value of 0.6 kg CH_4/kg BOD, if the parameter $BOD_{5,20}$ is used to determine the organic content of the wastewater. In this case, baseline and project emissions calculations shall use BOD instead of COD in the equations, and the monitoring of the project activity shall be based in direct measurements of $BOD_{5,20}$, i.e. the estimation of BOD values based on COD measurements is not allowed.

[28] Reference: FCCC/SBSTA/2003/10/Add.2, page 25.

Table 5. IPCC default values[29] for Methane Correction Factor (*MCF*)

Type of wastewater treatment and discharge pathway or system	*MCF* value
Discharge of wastewater to sea, river or lake	0.1
Land application	0.1
Aerobic treatment, well managed	0.0
Aerobic treatment, poorly managed or overloaded	0.3
Anaerobic digester for sludge without methane recovery	0.8
Anaerobic reactor without methane recovery	0.8
Anaerobic shallow lagoon (depth less than 2 metres)	0.2
Anaerobic deep lagoon (depth more than 2 metres)	0.8
Septic system	0.5
Land application [30]	0.1

c) *Methane emissions from baseline sludge treatment systems ($BE_{s,treatment,y}$)*

There is no sludge treatment system in the baseline scenario, only a wastewater treatment system based on open anaerobic lagoons, hence baseline emissions from sludge treatment are not taken into consideration.

$$BE_{s,treatment,y} = 0$$

d) *Baseline methane emissions from degradable organic carbon in treated wastewater discharged into sea/river/lake ($BE_{ww,discharge,y}$)*

In the baseline scenario, treated wastewater is not discharged into sea/lake/river, therefore methane emissions from degradable organic carbon in treated wastewater discharged ($BE_{ww, discharge, y}$) in e.g. a river, sea or lake in the baseline situation is assumed to be zero.

$$BE_{ww, discharge, y} = 0$$

e) *Baseline methane emissions from anaerobic decay of the final sludge produced ($BE_{s,final,y}$)*

For the sake of conservativeness, it is assumed that the sludge is used for soil application in the baseline scenario. Therefore baseline methane emissions from anaerobic decay of the final sludge ($BE_{s, final, y}$) produced is also neglected.

$$BE_{s, final, y} = 0$$

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[29] Default values from chapter 6 of volume 5. Waste in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

[30] Please refer SSC_664, “Clarification on methane correction factors for treated water used for irrigation under AMS-III.H ver. 16”.

Baseline emissions calculation as per AMS I.D

Baseline emissions include only CO_2 emissions from electricity generation in power plants that are displaced due to the project activity. The methodology assumes that all project electricity generation above baseline levels would have been generated by existing grid-connected power plants and the addition of new grid-connected power plants. The baseline emissions are to be calculated as follows:

$$BE_y = EG_{PJ,y} \times EF_{grid,y}$$ **Equation (1)**

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2)
$EG_{PJ,y}$	=	Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the project activity in year *y* (MWh)
$EF_{grid,y}$	=	Combined margin CO_2 emission factor for grid connected power generation in year *y* calculated using the latest version of the "Tool to calculate the emission factor for an electricity system" (t CO_2/MWh)

Greenfield power plants

If the project activity is the installation of a greenfield power plant, then:

$$EG_{PJ,y} = EG_{PJ,facility,y}$$ **Equation (2)**

Where:

$EG_{PJ,facility,y}$	=	Quantity of net electricity generation supplied by the project plant/unit to the grid in year *y* (MWh)

The emission factor shall be calculated in a transparent and conservative manner as follows:

a) A combined margin (CM), consisting of the combination of operating margin (OM) and build margin (BM) according to the procedures prescribed in the "Tool to calculate the emission factor for an electricity system"; or
b) The weighted average emissions (in t CO_2/MWh) of the current generation mix. The data of the year in which project generation occurs must be used.

Determination of $EF_{grid,y}$

The option a) : a combined margin (CM) which consisting of the combination of operating margin (OM) and build margin (BM) , is chosen in this case.

The combined margin emission factor for Grid system in Thailand is calculated and reported by Thailand Greenhouse Gas Management Organization or TGO[31]. The data used for national grid emission calculation is provided by Energy Regulatory Commission or ERC. The $EF_{grid,CM,y}$ from latest available version of the grid emissions study will be used. This approach is in line with the condition identified in clause 19: option A1 of the reference tool, ($EF_{EL,j,y} = EF_{grid,CM,y}$).

The result of grid emission factor for general project reported by the "*Thailand Grid Emission Factor for GHG Reduction Project/Activity*" , published by TGO on 28/09/2017 is shown in table below ;

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[31] http://ghgreduction.tgo.or.th/t-ver/images/Grid_Emission_Factor_2559_-_Finalised.pdf

Tool	Weight	Emission Factor	Unit
Operating Margin: OM	0.5	0.5719	tCO_2/MWh
Build Margin: BM	0.5	0.5609	
Combined Margin: CM – General Project		**0.5664**	

Refer to clause 84 (b) of *'Tool to calculate the emission factor for an electricity system'* , version 05.0 , *All other projects:* $w_{OM} = 0.5$ *and* $w_{BM} = 0.5$ *for the first crediting period, and* $w_{OM} = 0.25$ *and* $w_{BM} = 0.75$ *for the second and third crediting period.*

$$EF_{grid,CM,y} = EF_{grid,OM,y} * w_{OM} + EF_{grid,BM,y} * w_{BM}$$ **Equation (16)**

Where :

$EF_{grid,BM,y}$	Build margin CO2 emission factor in year y ($t\ CO_2/MWh$)
$EF_{grid,OM,y}$	Operating margin CO2 emission factor in year y ($t\ CO_2/MWh$)
W_{OM}	Weighting of operating margin emissions factor (per cent)
W_{BM}	Weighting of operating margin emissions factor (per cent)

The $EF_{grid,CM,y}$ is re-calculated by using equation (16) , the value to be used is 0.5637.

