Indicative simplified baseline and monitoring methodologies
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TYPE III - OTHER PROJECT ACTIVITIES

Project participants shall apply the general guidelines to the SSC CDM methodologies, attachment A to Appendix B and general guidance on leakage in biomass project activities (attachment C to Appendix B) provided at <http://cdm.unfccc.int/methodologies/SSCmethodologies/approved.html> *mutatis mutandis*.

III.K. Avoidance of methane release from charcoal production

Technology/measure

1. This methodology is applicable to project activities that avoid release of methane from traditional open-ended charcoal production methods.[1] The following project activities are eligible under this methodology:

   (a) The replacement of existing traditional open-ended charcoal production facility(ies) with new facility(ies) equipped with recovery and flaring/combustion of gases containing methane generated in the production process;

   (b) The upgrade or retrofit of existing traditional open-ended charcoal production facility(ies) to install equipment/systems for recovery and flaring/combustion of gases containing methane generated in the production process;

   (c) Greenfield project, consisting of the installation of new kilns/charcoaling facilities equipped with recovery and flaring/combustion of gases containing methane generated in the production process, instead of the installation of conventional facilities without gas recovery.

2. The methodology is applicable under one of the following conditions:

   (a) Local regulations do not require controlling methane emissions in charcoal production;

   (b) There is a widespread non-compliance[2] of the local regulation evidenced by:

      (i) Annually collected data from control groups set up by the project activity; or

      (ii) Annually collected data on legal action and enforcement mechanisms implemented under the prevailing regulation; or

      (iii) Official reports (e.g. annual reports of regulatory bodies for pollution control).

[1] Traditional open-ended charcoaling methods are defined as non-industrial production processes where the gases produced by the wood pyrolysis are not destroyed or used for other purposes, therefore being released directly to the atmosphere. