CDM-SSCWG48-A07

Draft Small-scale Methodology

AMS-III.O: Hydrogen production using methane extracted from biogas

Version 02.0

Sectoral scope(s): 05

United Nations
Framework Convention on
Climate Change

COVER NOTE

1. Procedural background

1. The Executive Board of clean development mechanism (CDM) (hereinafter referred as the Board) at sixty-eighth meeting mentioned that approved methodologies are eligible for application in a programme of activities (PoA) irrespective of whether it includes guidance on how to translate the relevant requirements into eligibility criteria.

2. The small-scale working group (SSC WG) has previously reviewed PoA requirement in all Type I and Type II small-scale methodologies and noted that all these methodologies are applicable for PoA.

3. To continue working on this mandate the SSC WG analysed Type-III small-scale methodologies and noted that further guidance on application for PoA is required in the few Type-III small-scale methodologies.

2. Purpose

4. The draft revision to this methodology is proposed under the on-going work by the SSC WG in addressing the Board's guidance to make all methodologies applicable to PoAs.

3. Key issues and proposed solutions

5. The SSC WG noted that AMS-III.O refers to AMS-III.G and AMS-III.H for estimation of emission reductions including leakage estimation, thus the issues related to leakage for a PoA application are already considered within the methodology. The section providing guidance on PoA application is revised accordingly.

6. The revised draft of the methodology also consists of changes due to transferring the methodology into new methodology template and also addresses consistency issues.

4. Impacts

7. The revision to this methodology will enhance its usability for PoAs.

5. Subsequent work and timelines

8. The methodology is recommended by the SSC WG for consideration by the Board at its eighty-fifth meeting. No further work is envisaged.

6. Recommendations to the Board

9. The SSC WG recommends that the Board adopt this methodology, to be made effective at the time of the Board's approval.

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1. Introduction

1. The following table describes the key elements of the methodology:

Table 1. Methodology key elements

Typical project(s)	Installation of biogas purification system to isolate methane from biogas for the production of hydrogen displacing LPG as both feedstock and fuel in a hydrogen production unit.
Type of GHG emissions mitigation action	Fuel and feedstock switch: Fuel and feed stock switch to reduce consumption of fossil fuel

2. Scope, applicability, and entry into force

2.1. Scope

2. The methodology comprises of installation of biogas purification system to isolate methane from biogas to produce hydrogen.

2.2. Applicability

3. The ~~is methodology is applicable to~~ project activityies ~~that~~ installs

(a) a biogas purification system to isolate methane from biogas, which is being flared in the baseline situation for the production of hydrogen displacing liquefied petroleum gas (LPG) as both feedstock and fuel in a hydrogen production unit; or

(b) ~~Examples of project activities covered under this methodology are installation of~~ a biogas purification system in combination with installation of new measures that recover methane from biogenic organic matter from waste water treatment plants or landfills, using technologies/measures covered in AMS-III.H or AMS-III.G.

4. Emission reductions resulting from the installation of methane recovery system shall be calculated as per AMS-III.H or AMS-III.G.

5. ~~The methodology is only applicable if it can be ensured that t~~There is no diversion of biogas that is already being used for thermal or electrical energy generation or utilized in any other (chemical) process in the baseline.

6. The project activity complies with all local regulations including all safety related measures.

7. Measures are limited to those that result in aggregate emission reductions of less than or equal to 60,000 t CO_2 equivalent annually from all type III components.

8. This methodology is not applicable to technologies displacing the production of hydrogen from electrolysis.

2.3. Entry into force

9. The date of entry into force is the date of the publication of the EB 85 meeting report on 24 July 2015.

3. Normative references

10. This methodology is based on the submissions SSC_102 and SSC_110 "Integrated Methane Capture and Hydrogen Production from Biogas" submitted by Mitsubishi UFJ Securities Co. Ltd.

11. Project participants shall take into account the general guidance to the methodologies, information on additionality, abbreviations and general guidance on leakage provided at <http://cdm.unfccc.int/methodologies/SSCmethodologies/approved.html>.