Table 6 : Summary of Baseline Emissions (BE) calculation

Baseline Emissions as per AMS.III.H		
Design capacity of palm oil mill	60	t/h
Operating hours	15	h/d
Wastewater generation - design value	0.50	m3/t
Operating days	300	d/y
Wastewater flow - $Q_{ww,y}$	135,000	m3/year
COD in	80,000	mg/l
Efficiency of lagoon system - COD removal	87.49%	
COD out - based on baseline system efficiency	10,010	mg/l
Model correction factor - UF_{BL}	*0.89*	
COD removal - baseline	0.069990	t/m3
$B_{o,ww}$	*0.25*	tCH4/tCOD
$MCF_{ww,treatment,BL,i}$	*0.8*	
GWP_{CH4}	25	
$BE_{ww,treatment,y}$	**42,046**	**t CO2 e/year**
MD_y	**39,901**	**t CO2 e / year**

COD removal efficiency of CSTR system	80%	
COD removal efficiency of CL	60%	
COD out - project activity	6,400	mg/l
COD removed - project activity (anaerobic)	0.0736	t/m3

Baseline Emissions as per AMS.I.D		
Electricity generation - $EG_{PJ,y}$	7,901.68	MWh
Efficiency of generator	100%	
Grid emisison factor	0.5637	tCO2/MWh
BE_y	**4,454**	**tCO2e/year**

3.2 Project Emissions

Project emissions calculation as per AMS III.H

The project emissions are calculated from

$$PE_y = \begin{Bmatrix} PE_{power,y} + PE_{ww,treatment,y} + PE_{s,treatment,y} + PE_{ww,discharge,y} + PE_{s,final,y} + \\ PE_{fugitive,y} + PE_{biomass,y} + PE_{flaring,y} \end{Bmatrix}$$ **Equation (8)**

Where:

PE_y	Project activity emissions in the year y (t CO2e)
$PE_{power,y}$	Emissions from electricity or fuel consumption in the year *y* (t CO_2e).
$PE_{ww,treatment,y}$	Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery, in year *y* (t CO_2e).
$PE_{s,treatment,y}$	Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery, in year *y* (t CO_2e).
$PE_{ww,discharge,y}$	Methane emissions from degradable organic carbon in treated wastewater in year *y* (tCO_2e).
$PE_{s,final,y}$	Methane emissions from anaerobic decay of the final sludge produced in year *y* (t CO_2e).
$PE_{fugitive,y}$	Methane emissions from biogas release in capture systems in year *y* (t CO_2e)
$PE_{flaring,y}$	Methane emissions due to incomplete flaring in year *y* (t CO_2e).
$PE_{biomass,y}$	Methane emissions from biomass stored under anaerobic conditions. (t CO_2e)

a) ***CO_2 emissions from electricity and fuel used by the project facilities ($PE_{power,y}$)***

These emissions shall be calculated as per paragraph 28 of the methodology, *If recovered biogas in the baseline is used to power auxiliary equipment it should be taken into account accordingly, using zero as its emission factor.* The electricity used by project activity will be firstly supplied by the gas engines which use biogas as fuel, to import electricity from the grid is the second option when the gas engines does not operate. However, after the COD of the biomass power plant in 2013 as VSPP, this power plant also deliver the electricity to the project activity before delivery to the grid. Then the chance that the project activity will use electricity from grid is very low. Therefore, $PE_{power,y}$ can be considered as zero.

Only when the biogas plant need to import the electricity from grid the $PE_{power,y}$ will be taken into account , which can be calculated from the same equation (1) of the baseline calculation formula for AMS I.D.

$$BE_y = EG_{PJ,y} \times EF_{grid,y}$$

b) ***Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery in the project scenario ($PE_{ww,treatment,y}$)***

These emissions shall be calculated as per equation (2) in the baseline emission calculation, using an uncertainty factor of 1.12 and data applicable to the project situation ($MCF_{ww,treatment,PJ,k}$) and with the following changed definition of parameters:

$MCF_{ww,treatment,PJ,k}$	Methane correction factor for project wastewater treatment system *k* (*MCF* values as per Table 5 above)

$$BE_{ww,treatment,y} = \sum_{i} \left(Q_{ww,i,y} \times COD_{inflow,i,y} \times \eta_{COD,BL,i} \times MCF_{ww,treatment,PJ,k}\right) \times B_{o,ww} \times UF_{BL} \times GWP_{CH4}$$

c) *Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery in the project situation ($PE_{s,treatment,y}$)*

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

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

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

e) *Methane emissions from the decay of the final sludge generated by the project activity treatment systems ($PE_{s,final,y}$)*

A relatively small amount of final sludge will be removed from the digester. The project proponent will apply final sludge for field application as fertilizer and the final disposal of the sludge shall be monitored during the crediting period. Therefore as suggested by the AMS III.H, the emission from anaerobic decay from the final sludge produced can be omitted.

f) *Methane fugitive emissions due to inefficiencies in capture systems ($PE_{fugitive,y}$)*

Project activity emissions from methane release in capture systems are determined as follows:

$$PE_{fugitive,y} = PE_{fugitive,ww,y} + PE_{fugitive,s,y}$$ **Equation (9)**

Where:

$PE_{fugitive,ww,y}$ = Fugitive emissions through capture inefficiencies in the anaerobic wastewater treatment systems in the year y (t CO2e)

$PE_{fugitive,s,y}$ = Fugitive emissions through capture inefficiencies in the anaerobic sludge treatment systems in the year *y* (t CO_2e)

$$PE_{fugitive,ww,y} = (1 - CFE_{ww}) \times MEP_{ww,treatment,y} \times GWP_{CH4}$$ **Equation (10)**

Where:

CFE_{ww} = Capture efficiency of the biogas recovery equipment in the wastewater treatment systems (a default value of 0.9 shall be used)

$MEP_{ww,treatment,y}$ = Methane emission potential of wastewater treatment systems equipped with biogas recovery system in year *y* (t)

$$MEP_{ww,treatment,y} = Q_{ww,y} \times B_{o,ww} \times UF_{PJ} \times \sum_{k} COD_{removed,PJ,k,y} \times MCF_{ww,treatment,PJ,k}$$ **Equation (11)**

Where:

$COD_{removed,PJ,k,y}$ = The chemical oxygen demand removed[32] by the treatment system *k* of the project activity equipped with biogas recovery in the year *y* (t/m^3)

$MCF_{ww,treatment,PJ,k}$ = Methane correction factor for the project wastewater treatment system *k* equipped with biogas recovery equipment (*MCF* values as per Table 2 above)

UF_{PJ} = Model correction factor to account for model uncertainties (1.12)

Since there is no anaerobic sludge treatment in the project activity. Therefore the $PE_{fugitive,s,y}$ is considered as zero and excluded from the project emission calculation.

Thus, the fugitive emissions through capture inefficiencies in the anaerobic wastewater treatment systems are given as:

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

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

If the project activity includes flaring of biogas, then project emissions from flaring of biogas ($PE_{flare,y}$) shall be estimated using the methodological tool "*Project emissions from flaring"* version 02.0.0 *.* The following applies:

- For small scale projects, project participants may adopt a default value for the fraction of methane in the biogas ($f_{CH4,default}$) in applying the tool; and
- The tool provides default factors for the flare efficiency, which can be used for large or small scale projects as described in the tool.

The calculation procedure in this tool determines the project emissions from flaring the residual gas ($PE_{flare,y}$) based on the flare efficiency ($\eta_{flare,m}$) and the mass flow of methane to the flare ($F_{CH4,RG,m}$). The flare efficiency is determined for each minute *m* of year *y* based either on monitored data or default values.

The project emission calculation procedure is given in the following steps:

---

[32] Difference between the inflow COD and the outflow COD.

Step 1: Determination of the methane mass flow in the residual gas

The "Tool to determine the mass flow of a greenhouse gas in a gaseous stream" shall be used to determine the following parameter:

Parameter	**Details**
$F_{CH4,m}$	Mass flow of methane in the residual gaseous stream in the minute *m* (kg)

The following requirements apply:

- The gaseous stream tool shall be applied to the residual gas;
- The flow of the gaseous stream shall be measured continuously;
- CH_4 is the greenhouse gas *i* for which the mass flow should be determined;
- The simplification offered for calculating the molecular mass of the gaseous stream is valid (equations 3 and 17 in the tool); and
- The time interval *t* for which mass flow should be calculated is every minute *m.*

  $F_{CH4,m}$, which is measured as the mass flow during minute *m,* shall then be used to determine the mass of methane in kilograms fed to the flare in minute *m* ($F_{CH4,RG,m}$). $F_{CH4,m}$ shall be determined on a dry basis.

Step 2: Determination of flare efficiency

Open flare

In the case of open flares, the flare efficiency in the minute m ($\eta_{flare,m}$) is 50% when the flame is detected in the minute m ($Flame_m$)**,** Otherwise $\eta_{flare,m}$ is 0%. Therefore the project will apply 0% of flare efficiency for conservativeness.

Step 3: Calculation of project emissions from flaring

Project emissions from flaring are calculated as the sum of emissions for each minute *m* in year *y,* based on the methane mass flow in the residual gas ($F_{CH4,RG,m}$) and the flare efficiency ($\eta_{flare,m}$), as follows:

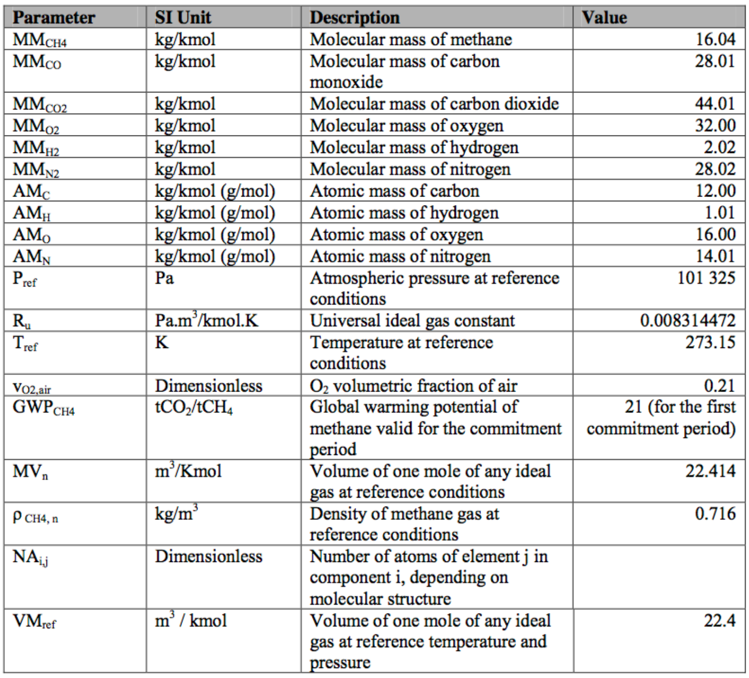
$$PE_{flare,y} = GWP_{CH4} * \sum_{m=1}^{525600} F_{CH4,RG,m} * \left(1 - \eta_{flare,m}\right) * 10^{-3} \qquad \textbf{(15)}$$

Where:

Parameter	**Details**
$PE_{flare,y}$	Project emission from flaring of the residual gas stream in year *y* (tCO_2e)
GWP_{CH4}	Global warming potential of methane valid for the commitment period (tCO_2e/tCH_4)
$F_{CH4,RG,m}$	Mass flow of methane in the residual gas in the minute *m* (kg)
$\eta_{flare,m}$	Flare efficiency in minute *m*

Parameters and data that are not monitored include the constants used in equations, as listed in table below.

Table 7 : Constants used in equations



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
P_{ref}	Pa	Atmospheric pressure at reference conditions	101 325
R_u	$Pa.m^3/kmol.K$	Universal ideal gas constant	0.008314472
T_{ref}	K	Temperature at reference conditions	273.15
$v_{O2,air}$	Dimensionless	O_2 volumetric fraction of air	0.21
GWP_{CH4}	tCO_2/tCH_4	Global warming potential of methane valid for the commitment period	21 (for the first commitment period)
MV_n	$m^3/Kmol$	Volume of one mole of any ideal gas at reference conditions	22.414
$\rho_{CH4,n}$	kg/m^3	Density of methane gas at reference conditions	0.716
$NA_{i,j}$	Dimensionless	Number of atoms of element j in component i, depending on molecular structure	
VM_{ref}	m^3 / kmol	Volume of one mole of any ideal gas at reference temperature and pressure	22.4

h) *Methane emissions from biomass stored under anaerobic conditions which would not have occurred in the baseline situation ($PE_{biomass,y}$).*

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

Table 8 : Summary of Project Emissions (PE) calculation

Project Emissions as per AMS.III.H		
Rated power capacity	181	kWh
Annual Power Consumption	1,685	MWh/year
Emission Factor of electricity (EF_y)	0.5637	tCO2/MWh
TDL	6.073%	
$PE_{power,y}$	**1,007**	**tCO2e/year**
Wastewater flow - Q ww,y	135,000	m3/year
CODout from project activity	0.0064	t/m3
COD - reduction in open lagoon	87.5%	
$B_{o,\ ww}$	0.25	tCH4/tCOD
UF_{PJ} - Model correction factor	1.12	
$MCF_{ww,\ treatment,\ PJ,\ k}$	0.8	
$PE_{ww,\ treatment,y}$	**4,233**	**tCO2e/year**
CFE - ww	0.9	
$MEP_{ww,treatment,y}$	2,226	t CH4/year
$PE_{fugitive,y}$	**6,232**	**tCO2e/year**
Biogas to be flared ($BG_{ToFlare,y}$)	0	Nm3/year
	0	kg/year
Flare efficiency	0%	
$PE_{flare,\ y}$	**0**	**tCO2e/year**

3.3 Leakage

The used technology is not equipment transferred from another activity, therefore according to AMS.III.H and AMS.I.D, there is no leakage to be considered.

