

**CLEAN DEVELOPMENT MECHANISM
PROJECT DESIGN DOCUMENT FORM (CDM-SSC-PDD)
Version 03 - in effect as of: 22 December 2006**

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Revision history of this document

Version Number	Date	Description and reason of revision
01	21 January 2003	Initial adoption
02	8 July 2005	<ul style="list-style-type: none">•The Board agreed to revise the CDM SSC PDD to reflect guidance and clarifications provided by the Board since version 01 of this document.•As a consequence, the guidelines for completing CDM SSC PDD have been revised accordingly to version 2. The latest version can be found at <http://cdm.unfccc.int/Reference/Documents>.
03	22 December 2006	<ul style="list-style-type: none">•The Board agreed to revise the CDM project design document for small-scale activities (CDM-SSC-PDD), taking into account CDM-PDD and CDM-NM.

SECTION A. General description of small-scale project activity
A.1 Title of the small-scale project activity:

Title: “Nubika Jaya Biogas Extraction for Bio-Hydrogen Production”

Version : Version 1.0.0

Completion Date: 20/03/2008

This document is written following Guidelines for Completing Simplified Project Design Document (CDM-SSC-PDD) version 05.

A.2. Description of the small-scale project activity:

PT Nubika Jaya (NUB) plans to implement a biogas extraction facility coupled with hydrogen production plant to cater for its hydrogen demand as feedstock to the new oleo-chemical facility (“The Project”). The Project will capture methane from the complex industrial waste-water generated primarily by its palm fruit milling activities and convert the recovered methane to hydrogen (H₂) as feedstock for the hydrogenation process in the newly constructed oleochemical facility.

Current Situation at Nubika Jaya

Effluent generated by NUB activities is collected and treated in a series of anaerobic lagoons with total holding capacity of 131,336m³. The effluent is primarily generated by NUB palm oil mill for its FFB cooking activity and effluent collected from EFB (as liquor). Other processing facilities that are already in operations: the kernel crushing plant and refinery contributes a much smaller proportion of wastewater with a much lower COD characteristics.

Waste water flows sequentially from one lagoon to another before being released to a water body stream. All the lagoons in the system have 5m depth, except for the sedimentation lagoon, which is of 6m depth. This existing lagoon system is able to improve the quality of waste water to a level acceptable by local regulatory standard of 300mg of COD per liter of water. This is demonstrated by NUB’s environmental compliance report which shows waste water quality to be below the set standard.

The new oleo-chemical facility is not expected to increase the volume and quantity of the waste-water entering the lagoon as it has its own treatment plant. Thus, additional capacity of the anaerobic lagoon is not required with the implementation of the oleochemical process.

The Proposed System

The oleo-chemical facility in NUB demands 750NCMH¹ of hydrogen for the hydrogenation of fatty-acid. Without the Project, industrial hydrogen is produced by contacting hydrocarbons contained in natural gas or petrochemical gas (LPG) with high pressure steam generating sizable amount of CO₂ gas as by products of the reactions.

NUB is uniquely positioned because the newly built oleochemical facilities is constructed adjacent to its palm oil mill which is generating large amount of effluents with high COD characteristic. Opportunity opens to extract biogas from the existing waste water treatment plant and convert it to hydrogen, effectively displacing the otherwise-required hydrocarbon feedstock/fuel in the hydrogen production unit. If successfully implemented, NUB will be the first oleo-chemical facility in the world to use biogas-based hydrogen.

Project Installation and Purpose

With incentive from CDM, NUB plans to install:

- (1) a new methane capture system (MCS) to extract biogas from the waste water;
- (2) a biogas purification system using pressure swing adsorption (PSA) technology to purify biogas into methane and consequently reduces LPG as feedstock and fuel for hydrogen production;
- (3) modification to the boiler to co-fire the excess biogas and residual fuel.

The overall process is summarized in a simplified diagram (Figure 2) in Section A.4.2. The following provide a brief summary of individual installations. Individual technologies are further elaborated under Section A.4.2.

¹ NCMH: Normalized Cubic Meter per Hour (Nm³/hr)

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- **Methane extraction facility or Methane Capture System (MCS)**

The selected system is anaerobic reactors with hold-up capacity of 14,000m³ equipped with combination of fixed and floating roof. Wastewater from anaerobic lagoon number 2 and 3 will be routed to these reactors, and returned to the next lagoons with a much lower COD concentration. It is expected that the implementation of this facility will improve the quality of discharged wastewater significantly.

The new technology extracts methane rich biogas from the effluent which will be utilized primarily as feedstock for hydrogen production.

- **Biogas treatment facility to support hydrogen production (PSA)**

In addition to methane extraction facility, the Project also covers the installation of a pressure swing adsorption system (PSA) using carbon bed filter to isolate methane from other biogas impurities. The isolated methane will be used as feedstock and fuel to support production of 750NCMH (pure) hydrogen.

The hydrogen production facility and the biogas purification unit is supplied by German-based Linde AG. The production facility is dual-fuel and will be able to consume either LPG or methane isolated from biogas. The PSA system is designed to remove CO₂ and H₂S presence in biogas to prevent catalyst poisoning in the major reactor and therefore a critical unit for production.

- **Heat generation from biogas**

There is a future plan to extend this Project by utilizing excess biogas unconsumed by the hydrogen production process to reduce fuel oil consumption in one of Nubika Jaya fuel-oil boiler. This plan, however, is to be implemented upon confirmation that there is sufficient amount of excess that deems the implementation to be useful. Otherwise, excess biogas will be flared.

Contribution to Sustainable Development

- **Conversion of wastewater to useful intermediate product.**

The Project represents an innovative and energy efficient way to operate an industrial complex. With the project implementation, NUB no longer produces any unused industrial waste water.

- **Better air quality.**

In addition to green house gas mitigation, the project activity also improves air quality by eliminating the pungent smell released from the anaerobic lagoons. The proposed anaerobic digester is a closed system, and the released effluent return to the anaerobic lagoons will have a significantly lower organic content and therefore minimize production of odorous gases associated with organic material decomposition.

- **Improvement in water discharge quality.**

The Project installation increases the COD removal productivity of the overall wastewater system and subsequently improves the final quality of the discharged wastewater. Additionally, the anaerobic digester close system eliminates possibility of accidental release of untreated wastewater from lagoons overflowing that sometimes occur due to more-than-normal rainfall.

- **Production of carbon-neutral H₂.**

Hydrogen has been pictured as clean energy due to its efficient burning. However, production of commercial-scale hydrogen is based on hydrocarbon. Technology of bio-hydrogen production is still at infant-stage. NUB takes a bold-step to produce bio-hydrogen from its palm oil effluent and therefore contributes to the sustainable development of palm oil end-products.

A.3. Project participants:

Table 1 – List of Project Participants

Name of Party Involved	Private and/or Public Entity(ies) Project participant	Kindly indicate if the Party involved wishes to be considered as Project Participant (Yes/No)
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CDM – Executive Board

Indonesia (host)	PT Nubika Jaya (Private Entity)	No
Japan	Mitsubishi UFJ Securities Co. Ltd.(Private Entity)	No

PT Nubika Jaya (NUB) is wholly owned by PT Permata Hijau Group (PHG) based in Medan, North Sumatra, Indonesia.

Mitsubishi UFJ Securities Co. Ltd, is the CDM consultant for this Project.

A.4. Technical description of the small-scale project activity:

A.4.1. Location of the small-scale project activity:

A.4.1.1. Host Party(ies):

Indonesia

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

Province of Sumatera Utara

A.4.1.3. City/Town/Community etc.:

Kabupaten Labuhan Batu

A.4.1.4. Details of physical location, including information allowing the unique identification of this small-scale project activity :

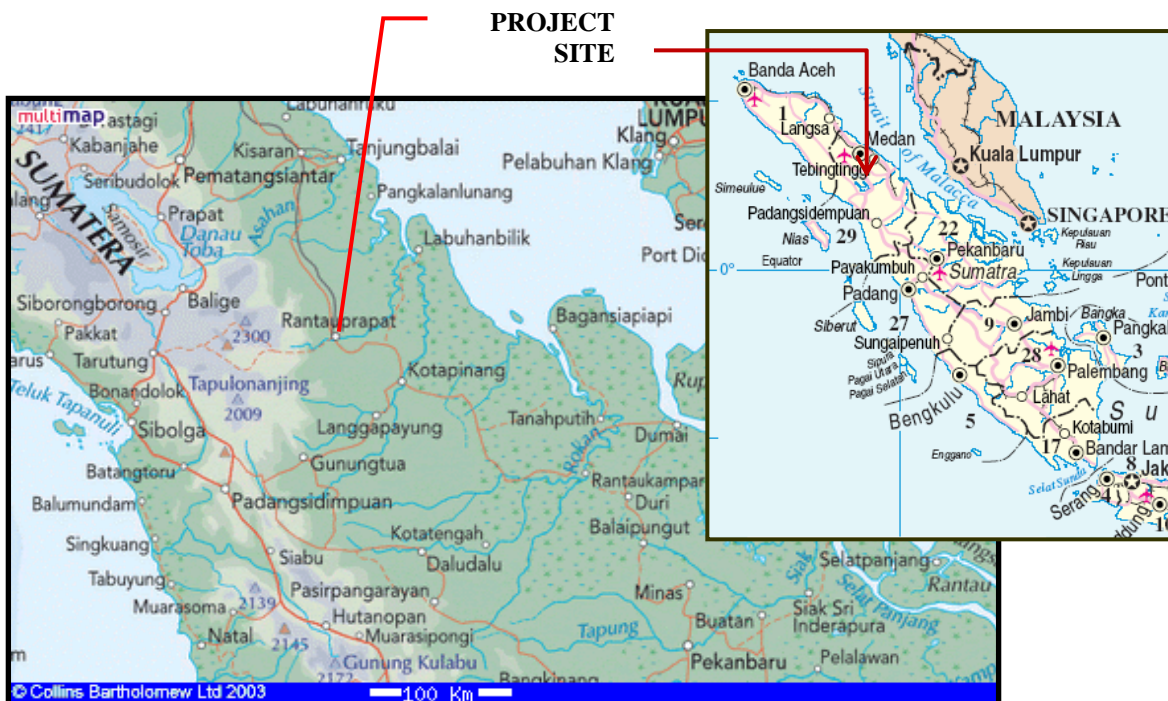


Figure 1 – Location of Nubika Jaya

A.4.2. Type and category(ies) and technology/measure of the small-scale project activity:

CDM – Executive Board

Project Type & Category:

In accordance with Appendix B of the simplified modalities and procedures for small-scale CDM project activities (“SSC M&P”), the proposed Project falls under the following categories:

- **Type III: Other Activities, Category O: Hydrogen production using methane extracted from biogas**
The Project utilizes methane extracted from renewable sources to produce H₂. Without the Project, industrial H₂ at the scale required by NUB would have been produced using hydrocarbon.
- **Type III: Other Activities, Category H: Methane recovery in waste water treatment**
The Project recovers methane from biogenic organic matter through introduction of a new methane-extraction step with energy recovery to the existing anaerobic lagoon or measure (vi) in methodology III-H.
- **Type I: Renewable Energy Project, Category C: Thermal energy for the user with or without electricity**
The Project generates heat from industrial waste water which is derived from renewable sources.

Project Technology

Methane extraction technology

As elaborated under Section A.2, the Project introduces a new step to the existing waste water treatment through installation of Anaerobic Digestion (AD) reactors (the term “anaerobic digester” or ‘digester’ is also used interchangeably in this document). The selected technology is a licensed waste water treatment process by Keck Seng Bhd, and will be implemented jointly by NUB and Aquarius System (Malaysia) Sdn. Bhd.

Under the current system (shown in grey in figure 2), the effluent is treated sequentially from lagoon 1 to 8 before it is released to the environment. The Project intercepts the waste water flow between lagoon number 2 and 3 and therefore is an additional step to the existing lagoon system.

Under the Project, treatment ponds 1 and 2 acts as pre-conditioning ponds to the anaerobic reactors. In these ponds, pH and temperature is adjusted, and impurities are removed using screening method to prevent digester clogging. The treatments adjust the wastewater conditions to meet the ideal conditions for effective digestion. The function of lagoon 1 and 2 does not change much – and therefore excluded from emission reduction calculation. Lagoon number 3 will not be used any longer, and thus function as buffer ponds when required.

The anaerobic digester is a series of interconnected continuous stirred tanks with sedimentation tanks and sludge return system to maintain appropriate sludge level for optimized digestion. The tanks are also equipped with necessary safety equipment to prevent leaks and protection from fire. Effluent treated by the AD system will be returned to lagoon number 4, which overflows in the same direction as per existing system.

The biogas produced by the AD process will be piped to 3 locations with the following order:

- (A) Hydrogen production facility via the H₂S Removal System;
- (B) Fuel oil boiler; and
- (C) Flare unit, to burn the excess of biogas.

The AD system is not a new technology in the wastewater treatment industry. However, without incentives – this technology hardly penetrates developing country like Indonesia. The existing lagoon system in NUB was built to meet the government set standards for disposal of wastewater to environment, which mandated COD to be controlled below 350mg/L. The additional step, however, will significantly improve the efficiency of the existing system, and improve the disposal quality.

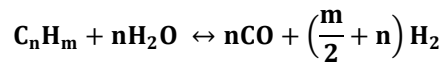
Hydrogen Production Facility

The chosen technology is Hydro-Chem process licensed by Linde AG from Germany. The base system is a modular hydrogen plant with propane-rich LPG as feedstock. Additional PSA system is installed as part of the project to allow the use of methane to displaced LPG.

The conversion of hydrocarbons (C_nH_m) in biogas or other non-renewable sources (LPG or natural gas) into hydrogen follows 2 steps via catalytic reactions. The reactions are simplified as follow:

Step 1 - Steam Reforming Reaction

Alkane hydrocarbons of various types (C_nH_m)² are contacted as **reaction feedstock** with steam at high pressure to generate carbon monoxide (CO) and hydrogen (H_2) summarized in the following reactions:

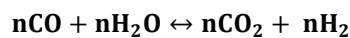


Equation 1

The reaction occurs in a steam reformer unit under high pressure (16barg) and very high temperature (above 800°C) in the presence of catalyst. To create this elevated pressure/temperature environment, the Hydro-Chem process burn some portion of the hydrocarbon as **fuel** in the reformer fire-box which generates more CO_2 .

Step 2 – Shift-Conversion Reaction

Carbon monoxide generated in the earlier step is further contacted with steam to produce hydrogen, and generates CO_2 as product of reaction. This reaction occurs is a much lower temperature inside a shift reactor.



Equation 2

For 750NCMH of Hydrogen, the entire process consumes: (a) either: 510NCMH of biogas or 245kg/hr LPG as feedstock; and (b) either: 210NCMH of biogas or 75kg/hr of LPG as fuel;

Methane in biogas is alkane hydrocarbon and thus can potentially replaced the hydrocarbon feedstock/fuel. Using methane-rich biogas, H_2 can be produced by using exactly the same method as if produced using LPG. Additionally, as bio-methane is available in high-pressure gas form, the vaporization step is no longer necessary. However, replacement using biogas has additional challenge as the gas contains impurities that are not presents in LPG and thus must undergo pre-treatment. As consequence, the selected bi-fuel process must employ both technologies – increasing the number of equipments and investment.

It is expected that the bio-gas contains acidic H_2S up to 0.3% mol which must be removed prior to reaction. This additional removal step is an additional step to the standard sulfur removal step typically used to treat LPG, which contains sulfur at much lower concentration³. In the Project, the H_2S is removed by way of Pressure Swing Adsorption (PSA) system employing molecular carbon sieve vessels. Pre-treated biogas joins LPG to be further treated in hydro-desulfurization process to ensure complete removal of all sulphur content prior to reactor feeding.

In both reactors (reformer and shift converter), the reactions proceed in much the same way as per LPG feed despite the differences in the hydrocarbon types. With bio-methane used as feedstock and fuel, the CO_2 formed in the primary reaction and combustion process are consequently carbon-neutral.

Heat generation from biogas

Approximately 69%mol of methane generated by the methane extraction facility will be used for bio-hydrogen production. To maximize energy recovery from biogas, the remaining gas not consumed in hydrogen plant will be used to reduce the amount of fossil fuel consumption of a boiler located within Nubika. This plan, however, is to be carried out only after confirmation that excess biogas is available in sufficient amount. Otherwise, the excess biogas will be flared.

Scenario without the Project

Without the Project, PHG has the option of simply purchasing hydrogen in bottle from specialist gas supplier or generating hydrogen in-house. In both cases, production of commercial scale hydrogen is by means of steam-reforming/shift reactions of hydrocarbon from natural gas which generates CO_2 gas as by-products of reactions. Production of hydrogen via water electrolysis is not feasible at the scale required by NUB, and less carbon-neutral due to large electricity requirement for electrolysis.

Due to unavailability of natural gas pipeline in the area, in-house production is only possible with bottled LPG as its main feedstock/fuel. LPG is widely available and affordable means of fuel in Indonesia and can be sourced from PERTAMINA⁴ petroleum refineries within Sumatra as one of the product from crude oil refining. In the absence of the Project, PHG will invest on a standard LPG-based (single fuel) hydrogen production plant without a PSA system necessary for biogas pre-treatment.

Without the need to generate hydrogen, the anaerobic ponds at Nubika will continue to emits green house gases.

² Alkane hydrocarbons includes: methane, ethane, n-(i-)butane, etc., where $m=2n+2$

³ Sulfur concentration in LPG is typically in part-per-million (ppm)

⁴ PERTAMINA: Indonesia's state oil company

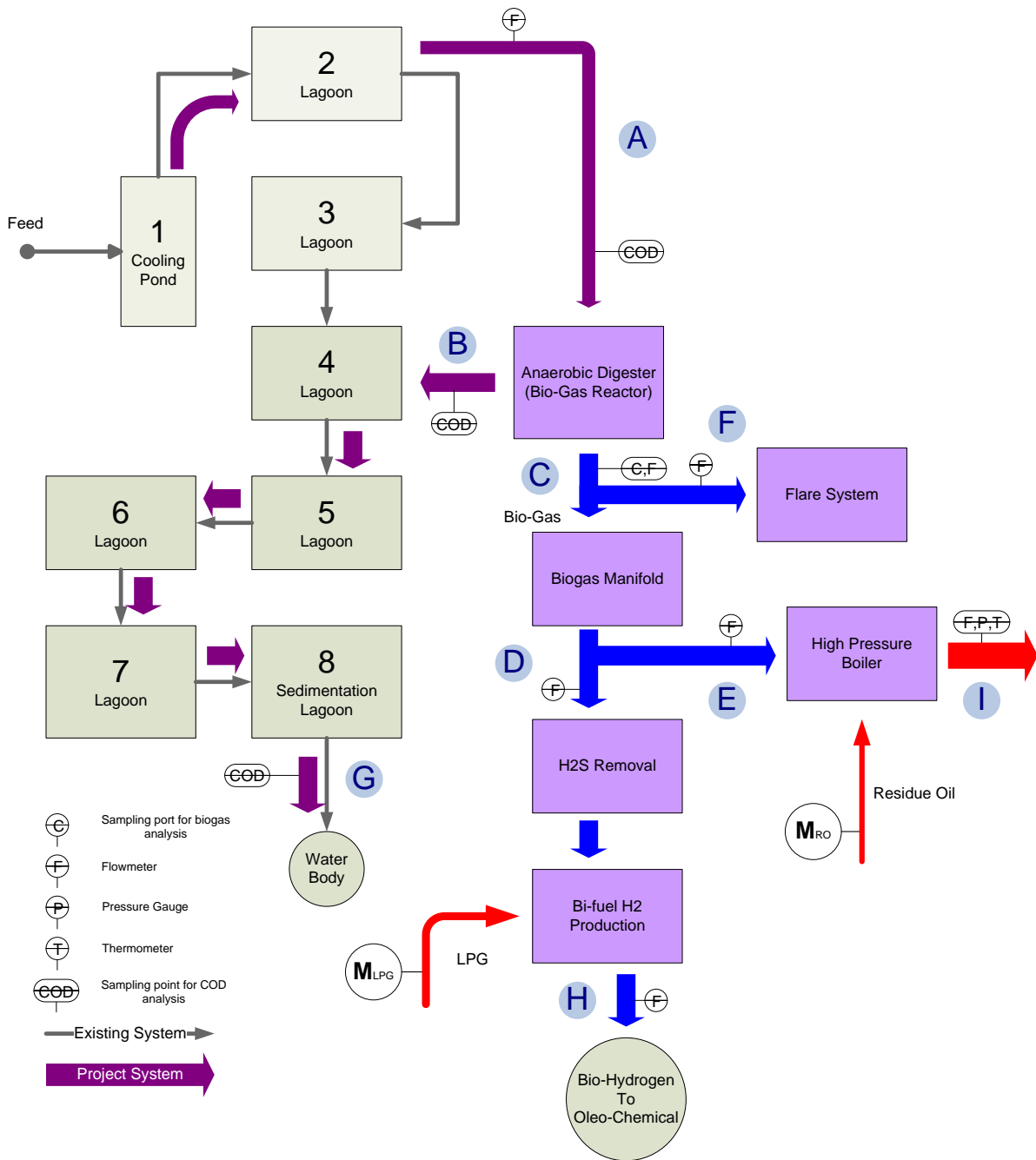


Figure 2 – Simplified Flow Diagram of Project and Existing Installations

A.4.3 Estimated amount of emission reductions over the chosen crediting period:

Table 2. Estimated Emission Reduction

Year	Estimation of Annual Emission Reductions (in tonnes of CO2 per year)
1	41,759
2	41,759
3	41,759
4	41,759

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5	41,759
6	41,759
7	41,759
Total estimated emission reductions	292,313
Total number of crediting years	7
Annual average of the estimated reductions over the crediting period (t-CO ₂ /yr)	41,759

A.4.4. Public funding of the small-scale project activity:

The project does not involve any public funding from Annex 1 countries.

A.4.5. Confirmation that the small-scale project activity is not a debundled component of a large scale project activity:

As defined in Appendix C of the *simplified modalities and procedures for small scale project activities*, this Project is not a debundled component of any larger project activity as the Project Proponent does not own or operate any other CDM registered project of similar nature and technology within 1km of the project boundary.

SECTION B. Application of a baseline and monitoring methodology
B.1. Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity:

AMS-III.H	Version 09	“Methane Recovery in Wastewater Treatment”
AMS-III.O	Version 01	“Hydrogen Production Using Methane Extracted from Biogas”
AMS-I.C	Version 13	“Thermal Energy for the User with or without Electricity”

Methodological Tool: “*Tool to determine project emissions from flaring gases containing methane*”, Annex 13, approved in EB28.

B.2 Justification of the choice of the project category:
AMS-III.H Version 09 “Methane Recovery in Wastewater Treatment”

The Project extracts methane from effluent currently treated in existing anaerobic lagoons. The treated effluent will be returned to the existing lagoon system in a sequential manner. This situation corresponds to activity (vi) point 1 of AMS-III.H: “Introduction of a sequential stage of waste water treatment with methane recovery and combustion to an existing waste water treatment system without methane recovery”

Paragraph 2 and 3 of this methodology stipulates if recovered methane is used directly for heat/electricity generation, AMS Type I can be used. Paragraph 4 prescribed the use of AMS-III.O if the recovered methane is used for hydrogen production.

AMS-III.O Version 01 “Hydrogen Production Using Methane Extracted from Biogas”

The Project comprises combination of the installation of measures that recover methane from biogenic waste water listed in Category H and utilization of the captured methane for hydrogen production. The production of hydrogen would be to supply hydrogen to a new oleo-chemical facility, effectively reducing the amount of LPG that would have been needed for this purpose.

Extraction of biogas is new to Nubika Jaya, thus does not result in the diversion of biogas previously used for thermal or electrical generation or previously utilized in any other (chemical) process. The project activity will be operated to comply with all regulations including safety procedures applicable in the host nation.

AMS-I.C Version 13 “Thermal Energy for the User with or without Electricity”

Excess biogas from the Project will be combusted in the modified boiler in the existing refinery currently operated using residue oil. It is approximated that the biogas can contribute to up to 33TJ/yr of energy out of 105TJ/yr required by the boiler. Thus, less than the 45MW_{th} limits set by methodology I.C.

The resulting emission reduction from the above type III activities are estimated to total below 60,000tCO₂ annually and the concerning boiler has thermal capacity of less than 45MW_{th}. Therefore, the Project meets the applicability conditions of the respective methodologies.

B.3. Description of the project boundary:

As stated in all SSC Methodologies, the project boundary is *the physical and geographical site where the activities take place*. In this case, the project boundary covers the location of waste-water & sludge treatments including the methane extraction systems, extended to the location of subsequent hydrogen production and biogas combustion. All of the above activities take place within the boundary of NUB facilities.

Table 3. Emission Sources Considered

Scenario	Area	Gas	Emission Sources Considered
Baseline	Anaerobic Lagoon	CH ₄	Emission from methane from the operation of existing anaerobic lagoons
	Hydrogen Production	CO ₂	Emission from reactions of LPG as feedstock
		CO ₂	Emission from combustion of LPG as fuel to reformer
	Heat Production	CO ₂	Emission reduction from displacement of fuel oil with biogas

Project	Anaerobic Lagoon	CO ₂	Emissions from power used to run the MCS
		CH ₄	Emission from untreated bio-organic matter escaping the anaerobic digester
		CH ₄	Emission (fugitive) from flare
		CH ₄	Emission from final sludge disposal
		CH ₄	Emission from methane dissolved in dispose (treated) waste water
	Hydrogen Production	CO ₂	Emissions from power used to run PSA (Pressure Swing Adsorption) system
		CO ₂	Emissions from fossil fuel required to run PSA system
		GHG	Emissions from additional chemical used in the PSA system. This emission is excluded as the adopted PSA uses steam recovered from a waste heat boiler for carbon regeneration

B.4. Description of baseline and its development:

METHANE RECOVERY FROM WASTE-WATER

As stated under point 23(vi) of methodology III.H, in the case of introduction of a sequential anaerobic waste water treatment system, the applicable baseline is the existing anaerobic waste water treatment system without methane recovery. It is pertinent to note that the additional oleo-chemical process is not expected to generate waste water with high organic loading. Thus there is no obligation to add new capacity to the existing anaerobic waste water treatment process to meet the standard set for waste water disposal set by the host nation.

As stipulated in paragraph 34 of methodology III.H, the calculation of emission reduction should be based on the methane recovered, fuelled or flared, that is monitored *ex-post*, reduced by the project emission and leakage. Consequently, in the project situation, the baseline emission is calculated based on volumetric measurements of biogas that is used for hydrogen production, combustion in boiler, and flared.

In this Project, the amount of methane utilized and burnt is equivalent to the amount of methane recovered in the Project installation. Thus, amount of methane recovered is calculated as the sum of all biogas delivered to various points in the project activity as shown in Figure 2 of this PDD.

$$V_{TR,y} = V_{D,y} + V_{E,y} + V_{F,y}$$

Equation 3

Parameter	Description	Unit
V _{TR,y}	Total volumetric amount of biogas recovered from the project	Nm ³ /yr
V _{D,y}	Volumetric amount of biogas used in H ₂ production or point D in Figure 2	Nm ³ /yr
V _{E,y}	Volumetric amount of biogas used for heat generation or point E in Figure 2	Nm ³ /yr
V _{F,y}	Volumetric amount of biogas flared or point F in figure 2	Nm ³ /yr

The volume of methane in the biogas is calculated by identifying the volumetric proportion of methane in biogas through periodic sampling. In order to have the recovered methane expressed in mass unit, the volumetric amount is converted into mass amount using the ideal gas equation. The baseline emission from methane recovery (BE_{y,CH4}) is calculated as follow:

$$BE_{y,CH4} = X_{CH4,y} \cdot \frac{P_N * V_{TR,y}}{R * T_N} \cdot \frac{MW_{CH4}}{X_1} \cdot GWP_{CH4}$$

Equation 4

Parameter	Description	Unit
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$X_{CH_4,y}$	Proportion of methane in biogas in volume/volume basis	Nm^3 / Nm^3
P_N	Reference pressure at normal condition in Pascal	Pa
V_{TR}	Volumetric amount of biogas recovered	Nm^3/yr
R	Ideal gas constant, 8.314	$m^3.Pa/mol.K$
T_N	Reference temperature at normal condition in Kelvin	K
MW_{CH_4}	Molecular weight of methane	gram/mol
X_1	Conversion factor 10^6 grams/tones	gram/ton
GWP_{CH_4}	Global warming potential of methane	tCO_2/tCH_4

For *ex-ante* estimation, the baseline emissions is estimated using method described in paragraph 24(d) of methodology IIIH which is based on waste water flow rate, removed COD loading of raw waste water and methane generation potential.

With consideration that the existing treatment system are fully anaerobic system, the associated baseline emission corresponds with methane emission that would have escaped from wastewater entering lagoons number 3 onward if the Project does not exists. Lagoon number 3 onwards are deep lagoons with depth of 5m, thus methane correction factor (MCF) lower value of 0.8 is deemed appropriate for estimation of corresponding baseline emission.

$$BE_{y,CH_4} = Q_{y,ww} \times \sum_i (COD_{y,removed,i} \times B_{o,ww} \times MCF_{yy,treatment,i} \times GWP_{CH_4})$$

Equation 5

Parameter	Description	Unit
$Q_{y,ww}$	Volumetric flow rate of effluent entering pond number 3 before the Project which is re-routed to the AD reactor upon the Project implementation	m^3/yr
$\sum_j COD_{y,removed,i}$	Chemical Oxygen Demand (COD) removed by the anaerobic wastewater treatment systems “i” of the effluent entering pond number 3 before the Project which is re-routed to the AD reactor upon the project implementation.	$t-COD/m^3$
$B_{o,ww}$	Methane generation potential of waste water	$t-CH_4/t-COD$
$MCF_{yy,treatment,i}$	Methane correction factor applicable for deep anaerobic lagoon.	Unit less
GWP_{CH_4}	Global warming potential of methane gas.	$t-CO_2/t-CH_4$
BE_{y,CH_4}	Baseline CH_4 emission from existing anaerobic lagoon system	$t-CO_2/yr$

Emission from sludge both in the baseline and in project emission are excluded as there are no sludge treatment involved in both situations.

HYDROGEN PRODUCTION FROM BIOGAS

As stated under Section A.4.2, the additional installation of biogas purification system effectively reduces LPG consumption as the primary feedstock and fuel for a hydrogen production unit. As stipulated in methodology AMS-III.O, the baseline emission from such Project is therefore CO_2 emission that would have been generated by the baseline process including:

- (a) CO_2 generated by the use of LPG as reaction feedstock in the absence of the Project
- (b) CO_2 generated by the use of LPG as fuel for combustion in the hydrogen production unit in the absence of the Project

Baseline emission from reaction of baseline feedstock, BE_{LPG_FEED}

As described in paragraph 9 of AMS-III.O, the CO_2 generated from reactions of baseline feedstock (LPG) in the hydrogen plant, BE_{LPG_FEED} , is calculated based on the CO_2 emission potential of baseline feedstock (R_{CO_2/H_2}) times hydrogen produced from biogas on molar basis ($m_{H_2,BIO}$).

$$BE_{LPG_FEED} = R_{CO_2/H_2} \times m_{H_2,BIO} \times MW_{CO_2} \times C_1$$

Equation 6

Parameter	Description	Unit
BE_{LPG_FEED}	Baseline CO ₂ emissions from the displaced LPG feedstock in the hydrogen production unit	tCO ₂ e.
R_{CO_2/H_2}	CO ₂ generation potential per mol of hydrogen, if produced using LPG as feedstock	kmol-CO ₂ /kmol-H ₂
$m_{H_2,BIO}$	Molar quantity of hydrogen produced from methane extracted from biogas	kmol-H ₂
MW_{CO_2}	Molecular weight of CO ₂ , 44 kg/kmol	kg/kmol
C_1	conversion factor, 10 ⁻³ tonne/kg	tonne/kg

CO₂ generation potential of baseline feedstock R_{CO_2/H_2}

The R_{CO_2/H_2} is calculated based on the compositional analysis of the stand-by LPG feedstock using equation described in paragraph 13 of AMS-III.O.

$$R_{CO_2/H_2} = \frac{[3m_1 + 4m_2]}{10m_1 + 13m_2}$$

Equation 7

Parameter	Description	Unit
m_1	% mol of the propane in the LPG	mol-C ₃ H ₈ /mol-LPG
m_2	% mol of the butane in the LPG	mol-C ₄ H ₁₀ /mol-LPG

Molar quantity of hydrogen produced from methane extracted from biogas ($m_{H_2,BIO}$)

This parameter is calculated as the difference between the total molar amount of hydrogen produced ($m_{H_2,T}$) and the molar amount of hydrogen produced from the stand-by LPG ($m_{H_2,LPG}$).

$$m_{H_2,BIO} = m_{H_2,T} - m_{H_2,LPG}$$

Equation 8

Total molar amount of hydrogen ($m_{H_2,T}$) is calculated based on direct measurement of the total volume of hydrogen produced ($V_{H_2,T}$), which is:

$$m_{H_2,T} = \frac{P_N \times V_{H_2,T}}{R \times T_N \times 10^3}$$

Equation 9

Parameter	Description	Unit
P_N	Reference pressure at normal condition	Pa
$V_{H_2,T}$	Volumetric amount of biogas recovered based on measurement	Nm ³ /yr
R	Ideal gas constant, 8.314	m ³ .Pa/mol.K
T_N	Reference temperature at normal condition	K
10 ³	Conversion factor, 10 ³ mol/kmol	mol/kmol

Molar amount of hydrogen produced from LPG ($m_{H_2,LPG}$) is calculated by monitored the amount of LPG used as feedstock (M_{LPG}) in the Project, multiplied with the hydrogen production potential of the baseline feedstock ($R_{H_2/LPG}$) estimated based on the compositional analysis of the stand-by feedstock using the equation described in paragraph 12 of AMS-III.O.

$$R_{H_2/LPG} = \frac{[10m_1 + 13m_2]}{100}$$

Equation 10

$$m_{H_2,LPG} = R_{H_2/LPG} \cdot \frac{M_{LPG}}{MW_{LPG}}$$

Equation 11

Parameter	Description	Unit
$R_{H_2/LPG}$	H ₂ generation potential of baseline feedstock	kmol-H ₂ /kmol-LPG
M_{LPG}	Mass of LPG consumed	kg-LPG
MW_{LPG}	Molecular weight of LPG consumed	kg-LPG/kmol-LPG
$m_{H_2,LPG}$	Molar amount of H ₂ produced using LPG	kmol-H ₂

Baseline emission from combustion of baseline fuel BE_{LPG_FUEL}

In addition to the replacement of LPG as feedstock to the reforming process, the Project also enables consumption of biogas to replace LPG as fuel to the reformer. In accordance with paragraph 14 of AMS–III.O, the CO₂ emission associated with the displacement of LPG as fuel is calculated based on the specific fuel consumption of the hydrogen production unit if operated using LPG (SFC_{LPG}), the volumetric amount of hydrogen produced using biogas ($V_{H_2,BIO}$) and emission factor of LPG using the following relationship:

$$BE_{LPG_FUEL} = SFC_{LPG} \cdot V_{H_2,BIO} \cdot EF_{LPG} \cdot C_3$$

Equation 12

Parameter	Description	Unit
SFC_{LPG}	Specific fuel consumption of the hydrogen production unit when operated using LPG	kg-LPG/Nm ³ -H ₂
$V_{H_2,BIO}$	Volume of hydrogen produced using biogas	Nm ³ -H ₂
C_3	Conversion factor from kilogram to tonnes	Tonnes/kg

Paragraph 15 of the methodology stipulates the specific fuel consumption SFC_{LPG} can be calculated using one of the three options (a) measurements during credit period, (b) one year of historical data, or (c) specifications provided by the manufacturer. For simplification, option (c) is chosen. The manufacturer of the hydrogen production unit specifies consumption of 75kg-LPG as fuel per 750Nm³-H₂ and thus the specific fuel consumption SFC_{LPG} is set as 0.1kgLPG/Nm³-H₂.

HEAT RECOVERY FROM BIOGAS

Paragraph 6 of AMS-I.C stipulates that for renewable energy technology displacing technology using fossil fuel, the baseline is the fuel consumption of the displaced technology. In this case, the fuel consumption of the displaced technology corresponds to the amount of fuel displaced by the biogas in the fuel oil boiler where co-firing occurs. Paragraph 10 further specifies that the baseline emissions is to be calculated based on heat output of the project activity times CO₂ emission factor of fuel used in the baseline, and efficiency of baseline equipment.

With consideration that co-firing with fuel **f** is likely, the heat output must be adjusted with thermal energy from fossil fuel calculated using specific fuel consumption and quantity of fossil fuel measured to comply with paragraph 21 of AMS-I.C.

$$BE_{y,f} = \frac{HG_y}{\eta_{th}} \times EF_{CO_2,f}$$

Equation 13

Parameter	Description	Unit
HG_y	Net quantity of heat supplied by the boiler	TJ/yr
$EF_{CO_2,f}$	Emission factor of fuel f displaced by biogas	tCO ₂ /TJ
η_{th}	Efficiency of the boiler	Unitless
f	Type of fossil fuel co-fired in the boiler	~

Efficiency of boiler

Parameter η_{th} will be set *ex-ante*. Paragraph 13 of methodology AMS-IC allows that efficiency of baseline boiler should adopt either one of the following: (a) highest measured efficiency of a unit with similar specifications; (b) highest of efficiency values provided by two manufacturers or more for units with similar specifications, or (c) maximum efficiency of 100%. For simplification, option (c) is selected.

Net quantity of heat supplied by the boiler, HG_y

In the Project situation, the net quantity of heat supplied by the boiler is to be calculated from the amount of steam and its state when leaving the boiler. For *ex-ante* calculation, the baseline emission from fuel displacement is estimated based on heat generated from the excess biogas (HG_{BIO}), which is not used in hydrogen production.

$$BE_{y,f} = HG_{BIO} \times EF_{CO_2,f}$$

Equation 14

The amount of heat derived from biogas is calculated as function of normalized volumetric flow rate of biogas times its low heating value (net calorific value).

$$HG_{BIO} = V_{E,y} \times LHV_{BIOGAS} \times C_4$$

Equation 15

The LHV of biogas is estimated based on the molar composition of methane in the biogas⁵ and the LHV of methane, which is 35.329MJ/Nm^{3,6}.

$$LHV_{BIOGAS} = LHV_{CH_4} \times \frac{m_{CH_4}}{m_{BIOGAS}}$$

Equation 16

Parameter	Description	Unit
LHV_{CH_4}	Low heating value of methane per normalized volume	MJ/Nm ³
$\frac{m_{CH_4}}{m_{BIOGAS}}$	Molar ratio of methane in biogas	molCH ₄ /molCO ₂
LHV_{BIOGAS}	Low heating value of biogas	MJ/Nm ³
$V_{E,y}$	Normalized volumetric flow-rate of biogas combusted in the boiler for heat generation	Nm ³
C_4	Conversion factor from MJ/TJ	MJ/TJ
HG_{BIO}	Amount of heat derived from biogas co-fired in the fuel-oil boiler.	TJ

BASELINE PARAMETER

⁵ This approach assumes that only methane contributes to the energy generation during combustion of biogas.