12. This methodology refers to the latest version of the following methodologies and tools[1] mutatis mutandis:

(a) "AMS-I.D: Grid connected renewable electricity generation";

(b) "AMS-III.G: Landfill methane recovery";

(c) "AMS-III.H: Methane recovery in wastewater treatment";

(d) "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion";

(e) "Tool to determine project emissions from flaring gases containing methane";

(f) Methodological tool "Demonstration of additionality of small-scale project activities".

4. Definitions

13. The definitions contained in the Glossary of CDM terms shall apply.

5. Project boundary

14. The project boundary is the physical, geographical sites where methane is captured, extracted and hydrogen is produced from biogas and LPG. The boundary also extends to other equipment consuming biogas or methane in the same site where applicable.

5.1. Baseline

15. The baseline emissions are calculated as the summation of the following:

(a) CO_2 generated in reactions of LPG (displaced by methane extracted from biogas in the project scenario) as feedstock during the steam-reforming/shift-reaction;

(b) CO_2 generated in the combustion process of LPG (displaced by methane extracted from biogas in the project scenario) as fuel to the reactors.

[1] Please refer to: <https://cdm.unfccc.int/Reference/index.html>.

16. The composition of LPG for the purpose of baseline emission calculations shall be determined based on the composition analysis of stand-by LPG[2] stock. This shall be based on:

(a) Information provided by the supplier; or

(b) Compositional analysis conducted by an independent certified laboratory; or

(c) Product specification statement provided by the national gas supplier of the host-country.

17. The CO_2 emissions generated in reactions of LPG during the steam-reforming/shift-reaction is determined by calculating the CO_2 generation potential per mol of hydrogen produced from the baseline feedstock LPG ($R_{CO2/H2}$) and the molar quantity of hydrogen produced using methane extracted from biogas as feedstock. The $R_{CO2/H2}$ ratio is calculated through analysis of the steam-reforming/shift-reactions specified in paragraph 18, involving the individual molecules contained in LPG (typically propane and butane).

$$BE_{LPG\_FEED} = R_{CO2/H2} \times m_{H2,BIO} \times MW_{CO2} \times C_1 \qquad \text{Equation (1)}$$

Where:

BE_{LPG_FEED}	=	Annual baseline CO_2 emissions from the displaced LPG feedstock in the hydrogen production unit (t CO_2e)
$R_{CO2/H2}$	=	CO_2 generation potential per mol of hydrogen produced with LPG as feedstock as defined in paragraph 25 (kmol-CO_2/kmol-H_2)
$m_{H2,BIO}$	=	Molar quantity of hydrogen produced annually from methane extracted from biogas as defined in paragraph 29 (kmol-H_2)
MW_{CO2}	=	Molecular weight of CO_2 (44 kg/kmol)
C_1	=	Conversion factor kilograms to tonnes (0.001)

18. The generic steam reforming reaction is:

$$C_n\mathrm{H}_m + \mathrm{nH_2O} \leftrightarrow \mathrm{nCO} + \left(\frac{\mathrm{m}}{2} + n\right)H_2 \qquad \text{Equation (2)}$$

19. The generic shift reaction is:

$$nCO + \mathrm{nH_2O} \leftrightarrow \mathrm{nCO_2} + \mathrm{n}H_2 \qquad \text{Equation (3)}$$

[2] Stand-by LPG is essential for process reliability. Standby LPG is the LPG stock stored by the operator to cover situations where biogas is not available in sufficient amount or production of hydrogen from biogas has halted for some reasons. For example in prolonged dry season wastewater treatment facility treating wastewaters such as palm oil mill effluent may not be operating in full capacity and therefore producing less biogas. Other possibilities include temporary non-availability of H2S removal system due to maintenance/ repair.

20. The net reaction from the above reactions is the sum of the above equations (2) and (3):

$$C_n H_m + 2nH_2O \leftrightarrow nCO_2 + \left(\frac{m}{2} + 2n\right) H_2$$ Equation (4)

21. Based on stoichiometric rules:

(a) 1 mol of C_nH_m and 2n mol of H_2O produce n mol of CO_2 and ((m/2)+2n)) mol of H_2;

(b) For example: 1 mol of propane gas (C_3H_8) and 6 mol of H_2O reacts to 3 mol of CO_2 and 10 mol of H_2.