3.4 Net GHG Emission Reductions and Removals

As per AMS III.H

Emission reductions shall be estimated ex ante in the PDD using the equations provided in the baseline, project and leakage emissions sections above. Emission reductions shall be estimated ex ante as follows:

$$ER_{y,ex\ ante} = BE_{y,ex\ ante} - \left(PE_{y,ex\ ante} + LE_{y,ex\ ante}\right)$$ **Equation (14)**

Where:

$ER_{y,ex\ ante}$ = Ex ante emission reduction in year *y* (t CO_2e)

$LE_{y,ex\ ante}$ = Ex ante leakage emissions in year *y* (t CO_2e)

$PE_{y,ex\ ante}$ = Ex ante project emissions in year *y* calculated as paragraph 41 (t CO_2e)

$BE_{y,ex\ ante}$ = Ex ante baseline emissions in year *y* calculated as per paragraph 27 (t CO_2e)

For cases 2(f) , ex post emission reductions shall be based on the lowest value of the following, as per paragraph 46 of the methodology;

a) The amount of biogas recovered and fuelled or flared (*MD_y*) during the crediting period, that is monitored ex post;

b) Ex post calculated baseline, project and leakage emissions based on actual monitored data for the project activity.

For cases 2(f): it is possible that the project activity involves wastewater and sludge treatment systems with higher methane conversion factors (*MCF*) or with higher efficiency than the treatment systems used in the baseline situation. Therefore the emission reductions achieved by the project activity is limited to the ex post calculated baseline emissions minus project emissions using the actual monitored data for the project activity. The emission reductions achieved in any year are the lowest value of the following:

$$ER_{y,ex\ post} = min\left(\left(BE_{y,ex\ post} - PE_{y,ex\ post} - LE_{y,ex\ post}\right), \left(MD_y - PE_{power,y} - PE_{biomass,y} - LE_{y,ex\ post}\right)\right)$$ **Equation (15)**

Where:

$ER_{y,ex\ post}$ = Emission reductions achieved by the project activity based on monitored values for year *y* (t CO_2e)

$BE_{y,ex\ post}$ = Baseline emissions calculated as per paragraph 27 using ex post monitored values

$PE_{y,ex\ post}$ = Project emissions calculated as per paragraph 41 using ex post monitored values

MD_y = Methane captured and destroyed/gainfully used by the project activity in the year *y* (t CO_2e)

In the case of flaring/combustion *MD_y* will be measured using the conditions of the flaring process:

$$MD_y = BG_{burnt,y} \times w_{CH4,y} \times D_{CH4} \times FE \times GWP_{CH4}$$ **Equation (16)**

Where:

$BG_{burnt,y}$ = Biogas[33] flared/combusted in year *y* (m^3)

$w_{CH4,y}$ = Methane content[13] of the biogas in the year *y* (volume fraction)

D_{CH4} = Density of methane at the temperature and pressure of the biogas in the year *y* (t/m^3)

FE = Flare efficiency in year *y* (fraction). If the biogas is combusted for gainful purposes, e.g. fed to an engine, an efficiency of 100 per cent may be applied

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[33] Biogas volume and methane content measurements shall be on the same basis (wet or dry).

As per AMS I.D

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y$$ **Equation (9)**

Where:

ER_y = Emission reductions in year *y* (t CO_2e)

BE_y = Baseline emissions in year *y* (t CO_2e)

PE_y = Project emissions in year *y* (t CO_2e)

LE_y = Leakage emissions in year *y* (t CO_2e)

Year	Estimated baseline emissions or removals (tCO_2e)	Estimated project emissions or removals (tCO_2e)	Estimated leakage emissions (tCO_2e)	Estimated net GHG emission reductions or removals (tCO_2e)
Year 0	27,125	6,693	0	20,433
Year 1	46,500	11,473	0	35,028
Year 2	46,500	11,473	0	35,028
Year 3	46,500	11,473	0	35,028
Year 4	46,500	11,473	0	35,028
Year 5	46,500	11,473	0	35,028
Year 6	46,500	11,473	0	35,028
Year 7	46,500	11,473	0	35,028
Year 8	46,500	11,473	0	35,028
Year 9	46,500	11,473	0	35,028
Year 10	19,375	4,780	0	14,595
Total	465,000	114,730	0	350,280

4 MONITORING

4.1 Data and Parameters Available at Validation

Data / Parameter	GWP_{CH4}
Data unit	-
Description	Global warning potential for methane
Source of data	Global warming potential for CH_4 valid for the relevant commitment period as per Annex 3 of EB 69
Value applied	25
Justification of choice of data or description of measurement methods and procedures applied	As per Annex 1 - clause 5 of VCS standard version 3.7, *Project shall transition to the updated GWP at their project crediting period renewal.*
Purpose of Data	Calculation of baseline and project emissions
Comments	-

Data / Parameter	$B_{o,ww}$
Data unit	kg CH_4/kg COD
Description	Methane producing capacity of the wastewater
Source of data	IPCC default value as per methodology AMS III-H version 18
Value applied	0.25
Justification of choice of data or description of measurement methods and procedures applied	Default value
Purpose of Data	Calculation of baseline and project emissions
Comments	-

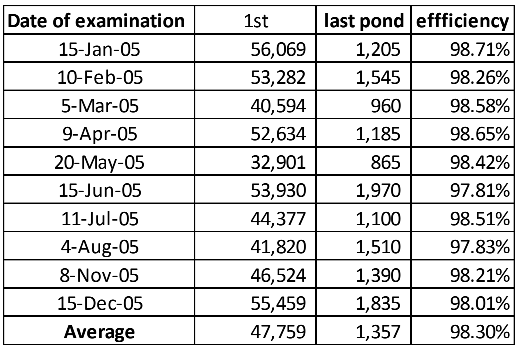
Data / Parameter	UF_{BL}
Data unit	-
Description	Model correction factor to account of model uncertainties
Source of data	AMS-III.H version18
Value applied	0.89
Justification of choice of data or description of measurement methods and procedures applied	Default value from AMS-III.H version 18
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	UF_{PJ}
Data unit	-
Description	Model correction factor to account of model uncertainties
Source of data	AMS-III.H version18
Value applied	1.12
Justification of choice of data or description of measurement methods and procedures applied	Default value from AMS-III.H version 18
Purpose of Data	Calculation of project emissions
Comments	-