⁶ This value is calculated based on standard heat of combustion of methane minus the heat of vaporization of 2 moles of water formed.

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Table 4. Baseline Parameters

Related Methodology	Baseline Parameter	Description	Value and Unit
AMS.III-H	GWP_{CH_4}	Global warming potential	21 tCO ₂ /tCH ₄
	MW_{CH_4}	Molecular weight of methane	16g/mol
	P_N	Reference pressure at normal condition	10 ⁵ Pa
	T_N	Reference temperature at normal condition	273.15K
	R	Ideal gas constant	8.314m ³ .Pa.mol ⁻¹ .K ⁻¹
AMS.III-O	SFC_{LPG}	Specific fuel consumption of the hydrogen production unit if operated using LPG	0.1kg/NCMH Manufacturer specifications
AMS.I-C	η_{th}	Boiler efficiency	100%

B.5. Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered small-scale CDM project activity:

In accordance with Attachment B of Appendix B of the *Simplified Modalities and Procedures for Small Scale CDM Project Activity*, the Project Participant shall demonstrate that the Project would not have occurred without CDM as it faces at least one of the barrier specified in Appendix A: financial barrier, technological barrier, barrier due to prevailing practise, and other barrier.

The production of hydrogen from biogas is the ‘first-of-its-kind’. It is a novel but a risky approach. Currently, the conversion of biogas to hydrogen from palm-based oleo-chemical facility is not known in South East Asia. Typically for oleochemical purpose, hydrogen is supplied in bottle by a specialist gas producer. By implementing this project, NUB faces the risk associated with the implementation of new technology.

Anaerobic lagoon is prevalent in Sumatra where land is sufficiently available and affordable. PHG operates five palm oil mills in Sumatra, all of which treats its effluent using anaerobic lagoon. At present, there is no applicable regulation that mandates the capture of methane gas from industrial waste water in Indonesia. Combination of these two factors creates no incentives for NUB and other industry players to capture methane from its waste water and thus create a barrier due to prevailing practice.

Indonesia has for quite sometimes conduct experiments in small scale biogas projects to meet house-hold energy requirement in places with limited energy resources. However, successful commercial biogas project are predominantly been implemented as CDM endeavours. At the time of writing, this includes the registered Lampung Bekri Biogas Project and Sungai Budi Project.

B.6. Emission reductions:

B.6.1. Explanation of methodological choices:

A. Baseline Emissions

A.1. Emissions from Anaerobic Lagoons, BE_{y,CH_4}

In compliance with paragraph 24(d) of AMS-III.H, for case involving the introduction of a new step to existing anaerobic lagoon, case (vi), the baseline emissions is calculated as the emissions that would have been generated by the anaerobic lagoon without the project. In this case, the relevant lagoons are subsequent lagoons from lagoon 3 to lagoon 7.

However, paragraph 34 of methodology III.H stipulates that the calculation of emission reduction should be based on the methane recovered, fuelled or flared that is monitored *ex-post* reduced by the project emission and leakage. Consequently, in the project situation, the baseline emission is calculated based on volumetric measurements of biogas that is used for hydrogen production, combustion in boiler, and flared.

Thus, the baseline emission for this particular source is calculated using equation below:

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$$BE_{y,CH_4} = X_{CH_4,y} \cdot \frac{P_N \cdot V_{TR,y}}{R \cdot T_N} \cdot \frac{MW_{CH_4}}{X_1} \cdot GWP_{CH_4}$$

Equation 17

Parameter	Description	Unit
$X_{CH_4,y}$	Proportion of methane in biogas in volume/volume basis	Nm^3/Nm^3
P_N	Reference pressure at normal condition in Pascal	Pa
V_{TR}	Volumetric amount of biogas recovered	Nm^3/yr
R	Ideal gas constant	$m^3.Pa/mol.K$
T_N	Reference temperature at normal condition in Kelvin	K
MW_{CH_4}	Molecular weight of methane	gram/mol
X_1	Conversion factor 10^6 grams/tones	gram/ton
GWP_{CH_4}	Global warming potential of methane	tCO ₂ /tCH ₄

In this Project, the amount of methane utilized and burnt is equivalent to the amount of methane recovered in the Project installation. Thus, amount of methane recovered is calculated as the sum of all biogas delivered to various points in the project activity as shown in Figure 2 of this PDD.

$$V_{TR,y} = V_{D,y} + V_{E,y} + V_{F,y}$$

Equation 18

Parameter	Description	Unit
$V_{TR,y}$	Total volumetric amount of biogas recovered from the project	Nm^3/yr
$V_{D,y}$	Volumetric amount of biogas used in H ₂ production or point D in figure 2	Nm^3/yr
$V_{E,y}$	Volumetric amount of biogas used in the high pressure boiler or point E in figure 2	Nm^3/yr
$V_{F,y}$	Volumetric amount of biogas flared or point F in figure 2	Nm^3/yr

A.2. Emissions from reactions of LPG used for feedstock, BE_{LPG_FEED}

The project activity avoids the use of LPG as reactor feedstock and consequently avoids the CO₂ generation from reaction of LPG to form hydrogen. Baseline CO₂ emission from the reactions of LPG in the reactor is calculated based on the molar amount of hydrogen generated from biogas, and the CO₂ generation potential of the baseline fuel (LPG) evaluated from its molar composition.

$$BE_{LPG_FEED} = R_{CO_2/H_2} \times m_{H_2,BIO} \times MW_{CO_2} \times C_1$$

Equation 19

Parameter	Description	Unit
R_{CO_2/H_2}	CO ₂ generation potential as defined in	mol-CO ₂ /mol-H ₂
$m_{H_2,BIO}$	Molar quantity of hydrogen produced from biogas as calculated in Equation 8	kmol-H ₂ /yr
MW_{CO_2}	Molecular weight of CO ₂	kg-CO ₂ /kmol-CO ₂
C_1	Conversion factor tonne/kg	t-CO ₂ /kg-CO ₂

BE _{LPG_FEED}	Baseline CO ₂ emission from LPG for feedstock in the hydrogen plant	t-CO ₂ /yr
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Determination of R_{CO₂/H₂}

The calculation of CO₂ generation potential is based on the molar analysis of the LPG. At the time of PDD writing, there are 2 types of LPG available in Indonesian market⁷: propane rich LPG and butane-rich LPG. Emission from the reactions of LPG feedstock is therefore calculated by evaluating the molar composition of the stand-by LPG feedstock.

$$R_{CO_2/H_2} = \frac{[3m_1 + 4m_2]}{10m_1 + 13m_2}$$

Equation 20

Parameter	Description	Unit
m ₁	% mol of the propane in the LPG	mol-C ₃ H ₈ /mol-LPG
m ₂	% mol of the butane in the LPG	mol-C ₄ H ₁₀ /mol-LPG

Properties of LPG feedstock

LPG is typically a mixture of propane and butane. The actual molar composition m₁ and m₂ is obtained from LPG specification from the gas supplier or if not available compositional analysis performed by an independent certified laboratory. Properties of individual molecules are summarized in the following table 4.

Table 5. Specification of LPG Mixture

Components	Formula	% mol	Molecular Weight (MW) in g/mol	Number of Carbon in molecule (n)	Number of hydrogen in molecule (m)
Propane	C ₃ H ₈	m ₁ %	44	3	8
Butane	C ₄ H ₁₀	m ₂ %	58	4	10

For LPG mixture containing m₁% mol of propane and m₂% mol of butane, molecular weight of the mixture (MW_{LPG}) can be calculated as weighted average of individual gas using the following relationship:

$$MW_{LPG} = m_1\% \times 44 + m_2\% \times 58$$

Equation 21

Reactions from LPG

Based on Equation 1 and Equation 2, and number of carbon and hydrogen atom per molecules specified in table 4, the following reactions occurred in the baseline process:

Table 6. LPG Reactions during Hydrogen Production

Source Gas	Reaction Type	Ref. Eq.	Reactions
Propane	Steam Reforming	(A)	C ₃ H ₈ + 3H ₂ O ↔ 3CO + 7H ₂
	Shift-Conversion	(B)	3CO + 3H ₂ O ↔ 3CO ₂ + 3H ₂
	Sub-total	(C)=(A)+(B)	C ₃ H ₈ + 6H ₂ O ↔ 3CO ₂ + 10H ₂
Butane	Steam Reforming	(D)	C ₄ H ₁₀ + 4H ₂ O ↔ 4CO + 9H ₂
	Shift-Conversion	(E)	4CO + 4H ₂ O ↔ 4CO ₂ + 4H ₂
	Sub-total	(F)=(D)+(E)	C ₄ H ₁₀ + 8H ₂ O ↔ 4CO ₂ + 13H ₂

⁷ Based on information in PERTAMINA website

For each 100mol of LPG containing m_1 mol of propane and m_2 mol of butane, the following reactions occurs:

Table 7. Reactions from 100mol LPG

Source Gas	Composition in 100 mol	Ref. Reaction from	Reactions
Propane	m_1	(C)	$[m_1]C_3H_8 + [6m_1]H_2O \leftrightarrow [3m_1]CO_2 + [10m_1]H_2$
Butane	m_2	(F)	$[m_2]C_4H_{10} + [8m_2]H_2O \leftrightarrow [4m_2]CO_2 + [13m_2]H_2$
Total			As 100mol LPG = $[m_1]C_3H_8 + [m_2]C_4H_{10}$, (C) + (F) is $100molLPG + [6m_1 + 8m_2]H_2O \leftrightarrow [3m_1 + 4m_2]CO_2 + [10m_1 + 13m_2]H_2$

CO₂ generation potential, R_{CO_2/H_2}

From total reaction in table 6, the *CO₂ generation potential* can be defined as:

$$R_{CO_2/H_2} = \frac{[3m_1 + 4m_2]}{[10m_1 + 13m_2]}$$

Equation 22

Determination of Hydrogen derived from biogas, $m_{H_2,BIO}$

The molar amount of hydrogen derived from biogas is calculated as the difference between the total molar amount of hydrogen produced in the hydrogen production unit and the molar amount of hydrogen produced using LPG

$$m_{H_2,BIO} = m_{H_2,T} - m_{H_2,LPG}$$

Equation 23

Parameter	Description	Unit
$m_{H_2,T}$	Total molar amount of hydrogen produced by hydrogen production unit	kmol-H ₂ /yr
$m_{H_2,LPG}$	Molar amount of hydrogen derived from LPG	kmol-H ₂ /yr
$m_{H_2,BIO}$	Molar amount of hydrogen derived from biogas	kmol-H ₂ /yr

Total molar production of hydrogen, $m_{H_2,T}$

The total hydrogen production will be measured in the unit of NCMH or normalized m³ per hour and converted into its equivalent molar unit using ideal gas equation⁸:

$$m_{H_2,T} = \frac{1 \times 10^5 Pa \times V_{H_2,T}}{8.314 \frac{Pa \cdot m^3}{mol \cdot K} \times 273.15K \times 1,000 \frac{mol}{kmol}}$$

Equation 24

Parameter	Description	Unit
$V_{H_2,T}$	Total volume of hydrogen produced in normal volume	Nm ³ /yr
$m_{H_2,T}$	Equivalent molar quantity of hydrogen produced	kmol-H ₂ /yr

⁸ Ideal gas equation: $PV=nRT$, where n is molar quantity, and R is gas constant with SI value of $8.314Pa \cdot m^3/mol \cdot K$, pressure and temperature at normal conditions [1 bar, 273.15K]

Molar amount of hydrogen derived from LPG, $m_{H_2,LPG}$

The molar amount of hydrogen derived from LPG is calculated as follow:

$$m_{H_2,LPG} = R_{H_2/LPG} \times \frac{M_{LPG}}{MW_{LPG}}$$

Equation 25

Parameter	Description	Unit
M_{LPG}	Amount of LPG used as reaction feedstock in mass unit based on monitoring	kg-LPG/yr
$R_{H_2/LPG}$	H ₂ generation potential as calculated in Equation 26	mol-H ₂ /mol-LPG
MW_{LPG}	Molecular weight of LPG	kgLPG/kmolLPG
$m_{H_2,LPG}$	Molar amount of hydrogen derived from LPG	kmol-H ₂ /yr

H₂ generation potential from LPG, $R_{H_2/LPG}$

From total reaction in table 6, the hydrogen generation potential from LPG is defined as follow:

$$R_{H_2/LPG} = \frac{[10m_1 + 13m_2]}{100}$$

Equation 26

A.3. Emission from combustion of LPG as fuel to reforming process, BE_{LPG_FUEL}

The project activity avoided the use of LPG as combustion fuel in the reformer and consequently avoided CO₂ derived from this process. The baseline emission from the combustion of LPG in the reformer box avoided by the project activity is calculated as follow:

$$BE_{LPG_FUEL} = SFC_{LPG} \times V_{H_2,BIO} \times EF_{LPG} \times C_3$$

Equation 27

Parameter	Description	Unit
SFC_{LPG}	Specific fuel consumption of hydrogen production unit (reformer burner) when run using LPG.	kgLPG/Nm ³ -H ₂
$V_{H_2,BIO}$	Volume of hydrogen derived from biogas as calculated using Equation 28	Nm ³ -H ₂ /yr
EF_{LPG}	Emission factor of LPG	kg-CO ₂ /kg-LPG
C_3	Conversion factor t/kg, 0.001	t/1000kg
BE_{LPG_FUEL}	Baseline CO ₂ emission from avoidance of LPG in reformer burner.	t-CO ₂

The volumetric amount of hydrogen derived from biogas is calculated based on its molar volume $m_{H_2,BIO}$, using ideal gas relationship.

$$V_{H_2,BIO} = \frac{m_{H_2,BIO} \times 1000 \frac{\text{mol}}{\text{kmol}} \times 8.314 \frac{\text{Pa} \cdot \text{m}^3}{\text{mol} \cdot \text{K}} \times 273.15\text{K}}{1 \times 10^5 \text{Pa}}$$

Equation 28

Parameter	Description	Unit
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$m_{H_2,BIO}$	Molar quantity of hydrogen produced from biogas as calculated in Equation 23	kmol-H ₂ /yr
$V_{H_2,BIO}$	Amount of hydrogen produced from biogas in volumetric unit	Nm ³ -H ₂ /yr

A.4. Emission from fuel oil displacement in co-firing boiler process, BE_{y,f}

As it is indicated in paragraph 6 of AMS-I.C, baseline for the co-firing process is the displaced fuel consumption by the biogas in the boiler where the co-firing occurs. According to paragraph 10, the baseline emission is to be calculated based on net heat output of the project activity times CO₂ emission factor of the fuel used in baseline.

The net heat output of the project activity is calculated from measurement results of the output of the boiler, which will be carried out by measuring the steam flow, pressure, and temperature in the boiler's output. The measured heat output must be adjusted to deduct thermal energy generation from fossil fuels using the specific fuel consumption and the quantity of fossil fuel consumed, as it mandated in paragraph 21 of AMS-I.C.

$$BE_{y,f} = \frac{HG_y}{\eta_{th}} \times EF_{CO_2,f}$$

Equation 29

Parameter	Description	Unit
HG _y	Net quantity of heat supplied by the boiler	TJ/yr
EF _{CO₂,f}	Emission factor of fuel f displaced by biogas	tCO ₂ /TJ
η _{BL}	Efficiency of the boiler	Unitless
f	Type of fossil fuel co-fired in the boiler	~

B. Project Emissions**B.1 Emission from combustion of fossil fuel to generate power used to run the project equipment, PE_{MCS,y,power}**
NUB complex generates its own electricity using biomass and does not use electricity from external sources (grid).

Consequently,

$$PE_{MCS,y,power} = 0$$

Equation 30**B.2 CH₄ emission from degradable organic matter in treated waste water returned to anaerobic lagoon, PE_{MCS,y,ww,treated}**

Due to the inefficiency of Project's installation, some organic matter remains in the waste water and exits the project installation to the anaerobic lagoon. Methane emission from the decomposition of the remaining organic matter is accounted as project emission and is calculated as follow:

$$PE_{MCS,y,ww,treated} = Q_{y,ww} \times COD_{y,ww,treated} \times B_{o,ww} \times MCF_{ww,final} \times GWP_{CH_4}$$

Equation 31

Parameter	Description	Unit
Q _{y,ww}	Total volumetric flow rate of effluent entering pond number 4 after being treated by the Project's reactors. It can be assumed that the volumetric flow rate is the same at point A and point B.	m ³ /yr
COD _{y,ww,treated}	Chemical Oxygen Demand (COD) concentration of the effluent entering pond	t-COD /m ³

	number 4 after being treated by the Project’s reactors.	
$B_{o,ww}$	Methane generation potential of waste water	t-CH ₄ /t-COD
$MCF_{ww,final}$	Methane correction factor applicable to the type of treatment and discharge pathway of the wastewater	Unit less
GWP_{CH4}	Global warming potential of methane gas.	t-CO ₂ /t-CH ₄
$PE_{MCS,ww,treated}$	Project emission from bio-organic matter escaping MCS	t-CO ₂

B.3 CH₄ emission from final sludge disposed, $PE_{MCS,y,s,final}$

The amount of sludge in the final effluent is disposed as suspended solid in the final effluent which drains into the water body behind NUB facility. Regularly, sedimentation in lagoon number 3 to 7 and impurities collected by the collection bin are removed and the sediment is disposed aerobically as fertilizer to the vegetation behind the facility.

$$PE_{MCS,y,s,final} = 0$$

Equation 32

B.4 Fugitive CH₄ emission from the inefficiency of the AD and flare system, $PE_{MCS,y,fugitive}$

The Project and existing anaerobic lagoons treat the suspended solid and the waste water under the same effluent treatment system. Most of this suspended solid would be broken down into simpler organic compound during the digestion process and the subsequent anaerobic lagoon. Consequently, the fugitive emission is calculated based on the overall treatment system.

$$PE_{MCS,y,fugitive} = (1 - CFE_p) \times MEP_{y,ww,treatment} \times GWP_{CH4}$$

Equation 33

Parameter	Description	Unit
$MEP_{y,ww,treatment}$	Methane emission potential from untreated waste water calculated under Equation 34.	t-CH ₄ /yr
CFE_p	Capture efficiency of the Project’s installation as established in the following Equation 35, based on periodic leak measurement test and default flare efficiency.	Unitless
GWP_{CH4}	Global warming potential of methane gas	t-CO ₂ /t-CH ₄

Methane emission potential from untreated waste water

$$MEP_{y,ww,treatment} = Q_{y,ww} \times \sum_j COD_{y,removed,j} \times B_{o,ww} \times MCF_{ww,j}$$

Equation 34

Parameter	Description	Unit
$Q_{y,ww}$	Total volumetric flowrate of effluent entering pond number 3 before the Project which is re-routed to the Project’s reactor	m ³ /yr
$\sum_j COD_{y,removed,j}$	The difference of Chemical Oxygen Demand (COD) concentration of the effluent entering pond number 3 before the project which is re-routed to the Project’s reactor (COD_A) and COD effluent entering lagoon 4 after the project (COD_B)	t-COD /m ³
$B_{o,ww}$	Methane generation potential of waste water	t-CH ₄ /t-COD
$MCF_{ww,j}$	Methane correction factor for the wastewater treatment system “j” equipped with methane recovery and combustion/flare/utilization equipment	Unitless
$MEP_{y,ww,treatment}$	Methane emission potential	t-CH ₄ /yr

Determining capture and utilization efficiency of AD system, CFE_p

The project installations consists of a series of fully-sealed stainless steel tanks with combination of fixed and floating roof and pipe networks, equipped with pumping equipments to deliver the biogas to its designated users.

The anaerobic digester system consists of fully-sealed stainless steel tanks with interconnecting steam pipeline. Prior to commissioning, these equipments undergo leakage test, and thus, leakage is expected to be very small. If leakage occurs in the digester system and its subsequent pipeline network, it will be reflected in the baseline calculation as it is based on actual biogas consumption at end-users (Equation 3). Consequently, the only source of leakage is the biogas not combusted in the open flare.

If the project proponent decided not to monitor the operation of the flare unit, methodology default value for capture and flare efficiency of 0.9 must be adopted. Otherwise, the capture and flare efficiency is estimated by deducting the proportion of biogas leak to atmosphere due to flare inefficiency ($L_{\text{flare},y}$):

$$\text{CFE}_p = 0.9, \text{ or if flare is monitored: } \text{CFE}_p = 1 - L_{\text{flare},y}$$

Equation 35

Proportion of biogas loss in flare, $L_{\text{flare},y}$

The calculation of biogas leakage from flare unit follows the guideline provided by ‘Tool to determine project emissions from flaring gases containing methane’ (or subsequently referred as ‘Tool’) using equation analogous to Equation 15 of Step 7 of the Tool. The equation calculates project emissions from biogas un-combusted in flare being proportional to 1(one) minus the flare efficiency, η_{FLARE} .

As not all biogas generated by the anaerobic digester are flared, the **proportion** of leakage of biogas from flare is calculated by adjusting the efficiency value with *the ratio of biogas flared relative to total biogas generated by the anaerobic digester*.

$$L_{\text{flare},y} = \frac{V_{E,y}}{V_{\text{TR},y}} \times (1 - \eta_{\text{FLARE},y})$$

Equation 36

In order to determine suitable η_{FLARE} , Step 6 of the ‘Tool’ mandated continuous monitoring of the flare operation to determine the hourly efficiency value ($\eta_{\text{FLARE},h}$). The Tool prescribed that if flame is not detected for more than 20minutes during hour h , then $\eta_{\text{FLARE},h}$ is 0, otherwise $\eta_{\text{FLARE},h}$ is 50%.

As there are only 2 types of hourly efficiency values (50% maximum value or 0% minimum value), the periodic efficiency, $\eta_{\text{FLARE},y}$, can be estimated by adjusting the maximum efficiency with the fraction of time of which the condition for maximum value is met, ie. flare is detected for more than 20 minutes, $F_{T,y}$.

$$F_{T,y} = \frac{\text{no. of hours in year } y, \text{ which flare is detected for more than 20 mins in an hour}}{\text{no. of hours per year}} = \frac{F_{T20,y}}{8,760}$$

$$\eta_{\text{FLARE},y} = F_{T,y} * 50\%$$

Parameter	Description	Unit
$L_{\text{flare},y}$	% Biogas loss due to flaring inefficiency	%
$V_{E,y}$	Volume of biogas flared	Nm ³
$V_{\text{TR},y}$	Total volume of biogas recovered as calculated in Equation 3 of this PDD	Nm ³
E_{FLARE}	Efficiency of flaring process	Unitless
$FT_{\text{flare},y}$	The fraction of time of which the biogas is flared	%

If no measurement is performed to establish the leakage rate as defined above, capture efficiency rate of 90% must be used as prescribed in paragraph 16 of AMS-III-H.

B.5 CH₄ emission from final treated waste water disposed to river system, PE_{MCS,y,dissolved}

The remaining effluent has some methane dissolved which will be disposed to the river system. The associated emission from this final effluent is calculated as follow:

$$PE_{MCS,y,dissolved} = Q_{y,ww} \times [CH_4]_{y,ww,treated} \times GWP_{CH_4}$$

Equation 37

Parameter	Description	Unit
$Q_{y,ww}$	Total effluent flow rate at point A in Figure 2	m ³
$[CH_4]_{y,ww,treated}$	Dissolved methane at point G in Figure 2	t-CH ₄ /m ³
GWP_{CH_4}	Global warming potential of methane gas	t-CO ₂ /t-CH ₄

B.6 CO₂ emission from power used to run biogas treatment system, PE_{PSA,y,power}

The complex generates its own electricity using biomass and does not use electricity from external sources (grid).

Consequently,

$$PE_{PSA,y,power} = 0$$

Equation 38**B.7 CO₂ emission from fuel used to run biogas treatment system, PE_{PSA,y,fuel}**

The PSA uses low pressure steam to regenerate its carbon bed. For this purpose, the hydrogen production unit itself is equipped with a waste heat boiler to recover excess heat from the reformer box – which is fuelled using biogas. The use of fossil fuel for this purpose is therefore unforeseen.

Consequently,

$$PE_{PSA,y,fuel} = 0$$

Equation 39**B.8 Greenhouse gas emissions from the use of additional chemical in the biogas cleaning system, PE_{PSA,y,chem}**

The biogas purification unit uses steam to regenerate the adsorbent, in this case carbon. No chemical will be used for the operation of this pressure swing adsorption.

Consequently,

$$PE_{PSA,y,chem} = 0$$

Equation 40**B.9 CO₂ emission from fuel burnt in the boiler, PE_{th,y,f}**

Co-firing process in the boiler burnt simultaneously the biogas and fuel oil type, *f*. While the total heat generated is regarded as a factor in baseline emission calculation, the emissions from fuel oil combustion would be considered as a source of project emission.

$$PE_{th,y,f} = \frac{M_{f,y}}{SFC_{BL}} \times EF_{CO_2,f}$$

Equation 41

Parameter	Description	Unit
$M_{f,y}$	Quantity of fossil fuel <i>f</i> consumed by the boiler	t-fuel/yr

SFC_{BL}	Specific fuel consumption of the boiler, if operated using fossil fuel	t-fuel/TJ
$EF_{CO_2,f}$	Emission factor of fuel f displaced by biogas	tCO ₂ /TJ
f	Type of fossil fuel co-fired in the boiler	~

C. Leakage Emissions

The adopted methodology AMS.I-C and AMS.III-H stipulates that leakage effect is to be considered if:

- The Project technology is equipment transferred from another activity; or
- The existing technology is transferred to another activity.

In the case of the Project, the Project equipments are new equipments and the anaerobic lagoon will not be used by other activity other than NUB's activity as it is located inside NUB. The displaced boiler will be modified as part of the project activity and will remain in service in its original designation for back-up purpose. Thus, from equipment movement point of view, there is no leakage source to be monitored.