22. For LPG containing m_1 mol of propane and m_2 mol of butane, the reactions are summarized as follow:

Table 2. LPG reactions during hydrogen production

Source Gas	Reaction Type	Ref. Eq.	Reaction
Propane	Steam Reforming	(A)	$C_3H_8 + 3H_2O \leftrightarrow 3CO + 7H_2$
	Shift-Conversion	(B)	$3CO + 3H_2O \leftrightarrow 3CO_2 + 3H_2$
	Sub-total	(C)=(A)+(B)	$C_3H_8 + 6H_2O \leftrightarrow 3CO_2 + 10H_2$
Butane	Steam Reforming	(D)	$C_4H_{10} + 4H_2O \leftrightarrow 4CO + 9H_2$
	Shift-Conversion	(E)	$4CO + 4H_2O \leftrightarrow 4CO_2 + 4H_2$
	Sub-total	(F)=(D)+(E)	$C_4H_{10} + 8H_2O \leftrightarrow 4CO_2 + 13H_2$

23. For 100 mol of LPG mixture containing m_1 mol of propane and m_2 mol of butane, the reactions are:

Table 3. Reactions during hydrogen production from 100 mol of 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	$m_1 + m_2$	(G)	As $100molLPG = [m_1]C_3H_8 + [m_2]C_4H_{10}$, (1) + (2) is $100molLPG + [6m_1 + 8m_2]H_2O \leftrightarrow [3m_1 + 4m_2]CO_2 + [10m_1 + 13m_2]H_2$

24. Based on reaction G in Table 3, the *hydrogen production potential per mol of LPG* is defined as:

$$R_{H2/LPG} = \frac{\lfloor 10m_1 + 13m_2 \rfloor}{100}$$ Equation (5)

25. Based on reaction G in Table 3, the *CO_2 generation potential per mol of hydrogen produced* is defined as:

$$R_{CO2/H2} = \frac{\lfloor 3m_1 + 4m_2 \rfloor}{[10m_1 + 13m_2]}$$ Equation (6)

26. The CO_2 emissions from LPG combusted, as fuel in the reactors in the baseline (displaced by methane extracted from biogas in the project scenario) shall be calculated based on:

(a) The specific fuel consumption of the hydrogen production unit using LPG as fuel as described under monitoring methodology ~~in paragraph 27~~; and

(b) The amount of hydrogen produced using methane extracted from biogas as fuel as calculated in paragraphs 29 and 30.

$$BE_{LPG\_FUEL} = SFC_{LPG} \times V_{H2,BIO} \times EF_{LPG} \times C_2$$ Equation (7)

Where:

BE_{LPG_FUEL}	=	Annual baseline CO_2 emission from LPG used as fuel in the reactors that is displaced by methane extracted from biogas in the project scenario (t CO_2e)
SFC_{LPG}	=	Specific fuel consumption of the hydrogen production unit using LPG as fuel (kg-LPG/Nm^3-H_2) ~~as defined in paragraph 27.~~
$V_{H2,BIO}$	=	Volume of hydrogen produced from methane extracted from biogas under normal condition. (Nm^3-H_2) annually as defined in paragraphs 30 and 31
EF_{LPG}	=	Emission factor of LPG ~~based on (a) evaluation of carbon content of LPG or (b) IPCC default value~~ (kg-CO_2/kg LPG)
C_2	=	Conversion factor kilograms to tones (0.001)

~~27. The specific fuel consumption of baseline process (SFC_{LPG}) refers to the fuel consumption per normal volume H_2 produced if LPG is used as fuel for the hydrogen production process. This should be based on one of the following options:~~

~~(a) Measurements during crediting period when the hydrogen plant is operated with LPG as fuel;~~

~~(b) Minimum 1 year historical data;~~

(c) Manufacturer's specification.

28. Option (b) and (c) can only be used if (a) is not the case, i.e. LPG is not used as a fuel during the crediting period.