Data / Parameter	$MCF_{ww, treatment,BL,i}$
Data unit	-
Description	Methane correction factor for the baseline anaerobic wastewater treatment system j
Source of data	Table 2 from AMS-III.H, Version 18, IPCC default values
Value applied	0.8
Justification of choice of data or description of measurement methods and procedures applied	The baseline wastewater treatment system consists of a succession of anaerobic deep lagoons (depth more than 2 metres) therefore the MCF value is chosen as 0.8
Purpose of Data	Calculation of baseline emissions
Comments	IPCC Default values from chapter 6 of volume 5. Waste in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Data / Parameter	$MCF_{ww, treatment,PJ,k}$
Data unit	-
Description	Methane correction factor for the project anaerobic wastewater treatment system k
Source of data	Table 2 from AMS-III.H, Version 18, IPCC default values
Value applied	0.8
Justification of choice of data or description of measurement methods and procedures applied	The project wastewater treatment system without biogas recovery (secondary treatment) consists in a succession of deep lagoons, with depth more than 2 metres, so the value of 0.8 has been chosen.
Purpose of Data	Calculation of project emissions
Comments	IPCC Default values from chapter 6 of volume 5. Waste in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Data / Parameter	CFE_{ww}
Data unit	Fraction
Description	Capture efficiency of the biogas recovery equipment in the wastewater treatment systems
Source of data	AMS-III.H version 18
Value applied	0.9
Justification of choice of data or description of measurement methods and procedures applied	Default value as per AMS-III.H
Purpose of Data	Calculation of project emissions
Comments	-

<table>
<tr><th>Data / Parameter</th><th>$\eta_{COD,BL,i}$</th></tr>
<tr><td>Data unit</td><td>%</td></tr>
<tr><td>Description</td><td>COD removal efficiency of the baseline system i</td></tr>
<tr><td>Source of data</td><td>Measurement campaign in the baseline wastewater system for 11 days</td></tr>
<tr><td>Value applied</td><td>87.5% - Used for ex-ante estimation of baseline emissions.</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td>The COD removal efficiency is based, on COD values for baseline system before implementation of project activity. The COD reduction across the baseline treatment system is multiplied by a factor of 0.89 for conservative estimation of baseline emissions. Actual reduction across the system is approximately 98.3%

<table>
<tr><th>Date of examination</th><th>1st</th><th>last pond</th><th>effficiency</th></tr>
<tr><td>15-Jan-05</td><td>56,069</td><td>1,205</td><td>98.71%</td></tr>
<tr><td>10-Feb-05</td><td>53,282</td><td>1,545</td><td>98.26%</td></tr>
<tr><td>5-Mar-05</td><td>40,594</td><td>960</td><td>98.58%</td></tr>
<tr><td>9-Apr-05</td><td>52,634</td><td>1,185</td><td>98.65%</td></tr>
<tr><td>20-May-05</td><td>32,901</td><td>865</td><td>98.42%</td></tr>
<tr><td>15-Jun-05</td><td>53,930</td><td>1,970</td><td>97.81%</td></tr>
<tr><td>11-Jul-05</td><td>44,377</td><td>1,100</td><td>98.51%</td></tr>
<tr><td>4-Aug-05</td><td>41,820</td><td>1,510</td><td>97.83%</td></tr>
<tr><td>8-Nov-05</td><td>46,524</td><td>1,390</td><td>98.21%</td></tr>
<tr><td>15-Dec-05</td><td>55,459</td><td>1,835</td><td>98.01%</td></tr>
<tr><td>Average</td><td>47,759</td><td>1,357</td><td>98.30%</td></tr>
</table></td></tr>
<tr><td>Purpose of Data</td><td>Calculation of baseline emissions</td></tr>
<tr><td>Comments</td><td>-</td></tr>
</table>

Data / Parameter	$EF_{grid,CM,y}$
Data unit	tCO_2e/MWh
Description	Combined margin CO_2 emission factor for grid connected power generation in year y
Source of data	A Study on Thailand Grid Emission Factor by Thai DNA

Value applied	0.5637 (Fixed ex-ante)
Justification of choice of data or description of measurement methods and procedures applied	The study of the estimation of grid emission factor is carried out by Thai DNA in accordance with the Methodological Tool: Tool to calculate the emission factor for an electricity system. The choice of data has been detailed in the published study by Thai DNA[34].
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	FE
Data unit	%
Description	Flare efficiency
Source of data	Tool to determine project emissions from flaring gases containing methane.
Value applied	50%
Justification of choice of data or description of measurement methods and procedures applied	Default value for open flare as per Tool to determine project emissions from flaring gases containing methane has been applied.
Purpose of Data	Calculation of baseline emissions
Comments	-

Data / Parameter	DE
Data unit	%
Description	Destruction efficiency of the electricity generator
Source of data	SSC WG
Value applied	100%
Justification of choice of data or description of measurement methods and procedures applied	According to clarification from SSC WG "*in the case that the biogas is combusted for a gainful use of the released energy as in an engine or a power plant, a destruction efficiency of 100% can be used for the portion of biogas that is combusted when applying AMS III.H., i.e. use a value of 100% for FE in equation 16 in paragraph 32 for the portion of biogas that is combusted for a gainful use"*[35]
Purpose of Data	Calculation of baseline emissions
Comments	-

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[34] The latest study in 2017 is available at the time of validation for renewable of crediting period. http://ghgreduction.tgo.or.th/t-ver/images/Grid_Emission_Factor_2559_-_Finalised.pdf

[35] http://cdm.unfccc.int/UserManagement/FileStorage/VNWAGY8MS92ZXDKUHEF5LB07QICT1P

4.2 Data and Parameters Monitored

Data / Parameter	$Q_{ww,i,y}$
Data unit	m^3/month
Description	The flow of wastewater
Source of data	Measured – Volumetric flow meter
Description of measurement methods and procedures to be applied	Measured continuously by flow meters installed before entering CSTR system.
Frequency of monitoring/recording	Parameter monitored continuously but aggregated monthly and annually for calculations.
Value applied	135,000 m^3/year (estimated for ex-ante calculation)
Monitoring equipment	Wastewater flow meter: Magnetic flow type
QA/QC procedures to be applied	Flow meters will undergo maintenance / calibration subject to appropriate industry standards, at least once every 3 years.
Purpose of data	Calculation of baseline and project emissions
Calculation method	-
Comments	-