D. Emission Reductions

All parameters are reported in t-CO₂/yr

Total emission reduction, ER_T

$$ER_T = BE_T - PE_T$$

Equation 42

Total baseline emissions, BE_T

$$BE_T = BE_{y,CH_4} + BE_{LPG,feed} + BE_{LPG,fuel} + BE_{y,f}$$

Equation 43

Parameter	Description
BE_{y,CH_4}	CH ₄ emission from pre-Project anaerobic lagoons system
$BE_{LPG,feed}$	CO ₂ emission from use of LPG for feedstock to hydrogen plant
$BE_{LPG,fuel}$	CO ₂ emission from use of LPG as fuel to hydrogen plant
BE_{HP}	CO ₂ emission from use of residue oil in HP boiler

Total project emissions, PE_T

$$PE_T = PE_{MCS,y,power} + PE_{MCS,y,ww,treated} + PE_{MCS,y,s,final} + PE_{MCS,y,fugitive} + PE_{MCS,y,dissolved} + PE_{PSA,y,power} + PE_{PSA,y,fuel} + PE_{PSA,y,chem} + PE_{th,y,f}$$

Equation 44

Parameter	Description
$PE_{MCS,y,power}$	CO ₂ emission from power used to run the MCS
$PE_{MCS,y,ww,treated}$	CH ₄ emission from bio-organic matter untreated in the MCS and returned to lagoon.
$PE_{MCS,y,s,final}$	CH ₄ (fugitive) emission from the inefficiency of the AD and reactor flare system
$PE_{MCS,y,fugitive}$	CH ₄ emission from final sludge disposal

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$PE_{MCS,y,dissolved}$	CH ₄ emission from final treated waste water disposed to river system
$PE_{PSA,y,power}$	CO ₂ Emission from power use to run biogas treatment system (PSA)
$PE_{PSA,y,fuel}$	CO ₂ Emission from fuel use to run biogas treatment system (PSA)
$PE_{PSA,y,chem}$	GHG Emission from additional chemical to run biogas treatment system (PSA)
$PE_{th,y,f}$	CO ₂ emission from fuel burnt in the boiler

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

Data / Parameter:	P_N
Data unit:	Pressure in Pascal (Pa)
Description:	Reference pressure (P) at normal (N) condition as adopted by the volume measurement device
Source of data used:	IUPAC (present) definition or other internationally accepted definition
Value applied:	IUPAC (present) definition: Normal Pressure 100kPa or 105Pa IUPAC (past) definition: Normal Pressure 101.325kPa or 1.01325×105Pa
Justification of the choice of data or description of measurement methods and procedures actually applied :	
Any comment:	N/A

Data / Parameter:	T_N
Data unit:	Temperature in Kelvin (K)
Description:	Reference temperature (T) at normal (N) condition as adopted by the volume measurement device
Source of data used:	IUPAC (present) definition or other internationally accepted definition
Value applied:	IUPAC definition: Normal Temperature 0°C or 273.15°K
Justification of the choice of data or description of measurement methods and procedures actually applied :	
Any comment:	N/A

Data / Parameter:	R
Data unit:	$m^3.Pa.mol^{-1}.K^{-1}$
Description:	Ideal gas constant in SI Unit
Source of data used:	Standard engineering literature
Value applied:	8.314
Justification of the choice of data or description of measurement methods and procedures actually applied :	
Any comment:	

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Data / Parameter:	B_{o,ww}
Data unit:	t-CH ₄ /t-COD
Description:	Methane generation potential of waste water
Source of data used:	Methodology default value
Value applied:	0.21 t-CH ₄ /t-COD
Justification of the choice of data or description of measurement methods and procedures actually applied:	
Any comment:	N/A

Data / Parameter:	MCF_{AL}
Data unit:	Unitless
Description:	Methane correction factor applicable to anaerobic lagoon
Source of data used:	Lower value (L) or High value (H) of Table III.H-1 for deep anaerobic lagoon
Value applied:	Lower value 0.8 High value 1.0
Justification of the choice of data or description of measurement methods and procedures actually applied:	The existing lagoons has depth about 5m
Any comment:	N/A

Data / Parameter:	GWP_{CH4}
Data unit:	t-CO ₂ /t-CH ₄
Description:	Global warming potential of methane
Source of data used:	IPCC Data
Value applied:	21 t-CO ₂ /t-CH ₄
Justification of the choice of data or description of measurement methods and procedures actually applied:	
Any comment:	To be updated with re-issuance of latest IPCC report

Data / Parameter:	SFC_{LPG}
Data unit:	kg _{LPG} /Nm ³ _{H2}
Description:	Specific fuel consumption of the hydrogen production unit using LPG as fuel
Source of data used:	Manufacturer's specification
Value applied:	0.1kg _{LPG} /Nm ³ _{H2}
Justification of the choice of data or description of measurement methods and procedures actually applied:	
Any comment:	

Data / Parameter:	η_{th}
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Data unit:	Unitless
Description:	Boiler efficiency
Source of data used:	AMS I.C
Value applied:	100%
Justification of the choice of data or description of measurement methods and procedures actually applied:	Methodology default value, conservative approach
Any comment:	

Data / Parameter:	E_{flare}
Data unit:	Unitless
Description:	Flare efficiency
Source of data used:	Default number for enclosed flare in the “Tool to determine project emission from flaring gases containing methane”
Value applied:	0.5 for open flare case
Justification of the choice of data or description of measurement methods and procedures actually applied:	
Any comment:	

Data / Parameter:	CFE_p
Data unit:	Unitless
Description:	Capture and utilization efficiency of the project installation
Source of data used:	AMS III.H
Value applied:	0.9
Justification of the choice of data or description of measurement methods and procedures actually applied:	Methodology default value
Any comment:	

Data / Parameter:	CH_{4,y,ww,treated}
Data unit:	t-CH ₄ /m ³
Description:	Dissolved methane at final effluent
Source of data used:	AMS III.H
Value applied:	10 ⁻⁴
Justification of the choice of data or description of measurement methods and procedures actually applied:	Methodology default value
Any comment:	

Data / Parameter:	MW_{CO2}; MW_{C3H8}; MW_{C4H10}; MW_{CH4}
Data unit:	g/mol

Description:	Molecular weight of CO ₂ , C ₃ H ₈ , C ₄ H ₁₀ , and CH ₄ respectively
Source of data used:	Standard chemistry literature
Value applied:	44g/mol; 44g/mol; 58g/mol; and 16g/mol
Justification of the choice of data or description of measurement methods and procedures actually applied:	
Any comment:	

B.6.3 Ex-ante calculation of emission reductions:

A. BASELINE EMISSIONS

A.1 Emissions from existing anaerobic lagoons, BE_{y,CH4}

It is estimated that the palm oil mill activity generates 210,000m³ of wastewater per year with COD loading of 52,000mg/L. The pond system reduces the loading below the government set level of 300mg/L. However, since the baseline is calculated only based on the methane captured in the new anaerobic digester, the baseline emission is calculated based on COD at the outlet of the digester. Using *ex-ante* parameter shown above, the methane emitted from existing anaerobic lagoon is calculated as follow:

$$BE_{y,CH_4} = 228,000 \frac{m^3}{yr} \times (0.052 - 0.03) \frac{t-COD}{m^3} \times 0.21 \frac{t-CH_4}{t-COD} \times 0.8 \times 21 \frac{t-CO_2}{t-CH_4} = 39,414 \frac{t-CO_2}{yr}$$

A.2 Emission from reactions of LPG feedstock, BE_{LPG_FEED}

The stand-by feedstock to the Hydrogen plant is LPG with molar concentration of propane and butane of 0.95 and 0.5 respectively. Using

Equation 6, the CO₂ generation potential of this fuel is calculated as follow:

$$R_{CO_2/H_2} = \frac{[3 \times 0.95 + 4 \times 0.05]}{[10 \times 0.95 + 13 \times 0.05]} = \frac{3.05}{10.15} = 0.3005 \frac{kmolCO_2}{kmolH_2}$$

Total molar production of hydrogen, m_{H2,T}

The hydrogen plant is designed to produce 750NCMH at normal operating requirement, or equivalent to 5,400,000Nm³/yr based on 7,200hr/yr operation hour. The equivalent molar amount of hydrogen produced is calculated as follow:

$$m_{H_2,T} = \frac{1.0 \times 10^5 Pa \times 5,400,000 \frac{m^3}{yr}}{8.314 \frac{Pa \cdot m^3}{mol \cdot K} \times 273.15 K \times 1,000 \frac{mol}{kmol}} = 237,784 \frac{kmolH_2}{yr}$$

Molar amount of hydrogen derived from LPG, m_{H2,LPG}

When biogas is not available, hydrogen will be produced (and subsequently fuelled) using LPG. The manufacturer specification specifies that the plant will consume about 245kg of LPG per hour for production of 750NCMH of hydrogen. The LPG is only used if the MCS does not generate sufficient biogas due to low production activity. For *ex-ante* estimation purpose, it is assumed that this situation does not occur, and thus the LPG consumption (M_{LPG}) and subsequent molar amount of hydrogen derived from LPG (m_{H2,LPG}) is also zero.

Molar amount of hydrogen derived from biogas, m_{H2,BIO}

The molar amount of hydrogen derived from biogas is calculated as the difference between the total molar amount of hydrogen produced in the hydrogen production unit and the molar amount of hydrogen produced using LPG.

$$m_{H_2,BIO} = 237,784 \frac{kmolH_2}{yr} - 0 \frac{kmolH_2}{yr} = 237,784 \frac{kmolH_2}{yr}$$

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Avoided CO₂ emission from consumption of LPG as feedstock to reaction, BE_{LPG_FEED}

The associated emission from the use of LPG as baseline feedstock is calculated as follow:

$$BE_{LPG_FEED} = 0.3005 \frac{\text{kmolCO}_2}{\text{kmolH}_2} \times 237,784 \frac{\text{kmol H}_2}{\text{yr}} \times 44 \frac{\text{kgCO}_2}{\text{kmolCO}_2} \times \frac{1\text{tCO}_2}{10^3\text{kgCO}_2} = 3,144 \frac{\text{tCO}_2}{\text{yr}}$$

A.3 Baseline Emission from combustion of LPG as fuel to reforming process, BE_{LPG_FUEL}**Volume of hydrogen derived from biogas, V_{H₂,BIO}**With assumption that there are no hydrogen is derived from LPG the consumption, the volume of hydrogen derived from biogas is equivalent to total hydrogen production of 5,400,000Nm³/yr.

$$V_{H_2,BIO} = 5,400,000 \frac{\text{Nm}^3\text{H}_2}{\text{yr}}$$

Emission factor of LPG containing 95% propane and 5% butane, EF_{LPG}

The emission factor of LPG is calculated based on the on the weighted-average carbon content of LPG, which is evaluated based on its composition as shown below.

Component	% mol	MW	Mass 1mol LPG	Mass of LPG ⁹	% Carbon ¹⁰	Mass of Carbon per mass of LPG
	(A)	(B)	(C)	(D)	(E)	(F)
Formula			(A)*(B)			(D)*(E)
Propane, C ₃ H ₈	0.95	44	41.8	0.9268	0.818	0.758
Butane, C ₄ H ₁₀	0.05	66	3.3	0.0732	0.727	0.053
			45.1	1		0.811

Based on the carbon content of LPG, the emission factor is calculated as follow:

$$EF_{LPG} = 0.811 \frac{\text{kgC}}{\text{kgLPG}} \cdot \frac{44 \text{ kgCO}_2}{12 \text{ kgC}} = 2.974 \frac{\text{kgCO}_2}{\text{kgLPG}}$$

The hydrogen production unit is designed to consume 75kgLPG/750Nm³-H₂ or 0.1kgLPG/Nm³-H₂. Without the Project, the emission associated with production 5,400,000Nm³ of H₂ per year is calculated to be 1,604tCO₂/yr.

$$BE_{LPG_FUEL} = 0.1 \frac{\text{kgLPG}}{\text{Nm}^3\text{H}_2} \times 5,400,000 \frac{\text{Nm}^3\text{H}_2}{\text{yr}} \times \frac{2.974\text{kgCO}_2}{\text{kgLPG}} \times \frac{1\text{t}}{10^3\text{kg}} = 1,606 \frac{\text{tCO}_2}{\text{yr}}$$

A4. Emissions from combustion of fuel oil in the boiler, BE_{th,y,f}

Excess biogas unconsumed by hydrogen production will be burned in a boiler to reduce its fossil fuel consumption. The emission reduction corresponds to the amount of fuel displaced in equivalent energy unit and subsequently the amount of methane combusted for this purpose in energy unit. The following few paragraphs estimate the amount methane used for this purpose via molar balance.

Methane Emission Potential, M_{CH₄,AL}

Using the same parameters as those used for baseline estimate (B.6.3-A.1), the amount of methane captured by the anaerobic digester is calculated to be 2,3

⁹ Normalized mass fraction based on Column C¹⁰ The % of carbon is evaluated based on the carbon content of individual component. For example, propane contains 3 carbon atoms per molecule with total mass of 44g per mole. Each carbon atom has mass of 12g per mole, hence the carbon content is: 3*12/44=0.818 mass/mass basis.