29. The molar amount of hydrogen produced from methane extracted from biogas ($m_{H2,BIO}$) is calculated as the difference between the total molar amount of hydrogen produced ($m_{H2,T}$) and the molar amount of hydrogen produced from the stand-by LPG ($m_{H2,LPG}$).

$$m_{H2,BIO} = m_{H2,T} - m_{H2,LPG}$$ Equation (8)

Where:

$m_{H2,BIO}$	=	Molar amount of hydrogen produced from methane extracted from biogas annually (kmol-H_2)
$m_{H2,T}$	=	Total molar amount of hydrogen produced annually. This parameter shall be based on monitoring of volume of hydrogen produced by the hydrogen production unit. If the volume is reported as normal volume, the equivalent molar amount can be calculated using ideal gas relationship described in paragraph 31 (kmol-H_2)
$m_{H2,LPG}$	=	Molar amount of hydrogen produced from LPG annually as calculated in paragraph 30 (kmol-H_2)

30. The molar amount of hydrogen produced from LPG ($m_{H2,LPG}$) should be calculated through monitored amount of LPG used as feedstock to the reaction (M_{LPG}) multiplied by the hydrogen production potential calculated in equation (5).

$$m_{H2,LPG} = R_{H2/LPG} \times \frac{M_{LPG}}{MW_{LPG}}$$ Equation (9)

$$MW_{LPG} = m_1 \times MW_{C3H8} + m_2 \times MW_{C4H10}$$ Equation (10)

Where:

$m_{H2,LPG}$	=	Molar amount of hydrogen produced from LPG annually (kmol-H_2)
$R_{H2/LPG}$	=	Hydrogen production potential as define in equation (5) (kmol H_2/kmol-LPG)
M_{LPG}	=	Mass of LPG used as reaction feedstock annually (kg-LPG)
MW_{LPG}	=	Molecular weight of LPG (kg-LPG/kmol-LPG)
m_1	=	% mol of propane in LPG (mol/mol)
MW_{C3H8}	=	Molecular weight of propane (44 kg/kmol)

m_2	=	% mol of butane in LPG (mol/mol)
MW_{C4H10}	=	Molecular weight of butane (66 kg/kmol)

31. The amount of molecules per volume of low-pressure gas is defined by '*ideal gas*' relationship shown in equation (11). Using this relationship, a molar amount of hydrogen can be converted into its equivalent volume of low-pressure gas or vice-versa.

$$P_N.V_N = m_{H2}.R.T_N.C_3 \quad \text{Equation (11)}$$

Where:

$V_{N,H2}$	=	Normalized volume of hydrogen produced annually (Nm^3)
P_N	=	Pressure in Pascal at normal condition (Pa)
T_N	=	Temperature in Kelvin at normal condition (273 K)
R	=	Gas constant in SI Unit (8.314 $Pa.m^3.mol^{-1}.K^{-1}$)
C_3	=	Conversion factor kmol to mol (1000)
m_{H2}	=	Molar amount of hydrogen produced (kmol)

5.2. Project ~~Activity~~ Emissions

32. The project ~~activity~~ emissions are calculated as the summation of the ~~following~~ emissions from fossil fuels and/or electricity used, unless it is demonstrated that electricity/steam used is generated from renewable energy sources with no possibility for emissions:

    (a) The emissions from fossil fuels and/or electricity used to generate steam for the purpose of regeneration of the biogas purification system for operating the biogas purification system calculated in accordance with the methods specified in

        (i) "AMS-I.D: Grid connected renewable electricity generation", and

        (ii) ~~Emissions from fossil fuels used to generate steam for the purpose of regeneration of the biogas purification system calculated in accordance with the~~ "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion".

33. If additional chemicals or energy is used to regenerate the adsorbent or absorbent for purpose of biogas purification, contribution of the used chemicals to GHG emissions during the lifecycle shall be taken into account, if not already included in paragraph 32.

5.3. Leakage

34. If the project equipment is transferred from another activity, or if the displaced equipment is transferred to another activity, leakage is to be considered.