Data / Parameter	$COD_{ww,untreated,y}$
Data unit	t COD/m^3
Description	The chemical oxygen demand of the wastewater before the treatment system affected by the project activity.
Source of data	Measured as per colorimetric method
Description of measurement methods and procedures to be applied	The COD content will be analyzed using a colorimetric method in the on-site laboratory of the treatment plant. The results will be logged in the plant operation report on a daily basis.
Frequency of monitoring/recording	Samples and measurements shall ensure a 90/10 confidence level
Value applied	0.08
Monitoring equipment	Spectrophotometer for Colorimetric analysis, USEPA approved for wastewater analysis (standard method 5220 D).
QA/QC procedures to be applied	Sampling and analysis will be carried out adhering to internationally recognized procedures. The spectrophotometer is calibrated at least once every 3 years.
Purpose of data	Calculation of baseline and project emissions
Calculation method	-
Comments	-

Data / Parameter	$COD_{ww,treated,y}$
Data unit	t COD/m^3
Description	The chemical oxygen demand of the wastewater after the treatment system affected by the project activity.
Source of data	Measured as per colorimetric method
Description of measurement methods and procedures to be applied	The COD content will be analyzed using a colorimetric method in the on-site laboratory of the treatment plant. The results will be logged in the plant operation report on a daily basis.
Frequency of monitoring/recording	Samples and measurements shall ensure a 90/10 confidence level
Value applied	0.0064
Monitoring equipment	Spectrophotometer for Colorimetric analysis, USEPA approved for wastewater analysis (standard method 5220 D).
QA/QC procedures to be applied	Sampling and analysis will be carried out adhering to internationally recognized procedures. The spectrophotometer is calibrated at least once every 3 years.
Purpose of data	Calculation of baseline and project emissions
Calculation method	-
Comments	-

Data / Parameter	$S_{final,PJ,y}$
Data unit	t
Description	Amount of dry matter in the sludge
Source of data	Measured – same weighbridge at starch plant for tapioca procuring
Description of measurement methods and procedures to be applied	Measure the total quantity of sludge on a wet basis. The volume (m^3) and density or direct weighing may be used to determine the sludge amount (wet basis). Representative samples are taken to determine the moisture content to calculate the total sludge amount on dry basis. If the methane emissions from anaerobic decay of the final sludge are to be neglected because the sludge is controlled combusted, disposed of in a landfill with methane recovery, or used for soil application, then the end-use of the final sludge will be monitored during the crediting period.
Frequency of monitoring/recording	Monitoring of 100 per cent of the sludge amount through continuous or batch measurements and moisture content through representative sampling to ensure the 90/10 confidence/precision level
Value applied	0
Monitoring equipment	Truck scale at starch plant
QA/QC procedures to be applied	Plant manager’s signature is required on the record.

Purpose of data	Calculation of project emissions
Calculation method	-
Comments	-

Data / Parameter	$BG_{burnt,combusted,y}$
Data unit	Nm^3
Description	Amount of biogas combusted for gainful use in the year y
Source of data	Measured using gas flow meter Since the energy requirement of the starch plant is higher than the energy content of the biogas that can be delivered as per ex-ante calculations, it is assumed that 95% of the available biogas would be combusted in the boilers.
Description of measurement methods and procedures to be applied	Thermal-mass type flow meters shall automatically measure temperature and pressure, expressing biogas volumes in normalized cubic meters (Nm^3)
Frequency of monitoring/recording	Monitored continuously (at least hourly measurements are undertaken, if less, confidence/precision level of 90/10 shall be attained)
Value applied	3,715,200 • Gas engine no.1 : 2,513,455 Nm^3 • Gas engine no.2 : 1,201,745 Nm^3 • Boiler : 0 Nm^3 (Assumption of ex-ante : All biogas is combusted in gas engines , only whenever there is excess generation that biogas is sent to boiler.)
Monitoring equipment	Biogas flow meter: Thermal mass type
QA/QC procedures to be applied	Flow meters will undergo maintenance / calibration subject to appropriate industry standards, at least once every 3 years.
Purpose of data	Calculation of baseline emissions
Calculation method	-
Comments	-

Data / Parameter	$BG_{burnt,TOFlare,y}$ / $V_{RG,m}$
Data unit	Nm^3
Description	Amount of biogas sent to flare system in the year *y*
Source of data	Measured using gas flow meter
Description of measurement methods and procedures to be applied	Thermal-mass type flow meters shall automatically measure temperature and pressure, expressing biogas volumes in normalized cubic meters (Nm^3)

Frequency of monitoring/recording	Monitored continuously (at least hourly measurements are undertaken, if less, confidence/precision level of 90/10 shall be attained)
Value applied	0
Monitoring equipment	Biogas flow meter: Thermal mass type
QA/QC procedures to be applied	Flow meters will undergo maintenance / calibration subject to appropriate industry standards, at least once every 3 years.
Purpose of data	Calculation of project emissions
Calculation method	-
Comments	-

Data / Parameter	$w_{CH4,y}$
Data unit	%
Description	Methane content in biogas in the year y
Source of data	Measured using gas analyser
Description of measurement methods and procedures to be applied	The fraction of methane in the gas should be measured with a continuous analyser or, alternatively, with periodical measurements at a 90/10 confidence/precision level. The methane content measurement shall be carried out close to a location in the system where a biogas flow measurement takes place
Frequency of monitoring/recording	Either with continuous analyzer or alternatively with periodical measurement at 95% confidence level.
Value applied	60% (assumed based on feasibility study)
Monitoring equipment	Methane gas analyzer
QA/QC procedures to be applied	Gas analyzer will undergo maintenance/calibration subject to appropriate industry standards, at least once every 3 years.
Purpose of data	Calculation of baseline and project emissions
Calculation method	-
Comments	-

Data / Parameter	$\eta_{flare-m}$
Data unit	%
Description	The flare efficiency
Source of data	Tool “Project emissions from flaring” version 02.0.0
Description of measurement methods and procedures to be applied	In the case of open flares, the flare efficiency in the minute m ($\eta_{flare,m}$) is 50% when the flame is detected in the minute m ($Flame_m$), otherwise $\eta_{flare,m}$ is 0%.