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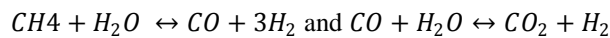
$$M_{CH_4,AL} = 228,000 \frac{m^3}{yr} \times 0.049 \frac{tCOD}{m^3} \times 0.21 \frac{tCH_4}{tCOD} \times 0.8 = 1,876 \frac{tCH_4}{yr}$$

With molecular weight of methane of 16 g/mol, the equivalent molar quantity ($m_{CH_4,AL}$) of the methane captured in equivalent molar unit is calculated as follow:

$$m_{CH_4,AL} = 1,876 \frac{tCH_4}{yr} \times 10^6 \frac{g_{CH_4}}{t_{CH_4}} \times \frac{1 \text{ mol}}{16 \text{ g}_{CH_4}} \times \frac{1 \text{ kmol}}{1,000 \text{ mol}} = 117,250 \frac{\text{kmol}}{\text{yr}}$$

Bio-methane required for hydrogen production feedstock, $m_{CH_4,FEED}$

Using the generic steam reforming/shift reaction described in Equation 1 and Equation 2, hydrogen production from methane is described by the following reactions:



From the above-described equation, 1 mol of methane produces 4 moles of hydrogen or 0.25mol of bio-methane is needed to generate 1mol of hydrogen. With reference to hydrogen production $m_{H_2,BIO}$ of 237,784kmol of H_2 calculated in B.6.3-A.2, the total molar quantity of bio-methane used for hydrogen production per year is calculated as follow:

$$m_{CH_4,FEED} = 0.25 \frac{\text{kmol}_{CH_4}}{\text{kmol}_{H_2}} \times 237,784 \frac{\text{kmol}_{H_2}}{\text{yr}} = 59,446 \frac{\text{kmol}}{\text{yr}}$$

Bio-methane required for replacing LPG as fuel in hydrogen production, $m_{CH_4,FUEL}$

Using manufacturer specified specific fuel (SFC_{LPG}) consumption of $0.1 \text{ kg/Nm}^3\text{-H}_2$, hydrogen production of $750 \text{ Nm}^3/\text{hr}$ and operating hour of 7,200hr per year. The LPG consumption for fuel in the baseline is estimated to be 540,000kg. Using IPCC specified NCV of LPG of 47.3MJ/kg, the heat needed by the reforming process for hydrogen production is 25.54TJ/yr

With assumption of methane heating value of 35.816 MJ/Nm^3 or to 802.3kJ/mol, the amount of bio-methane required as fuel in the baseline situation is calculated as follow:

$$m_{CH_4,FUEL} = 25.54 \frac{\text{TJ}}{\text{yr}} \times \frac{10^9 \text{ kJ}}{\text{TJ}} \times \frac{\text{mol}}{802.3 \text{ kJ}} \times \frac{\text{kmol}}{\text{mol}} = 31,833 \frac{\text{kmol}}{\text{yr}}$$

Total projected bio-methane required for hydrogen production

Based on the above-calculated consumption of 59,446kmol for feedstock and 31,833kmol for fuel, the amount of biomethane required is 91,279kmol/yr.

Bio-methane for displacing residue oil in the high pressure boiler

It is estimated earlier that the amount of biomethane captured in the anaerobic digester ($m_{CH_4,AL}$) is approximately 117,250kmol/yr. Out of this, 92,279kmol per year is consumed for hydrogen production. The amount of bio-methane directed for combustion to reduce fuel oil is therefore 24,971kmol/yr. Based on heating value of 802.3kJ/mol, the equivalent energy displaced is calculated as follow:

$$HG_{BIO} = 24,971 \frac{\text{kmol}}{\text{yr}} \times 802.3 \frac{\text{kJ}}{\text{mol}} \times 1000 \frac{\text{mol}}{\text{kmol}} \times 10^{-9} \frac{\text{TJ}}{\text{kJ}} = 20.03 \frac{\text{TJ}}{\text{yr}}$$

Avoided emission from displacement of residue oil by biogas

Emission from combustion of residue oil for heating value equal to the amount of biogas burnt in the residue oil boiler is calculated as follows:

$$BE_{th,y,f} = \frac{20.03 \frac{\text{TJ}}{\text{yr}} \times 74.1 \frac{tCO_2}{\text{TJ}}}{100\%} = 1,484 \frac{tCO_2}{\text{yr}}$$

B. PROJECT EMISSIONS

B.1 CO₂ emission from the combustion of fossil fuel to generate power used to run the project equipment, $PE_{MCS,y,power}$

The NUB complex generates its own electricity using biomass does not use electricity from external sources (grid).

Consequently,

$$PE_{MCS,y,power} = 0$$

B.2 CH₄ emission from the organic matter untreated by the Project and returned to anaerobic lagoon, $PE_{MCS,y,ww,treated}$

The Project reduces the COD effluent concentration to 3000mg/L, the emission associated with methane emission that will be released from this untreated bio-organic matter in the subsequent lagoons is calculated as follow:

$$PE_{MCS,y,ww,treated} = 228,000 \frac{m^3}{yr} \times 0.003 \frac{t-COD}{m^3} \times 0.21 \frac{t-CH_4}{t-CPD} \times 1 \times 21 \frac{t-CO_2}{t-CH_4} = 3,016 \frac{t-CO_2}{yr}$$

B.3 CH₄ emission from final sludge disposed to the sludge pit, $PE_{MCS,y,s,final}$

Sedimentation collected from the anaerobic lagoon will be applied aerobically as fertilizer, thus;

$$PE_{MCS,y,s,final} = 0$$

B.4 Fugitive CH₄ emission from the inefficiency of the AD and flare system, $PE_{MCS,y,fugitive}$

Methane emission potential from untreated waste water

Methane emission potential of the untreated waste water is calculated as follow:

$$MEP = 228,000 \frac{m^3}{yr} \times 0.049 \frac{t-COD}{m^3} \times 0.21 \frac{t-CH_4}{t-CPD} \times 1 = 2,346 \frac{t-CH_4}{yr}$$

Capture and utilization efficiency of project installation, CFE_p

It is expected that only less than 1% of biogas is flared. As there are no available data, it is assumed that flame is detected on the flare unit for more than 20 minutes in one hour for half of the total biogas plant operating hour or 3,300hours per year. Thus, the proportion of time of which the flare is in operation is 38% as calculated below:

$$F_T = \frac{F_{T20}}{8,760} = \frac{3,300}{8,760} = 38\%$$

The associated flare efficiency for F_{T20} is 50% and thus the total annual flare efficiency is 19%

$$\eta_{FLARE,y} = 50\% * 38\% = 19\%$$

The proportion of methane escaped unburnt during the flare process is therefore 0.008 as calculated below:

$$L_{FLARE} = 0.01 * (1 - 19\%) = 0.008$$

The capture efficiency is thus estimated to be 0.992

$$CFE_p = 1 - 0.008 = 0.992$$

Fugitive methane emissions $PE_{MCS,y,fugitive}$

Based on the calculated, MEP and CFE_p, the fugitive emissions is calculated as follow:

$$PE_{MCS,y,fugitive} = (1 - 0.992) \times 2,346 \frac{t-CH_4}{yr} \times 21 \frac{t-CO_2}{t-CH_4} = 394 \frac{t-CO_2}{yr}$$

B.5 CH₄ emission from final treated waste water disposed to river system, PE_{MCS,y,dissolved}

The amount of methane dissolved in the remaining treated waste water is calculated as follow:

$$PE_{MCS,y,dissolved} = 228,000 \frac{m^3}{yr} \times 10^{-4} \frac{t-CH_4}{m^3} \times 21 \frac{t-CO_2}{t-CH_4} = 479 \frac{t-CO_2}{yr}$$

B.6 CO₂ emission from power used to run biogas treatment system, PE_{PSA,y,power}

The complex generates its own electricity using biomass and does not use electricity from external sources (grid). Consequently,

$$PE_{PSA,y,power} = 0$$

B.7 CO₂ emission from fuel used to run biogas treatment system, PE_{PSA,y,fuel}

The PSA uses low pressure steam for re-generation of its carbon bed. The Project installation includes a waste heat boiler to recover excess heat from reformer box – which is fuelled using biogas. The use of fossil fuel for this purpose is therefore unforeseen. Consequently,

$$PE_{PSA,y,fuel} = 0$$

B.8 Greenhouse gas emissions from the use of additional chemical in the biogas cleaning system, PE_{PSA,y,chem}

The NUB biogas purification unit uses steam to regenerate the adsorbent, in this case carbon. No chemical will be used for the operation of this pressure swing adsorption. Therefore,

$$PE_{PSA,y,chem} = 0$$

B.9 CO₂ emission from fuel burnt on the boiler, PE_{th,y,f}

The ex-ante estimate of baseline emission from displacement of fuel oil for heat generation (Section B.6.3-A.4) was estimated based on the biogas delivered, and thus is a net displacement. As such, for ex-ante purpose, the project emission has been netted out and set zero here.

$$PE_{th,y,f} = 0$$

C. LEAKAGE EMISSIONS

As elaborated under methodological choices, no leakage emission is foreseen from this activity.

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

Table 8. Summary of emissions and emission reduction from category III.H

Year	Estimation of project activity emissions (t-CO ₂ /yr) (A)	Estimation of baseline emissions (t-CO ₂ /yr) (B)	Estimation of leakage emissions (t-CO ₂ /yr) (C)	Estimation of overall emission reduction (t-CO ₂ /yr) (B)-(A)-(C)
1	3,889	39,414	0	35,525
2	3,889	39,414	0	35,525
3	3,889	39,414	0	35,525

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4	3,889	39,414	0	35,525
5	3,889	39,414	0	35,525
6	3,889	39,414	0	35,525
7	3,889	39,414	0	35,525
Total (t-CO ₂)	27,223	275,898	0	248,675

Table 9. Summary of emissions and emission reduction from category III.O

Year	Estimation of project activity emissions (t-CO ₂ /yr) (A)	Estimation of baseline emissions (t-CO ₂ /yr) (B)	Estimation of leakage emissions (t-CO ₂ /yr) (C)	Estimation of overall emission reduction (t-CO ₂ /yr) (B)-(A)-(C)
1	0	4,750	0	4,750
2	0	4,750	0	4,750
3	0	4,750	0	4,750
4	0	4,750	0	4,750
5	0	4,750	0	4,750
6	0	4,750	0	4,750
7	0	4,750	0	4,750
Total (t-CO ₂ /yr)	0	33,250	0	33,250

Table 10 – Summary of emissions and emission reduction from category I.C

Year	Estimation of project activity emissions (t-CO ₂ /yr) (A)	Estimation of baseline emissions (t-CO ₂ /yr) (B)	Estimation of leakage emissions (t-CO ₂ /yr) (C)	Estimation of overall emission reduction (t-CO ₂ /yr) (B)-(A)-(C)
1	0	1,484	0	1,484
2	0	1,484	0	1,484
3	0	1,484	0	1,484
4	0	1,484	0	1,484
5	0	1,484	0	1,484
6	0	1,484	0	1,484
7	0	1,484	0	1,484
Total (t-CO ₂)	0	10,388	0	10,388

Table 11 – Summary of total emissions from all category

Year	Estimation of project activity emissions (t-CO ₂ /yr) (A)	Estimation of baseline emissions (t-CO ₂ /yr) (B)	Estimation of leakage emissions (t-CO ₂ /yr) (C)	Estimation of overall emission reduction (t-CO ₂ /yr) (B)-(A)-(C)

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1	3,889	45,648	0	41,759
2	3,889	45,648	0	41,759
3	3,889	45,648	0	41,759
4	3,889	45,648	0	41,759
5	3,889	45,648	0	41,759
6	3,889	45,648	0	41,759
7	3,889	45,648	0	41,759
Total (t-CO ₂ /yr)	27,223	319,536	0	292,313

B.7 Application of a monitoring methodology and description of the monitoring plan:
B.7.1 Data and parameters monitored:

Data / Parameter:	$Q_{y,ww}$
Data unit:	m ³ /yr
Description:	The volumetric flow rate of effluent entering the anaerobic digesters
Source of data to be used:	Volumetric flowrate meter at the digester feed
Value of data	210,000m ³ /yr
Description of measurement methods and procedures to be applied:	Data will be recorded using flow monitoring instrument and logged manually on daily basis
QA/QC procedures to be applied:	<p><i>Uncertainty level of data:</i> Low</p> <p><i>QA/QC Procedure to be applied:</i> Volumetric flowrate instrument must be calibrated using standard laboratory equipment for at least every maintenance shut-down.</p>
Any comment:	Maintenance shut-down is twice-per year minimum.