5.4. Emission reductions

35. The emission reductions are calculated as follows: ~~achieved by the project activity shall be calculated as the difference between the baseline emissions and the sum of the project emissions and leakage.~~

$$ER_y = BE_y - PE_y - LE_y \quad \text{Equation (12)}$$

Where:

ER_y	=	Emission reductions in the year *y* (t CO_2e)
PE_y	=	Project activity emissions in year *y* (t CO_2e)
LE_y	=	Leakage in year *y* (t CO_2e)

6. Monitoring methodology

6.1. Data and Parameters not monitored

Data / Parameter table 1.

Data / Parameter:	EF_{LPG}
Data unit:	kg-CO_2/kg LPG
Description:	Emission factor of LPG
Source of data:	-
Measurement procedures (if any):	The emission factor is based on; (a) evaluation of carbon content of LPG or (b) IPCC default value
Any comment:	-

Data / Parameter table 2.

Data / Parameter:	SFC_{LPG}
Data unit:	kg-LPG/Nm^3-H_2
Description:	Specific fuel consumption of baseline process
Source of data:	-
Measurement procedures (if any):	Specific fuel consumption of LPG is should be based on one of the following options: (a) Measurements during crediting period when the hydrogen plant is operated with LPG as fuel; (b) Minimum 1 year historical data; (c) Manufacturer's specification.

Any comment:	Option (b) and (c) can only be used if (a) is not the case, i.e. LPG is not used as a fuel during the crediting period.

6.2. Data and Parameters monitored

36. The project proponents shall maintain a biogas (or methane) balance based on:

(a) Continuous measurement of biogas produced by the waste water, treatment system, landfill gas capture system or other process producing biogas and

(b) Continuous measurement of biogas used for various purposes in the project activity: e.g. heat, electricity, flare, and hydrogen production. The difference is considered as loss due to physical leakage and deducted from the emission reductions. The method of monitoring should follow the provisions specified in either AMS-III.H or AMS-III.G or provisions of the “Tool to determine project emissions from flaring gases containing methane” in the event of flaring (where applicable).

Data / Parameter table 3.

Data / Parameter:	V_{H2BIO}
Data unit:	Nm^3-H_2
Description:	Volume of hydrogen produced from methane extracted from biogas under normal condition
Source of data:	-
Measurement procedures (if any):	Continuous metering of on volumetric basis
Any comment:	-

Data / Parameter table 4.

Data / Parameter:	M_{LPG}
Data unit:	kg-LPG
Description:	LPG used as feedstock to hydrogen production unit
Source of data:	-
Measurement procedures (if any):	Continuous metering
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	m_1
Data unit:	*%*
Description:	*% mol of Propane in LPG*
Source of data:	-
Measurement procedures (if any):	LPG molar composition analysis performed every quarter

Any comment:	

Data / Parameter table 6.

Data / Parameter:	m_2
Data unit:	*%*
Description:	*% mol of butane in LPG*
Source of data:	-
Measurement procedures (if any):	LPG molar composition analysis performed every quarter
Any comment:	-

Data / Parameter table 7.

Data / Parameter:	PE_{Elec}
Data unit:	tCO_2/year
Description:	Project emissions from electricity consumption in year y
Source of data:	As per AMS-I.D: Grid connected renewable electricity generation
Measurement procedures (if any):	AMS-I.D: Grid connected renewable electricity generation
Any comment:	AMS-I.D: Grid connected renewable electricity generation

Data / Parameter table 8.

Data / Parameter:	PE_{FF}
Data unit:	tCO_2/year
Description:	Project emissions from fossil fuel consumption in year y
Source of data:	As per the “Tool to calculate project or leakage CO2 emissions from fossil fuel combustion”
Measurement procedures (if any):	As per the “Tool to calculate project or leakage CO2 emissions from fossil fuel combustion”
Any comment:	As per the “Tool to calculate project or leakage CO2 emissions from fossil fuel combustion”

6.3. Project activity under a programme of activities

37. ~~It is not envisaged this category will be applied to a project activity under a Programme of Activities.~~ The methodology is applicable to a programme of activities. No additional leakage estimations are necessary other than that indicated under the leakage section above.

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Document information

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02.0	3 July 2015	SSCWG 48, Annex 07 To be considered by the Board at EB85. Revised to provide guidance for application of the methodology under programme of activities.
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