Frequency of monitoring/recording	Continuously monitored
Value applied	0% - conservative default value for open flare
Monitoring equipment	-
QA/QC procedures to be applied	-
Purpose of data	Calculation of project emissions
Calculation method	-
Comments	-

Data / Parameter	$EC_{PJ,j,y}$
Data unit	MWh
Description	Quantity of electricity consumed by the project activity in year y
Source of data	Measured – Electricity meter owned and maintained by Provincial Electricity Authority (PEA)
Description of measurement methods and procedures to be applied	The measurement of this parameter shall be done continuously using electricity meter supplied by the grid operator. Reading shall be recorded and reported on a monthly basis by PEA.
Frequency of monitoring/recording	Continuous measurement and monthly recording
Value applied	0 – The project activity is not expected to used electricity from grid. Ex-post estimation: the electricity consumption will use the actual data from electricity bill from PEA.
Monitoring equipment	PEA – Electricity purchasing meter
QA/QC procedures to be applied	The electricity meter is owned and maintained by PEA. Monthly report issued by PEA shall be used to get the amount of electricity consumed from grid.
Purpose of data	Calculation of project emissions
Calculation method	-
Comments	The meter maintenance is not under the jurisdiction of project proponent.

Data / Parameter	$EG_{PJ,facility,y}$
Data unit	MWh
Description	Quantity of net electricity generation supplied by the project plant/unit to the grid in year *y*
Source of data	Electricity meter(s)
Description of measurement methods	This parameter should be either monitored using bi-directional energy meter or calculated as difference between (a) the quantity

and procedures to be applied	of electricity supplied by the project plant/unit to the grid; and (b) the quantity of electricity the project plant/unit from the grid. In case it is calculated then the following parameters shall be measured: (i) The quantity of electricity supplied by the project plant/unit to the grid; and (j) The quantity of electricity delivered to the project plant/unit from the grid
Frequency of monitoring/recording	Continuous monitoring, hourly measurement and at least monthly recording
Value applied	7,722 • Gas engine no.1 : 5,261 MWh • Gas engine no.2 : 2,641 MWh
Monitoring equipment	PEA – Electricity purchasing meter
QA/QC procedures to be applied	The electricity meter is owned and maintained by PEA. Monthly report issued by PEA shall be used to get the amount of electricity delivered to grid.
Purpose of data	Calculation of baseline emissions
Calculation method	-
Comments	For grid supplied power if the value from invoices / receipts is available the same shall be used as it would represent a more conservative value.

4.3 Monitoring Plan

The monitoring plan is described in section 3.4 of the registered PD. The documented procedures, work instructions and forms have been established and implemented in accordance with ISO 9001 standard.

The daily operation data recording is carried out by plant operators. The report will be checked and approved by Biogas Plant Manager. The calibration of all monitoring equipment is planned and controlled by Calibration officer.

The wastewater samples are analysed and recording the result by QC staff. The result is approved by QC Manager.

All log sheet is collected and summarized to Factory Manager on daily basis. The monthly data file is sent to consultant for emission reduction calculation.

All monitoring data is available in an excel spreadsheet. This spreadsheet consists of:

1. A summary worksheet containing the results of the monitoring for every day of the monitoring period on a yearly basis;
2. The monitored parameters during the monitoring period.

Organization structure

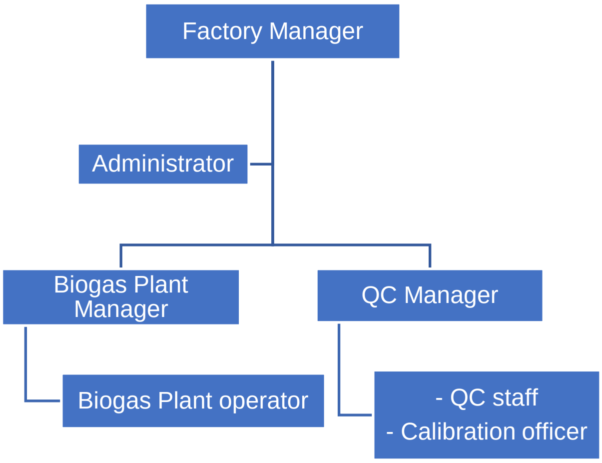
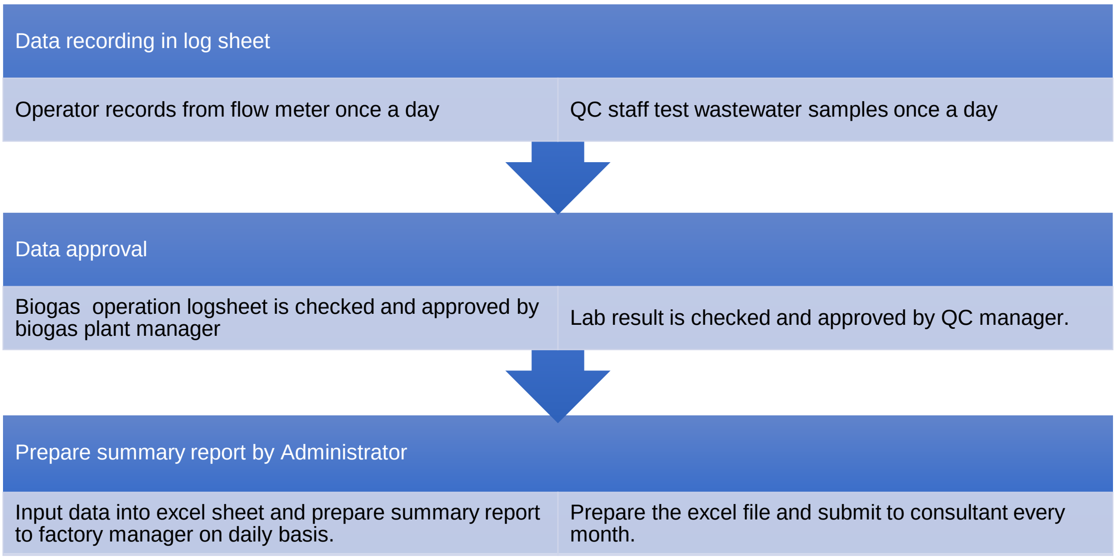


Figure 4 : The organization structure of Biogas Plant

Data Collection and management system



Data recording in log sheet

Operator records from flow meter once a day	QC staff test wastewater samples once a day

Data approval

Biogas operation logsheet is checked and approved by biogas plant manager	Lab result is checked and approved by QC manager.

Prepare summary report by Administrator

Input data into excel sheet and prepare summary report to factory manager on daily basis.	Prepare the excel file and submit to consultant every month.

Data storage and backup

- The original log sheets are collected and stored at factory office by Administrator.
- The excel spreadsheets and reports are stored in administrator's computer and company's server. The backup of sever is responded by IT staff.
- The excel spreadsheet submitted to consultant is stored and backup via consultant's internal server on monthly basis

5 SAFEGUARDS

5.1 No Net Harm

There is no any negative environmental and socio-economic impacts created by project activity.