Data / Parameter:	COD _{Removed, j}
Data unit:	t-COD/yr
Description:	The difference of COD concentration at point A and at point B of Figure 2
Source of data to be used:	Measurement from sampling port
Value of data	49,000mg/L or 0.049t-COD/m ³
Description of measurement methods and procedures to be applied:	Waste water is sampled on daily basis for in-house laboratory COD testing.
QA/QC procedures to be applied:	<p><i>Uncertainty level of data:</i> High</p> <p><i>QA/QC Procedure to be applied</i> The in-house COD testing device must calibrated on monthly basis using 2nd testing device for calibration purpose to ensure the accuracy of reading.</p>

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	The 2 nd testing device must be calibrated annually using standard laboratory equipment
Any comment:	

Data / Parameter:	$m_1; m_2$
Data unit:	%
Description:	Molar composition of propane and butane in LPG used in hydrogen plant
Source of data to be used:	Material property analysis from LPG supplier or if not available based on chromatography analysis of sample performed at least annually.
Value of data	95% propane; and 5% butane
Description of measurement methods and procedures to be applied:	Information should be requested for every stock-batch.
QA/QC procedures to be applied:	If values are based on sampling, analysis must be performed in an accredited laboratory.
Any comment:	

Data / Parameter:	EF_{LPG}
Data unit:	kgCO ₂ /kgLPG
Description:	CO ₂ emission factor from combustion of LPG
Source of data to be used:	(a) Analysis from the carbon content of LPG, or (b) IPCC Data
Value of data	2.974kg of CO ₂ /kgLPG This is calculated based on LPG with composition of 95% propane and 5% butane as shown in Section B.6.2-A2
Description of measurement methods and procedures to be applied:	Data is derived from parameter m_1, m_2
QA/QC procedures to be applied:	
Any comment:	

Data / Parameter:	M_{LPG}
Data unit:	Kg/yr
Description:	Amount of LPG used as reaction feedstock in mass unit
Source of data to be used:	Mass flow-meter to reactors
Value of data	7,350kg/yr based on 245kg/hr for 30hours
Description of measurement methods and procedures to be applied:	
QA/QC procedures to be applied:	
Any comment:	Measurement is based on flowmeter with less than 1% error

Data / Parameter:	X_{CH_4}
Data unit:	Composition of bio-methane in the biogas on volumetric basis Nm ³ CH ₄ /Nm ³ biogas
Description:	Percentage of methane in biogas

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Source of data to be used:	Biogas sampling
Value of data	65%
Description of measurement methods and procedures to be applied:	Online Graph-Chromatography Analysis
QA/QC procedures to be applied:	
Any comment:	

Data / Parameter:	$FT_{20,y}$
Data unit:	Unitless
Description:	The number of hours in year y , of which the flame is detected for more than 20 minutes in an hour h .
Source of data to be used:	Flame detection system
Value of data	$CFE_p = 0.992$
Description of measurement methods and procedures to be applied:	Continuous observation via flame detection system.
QA/QC procedures to be applied:	<i>Uncertainty level of data:</i> Low <i>QA/QC Procedure to be applied</i> Flame detection instrument is checked and tested for at least once per year
Any comment:	

Data / Parameter:	V_D
Data unit:	Nm^3/yr
Description:	The amount of biogas used for hydrogen production
Source of data to be used:	Flowmeter observation
Value of data	
Description of measurement methods and procedures to be applied:	Data will be recorded using flow monitoring instrument and logged manually on hourly basis
QA/QC procedures to be applied:	<i>Uncertainty level of data:</i> Low <i>QA/QC Procedure to be applied</i> All biogas flowrate equipment must be calibrated at least annually.
Any comment:	

Data / Parameter:	V_E
Data unit:	Nm^3/yr
Description:	The amount of biogas used for combustion in boiler for heat generation
Source of data to be used:	Flowmeter observation
Value of data	
Description of measurement methods and	Data will be recorded using flow monitoring instrument and logged manually

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procedures to be applied:	on hourly basis
QA/QC procedures to be applied:	<i>Uncertainty level of data:</i> Low <i>QA/QC Procedure to be applied</i> All biogas flowrate equipment must be calibrated at least annually.
Any comment:	

Data / Parameter:	V _F
Data unit:	Nm ³ /yr
Description:	The amount of biogas used flared
Source of data to be used:	Flowmeter observation
Value of data	0
Description of measurement methods and procedures to be applied:	Data will be recorded using flow monitoring instrument and logged manually on hourly basis
QA/QC procedures to be applied:	<i>Uncertainty level of data:</i> Low <i>QA/QC Procedure to be applied</i> All biogas flowrate equipment must be calibrated at least annually.
Any comment:	

B.7.2 Description of the monitoring plan:

Management Structure of CDM in NUB

In order to meet the CDM monitoring and reporting requirements as outlined above, NUB will appoint the Plant Manager as the CDM Coordinator reporting directly to a member of the Board of Director at the NUB parent company Permata Hijau Group. The CDM Coordinator will supervise the following activities:

1. Data collection and instrument calibration by the NUB's technical department;
2. Consolidation of results from various departments on a monthly basis; and
3. Issuance of emission reduction and monitoring reports for the purpose of verification.

The CDM Coordinator will also be responsible to ensure that data has been collected as per the requirements of this PDD and contain no errors.

Monitoring Equipment & Calibration Procedure

All monitoring equipment is installed by experts using standard methods. Once installed, this equipment will be calibrated to the highest standards and regularly maintained by the project operator. Any irregularities or problems with the equipment will be reported to the management and rectified as soon as possible. A thorough instrument calibration will be conducted at the start of the crediting period. A calibration report status is maintained for CDM purpose. The report identifies all instrumentations mandatory for calibration, its historical maintenance and calibration report. Calibration is performed minimum annually timed during Plant maintenance shut-down or if any irregularities are identified. The calibration status report will be checked for validity and compliance during audits prior to the release of six-monthly Emission Reduction Delivery Report (ERDP).

Monitoring Standard Operation Procedure will cover:

- Continuous metering of hydrogen produced by the project activity on volumetric basis;
- Continuous metering of LPG used as feedstock to hydrogen production unit;
- LPG molar composition analysis performed every quarter;

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- Continuous monitoring of specific fuel consumption of LPG when biogas is not available in sufficient quantity;
- Continuous measurement of electricity and fuel used by the biogas purification system.

PHG will conduct effort in data quality control to maintain biogas (or methane) balance based on:

- Continuous measurement of biogas produced by the waste water, treatment system, landfill gas capture system or other process producing biogas and
- Continuous measurement of biogas used for various purposes in the project activity: e.g. heat, electricity, flare, and hydrogen production.

PHG will train the power plant personnel to operate the equipment and to record all the data necessary for monitoring the Project activity as specified in the monitoring plan. This data will be directly used for calculation of project emissions. Fuel purchase records, measurement records and other records will be used to ensure consistency.

Archiving, Reporting, and Auditing Procedure

All data required to be logged on hourly basis will be recorded in the Operator Log Sheet system. At the end of the week, the operator log sheet will be transferred to a CDM Weekly Report covering all CDM-related instrumentation record. This weekly report covers periodic data of:

- (a) Methane captured based on monitoring of volumetric flow-rate of biogas combusted and flared, and percentage of methane at the digester outlet;
- (b) Thermal output of Boiler based on monitored temperature, pressure and flow-rate of steam and condensate;
- (c) Fuel consumption in the Boiler;
- (d) Electrical consumption of project installation sourced from diesel generator;
- (e) COD processed in anaerobic lagoons (3-7) based on monitored volumetric flow-rate of effluent and outlet COD from digester;
- (f) COD processed in anaerobic digester based on monitored volumetric flow-rate of effluent and inlet COD to the digester;

The update of data which is less regular, e.g. the calculation of captured efficiency, properties of fuels, etc., will be integrated into the implementation protocol of NUB. The hard copy of the weekly report will be stored locally at NUB site and an electronic copy is sent to PHG headquarter in Medan on weekly basis to prevent data loss. Both electronic and hard copy will be archived for at least 2 years after the end of the last crediting period.

On six-monthly basis, the Technical Department at PHG will issue an Emission Reduction Delivery Report (ERDP) covering a review of CDM implementation containing: a consolidated delivered emission reduction, calibration status report and an audit report verifying that implementation has been implemented in accordance with standard pre-set in the protocol. The ERDP is signed and approved by PHG's Technical Director and will make part of the monitoring report for annual verification.

The project proponent will form a CDM implementation team consisting of field engineers who oversee a number of field-operators. The CDM team will be led by NUB Plant Manager and will be reported on monthly basis to management at the PHG – who will audit the report on six-monthly basis.

A minute procedure will be established by the CDM team near Project commissioning. The procedure will establish which instrument, sampling ports, and parameters that must be logged for CDM purpose and its frequency of recording and reporting, including step-by-step procedure of data taking and sampling methods.

Implementation Training

The CDM team will ensure that all members understand CDM procedures and discuss field implementation on the monthly meeting, including improvement to the existing procedure.

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

Date of completion: 20/03/2008

Name of responsible entity: Clean Energy Finance Committee
Mitsubishi UFJ Securities Co. Ltd.
Marunouchi Building, 26th Floor
2-4-1 Marunouchi, Chiyoda-ku
100-6317 Tokyo, Japan

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Email: hatano-junji@sc.mufj.jp

Mitsubishi UFJ Securities Co. Ltd is the CDM Consultant for this Project and is also a project participant.

SECTION C. Duration of the project activity / crediting period**C.1 Duration of the project activity:****C.1.1. Starting date of the project activity:**

15/10/2006, based on the time of contract signing with the main technology provider.

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

21 year, 00 months

C.2 Choice of the crediting period and related information:**C.2.1. Renewable crediting period****C.2.1.1. Starting date of the first crediting period:**

30/09/2008 or after registration, whichever the later

C.2.1.2. Length of the first crediting period:

7 year, 00 months

C.2.2. Fixed crediting period:**C.2.2.1. Starting date:**

N.A

C.2.2.2. Length:

N.A

SECTION D. Environmental impacts**D.1. If required by the host Party, documentation on the analysis of the environmental impacts of the project activity:**

As the Project is located within NUB complex, its environmental documentations must follow the framework sets for NUB. In accordance with regulation issued by Environmental Ministry No. 11/2006, NUB does not need to submit Environmental Impact Statement, but mandated to provide “Efforts for Environmental Management and Monitoring”, or UPL/UKL.

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

The project activity has two direct environmental impacts: impact to waste-water disposed to the river and impact to air quality due to replacement of fuel oil with biogas.

Impact to waste water

The Project is expected to improve the water disposal quality from existing level. This is because the COD entry level into lagoon 4 will be lower than that prior to the Project implementation. Nevertheless, NUB is still required to meet the regulatory quality and reporting requirements. The Project (and the existing anaerobic lagoon) disposes water into the river system, and thus under applicable regulation is mandated to report the quality of water disposal to local regulatory body on regular basis. The analysis intends to control the quality of water disposed into the river system below a set benchmark set by government regulation No. 51/10/1995 Attachment IVB (palm industry) covering a number of parameters including solid suspension (max. 250mg/L), pH (6-

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9), ammonia concentration (max.50mg/L), BOD (max.100mg/L), COD (max.350mg/L) and grease and oil content (max. 25mg/L).

Impact to Air Quality

The combustion of biogas in boilers and flare are also not expected to lead to any worse environmental impact than the business-as-usual practice. Nevertheless, NUB operation (including the Project) must meet the government set regulation that mandates the control of ambient air quality and emission from stack gas.

No other significant environmental impacts is expected from this project activity

SECTION E. Stakeholders' comments

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

The Project proponents host a stakeholder meeting on June 16th 2007 at PT Nubika Jaya office in Blok Songo which is also the Project location. Invitations were distributed to local government via community leaders and residents surrounding the Project site.

The meeting was attended by 24 people excluding representatives from the Project Developer. Opening statement was given by the General Affair Manager of PHG, Mr Asep Dadang, and presenting the meeting material was Mr. Dodik Suyanto, the technical director of PHG. The meeting mentioned briefly about the impact of global warming and explained in depth about possible outcome of the Project toward the surrounding area.

A section of question and answer were held at the end of the meeting to accommodate comments and questions raised during the presentation, which are elaborated in the following section E.2.

E.2. Summary of the comments received:

Mr. Daniel Sihombing, resident from Blok Songo asked about the possibility of biogas leakage and the potential hazards of the biogas. NUB answered that safety measures will be employed to prevent the worse to the community. All pipe connections and joints will be monitored to allow early detection and prompt action.

Mr. Zulkar Iskandar, resident from gallon Sisumut asked about the compliance of the wastewater treatment program in NUB to regulatory requirement. NUB stated that NUB holds the UKL/UPL license from the Bapedalda Kabupaten Labuhan Batu to operate its complex, any new program in NUB will have to comply with the requirement sets in the UPL/UKL.

Mr. Iddarsyah Harahap, the head of the Village Karang Sari raised question on the effect of global warming to farming and cultivation, and what measures will take by NUB to prevent the harsh effect of the factory. NUB explained that global warming change the climate system and therefore disrupts farming activities by exposing farmers to longer drought, heavy precipitation in shorter period causing flooding. This disruption in climate can potentially disrupt planting and harvesting cycle to rice farmers, and reduces the maturing of fruits of palm trees and therefore causing severe damages to farmer income.

To answer 2nd question, NUB explained that the company has taken necessary measures in its facility to contribute to mitigation of climate change. NUB has taken efforts to minimize its waste through a zero-waste policy programme, where solid and liquid waste is recycled for energy generations. In addition to this biogas Project, NUB is also implementing biomass initiatives to convert all generated waste into electricity and steam for its own operation. By taking these steps, NUB no longer produce any residues from its activity and is taking measures to reduce consumption of fossil fuel for its operation.

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

The Project and explanations from NUB were well accepted by the representative from local government and community members. Community members appreciated the efforts taken by NUB to provide communication of its activity. There is no due account from the comments and enquiry received during the stakeholder meeting.

Annex 1**CONTACT INFORMATION ON PARTICIPANTS IN THE PROJECT ACTIVITY**

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Annex 2

INFORMATION REGARDING PUBLIC FUNDING

Please refer to Section A.4.4

Annex 3

BASELINE INFORMATION

Please refer to Section B.4

Annex 4

MONITORING INFORMATION

Please refer to Section B.7