5.2 Environmental Impact

The project, being a renewable energy biogas based thermal project, does not fall under the purview of the Environmental Impact Assessment (EIA) notification of the Ministry of Natural Resources and Environment (MONRE). The Government of Thailand with the approval of National Environment Board (NEB) has the power to specify notification for the type and size of projects or activities requiring EIA, which is currently regulated by Section 46 of the Enhancement and Conservation of Nation from the National Environmental Quality Act 1992. However, the expected environmental impact of the Project activity was considered as a part of the feasibility study. According to the results of the feasibility study, it is expected that the Project activity will improve the water quality as well as air quality.

By adopting the anaerobic wastewater treatment system which is more advanced technology than the existing system, it is expected that the Project activity will improve the water quality. In addition, no wastewater is discharged to the river; final treated wastewater will be used for irrigation or in other processes. At the same time, the anaerobic wastewater treatment system will be equipped with a biogas collection/utilization system. By collecting and utilizing biogas, to which odor emissions in the vicinity of the project site are directly attributable, the Project activity will improve the local air quality.

There will be no additional sludge generation by the Project activity. Sludge generated during the wastewater treatment process will be treated by land application.

In conclusion, the Project will result in a higher quality of wastewater treatment and a high standard of technology for pollution control (i.e. noise pollution, odour pollution and air pollution) during the project construction and commissioning.

5.3 Local Stakeholder Consultation

A detailed Stakeholder consultation was conducted by the project proponent at the project site and is explained as follows:

Invitation procedure
The Stakeholder Consultation has been conducted by the project owner Natural Palm Oil Co., Ltd Chumporn with assistance from South Pole Carbon Asset Management Limited (Switzerland based company responsible for VER project development). Stakeholder groups have been identified and informed through oral means about the meetings.

Place and date of the meetings
The stakeholder consultation was held in the communities around the plant on 10 September 2008. Thus, all participants were able to examine the location where the proposed project will take place.

Meeting Participants

The meeting was attended by local residents and representatives from the following stakeholder categories:

1. Local residents
2. Local government representatives
3. Teachers from local school
4. Local entrepreneurs

30 participants accepted the invitation and attended the meeting.

Language

Documentation and meeting was held in Thai (local language).

Meetings procedure

- Project description of and environmental impacts (10 min)
- Questions and Answers session (5 min)
- General feedback (5 min)

Meeting documents and protocols

On completion of the various meetings, the following documentation was collected and attested by the signatures of the stakeholders that were present:

1. Non-technical description of the project
2. Environmental impacts of the project
3. Contribution to sustainable development

5.4 Public Comments

Compilation of comments received:

The overall response to the project, from all invited stakeholders, was encouraging and positive to local environment and social-economic conditions by cleaning the wastewater in a more efficient way, avoiding odour emissions from the lagoons and creating new jobs.

In all, no adverse reactions, comments, or clarifications were received during the Stakeholder Consultation process. The project participants did not recognize any need to make changes to the project design or monitoring plan.

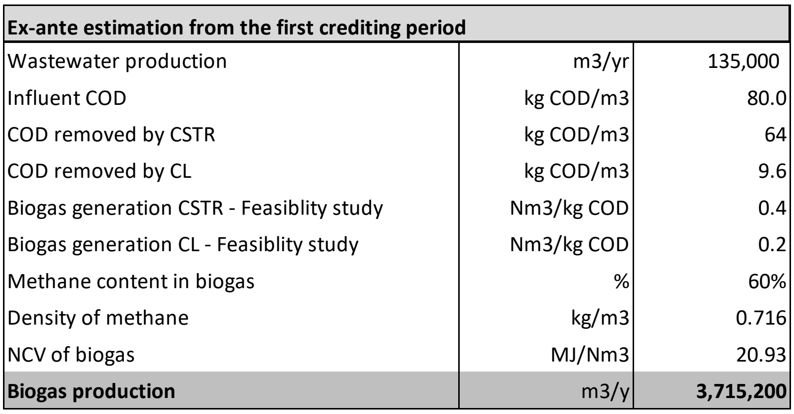
As a current practice, the project proponent encourages the people in nearby areas to actively provide feedback if any regarding operation of project activity. A register is maintained at site office for same purpose.

Current Practice

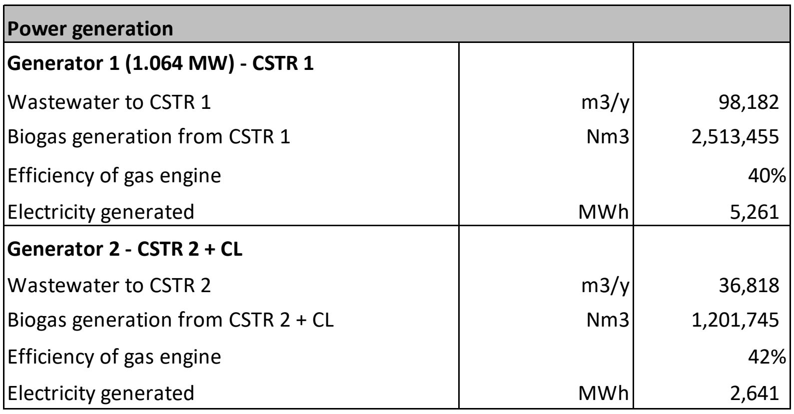
The project proponent maintains a register at the plant, to make sure any current feedback is provided by local people in fair and transparent manner. The communication between project owner and all stakeholders can be reachable via company website : www.naturalpalm.com

APPENDIX 1: ADDITIONAL INFORMATION

Table 9 : Assumptions for ex-ante estimation from the first crediting period



Ex-ante estimation from the first crediting period		
Wastewater production	m3/yr	135,000
Influent COD	kg COD/m3	80.0
COD removed by CSTR	kg COD/m3	64
COD removed by CL	kg COD/m3	9.6
Biogas generation CSTR - Feasiblity study	Nm3/kg COD	0.4
Biogas generation CL - Feasiblity study	Nm3/kg COD	0.2
Methane content in biogas	%	60%
Density of methane	kg/m3	0.716
NCV of biogas	MJ/Nm3	20.93
Biogas production	m3/y	**3,715,200**



Power generation		
Generator 1 (1.064 MW) - CSTR 1		
Wastewater to CSTR 1	m3/y	98,182
Biogas generation from CSTR 1	Nm3	2,513,455
Efficiency of gas engine		40%
Electricity generated	MWh	5,261
Generator 2 - CSTR 2 + CL		
Wastewater to CSTR 2	m3/y	36,818
Biogas generation from CSTR 2 + CL	Nm3	1,201,745
Efficiency of gas engine		42%
Electricity generated	MWh	2,641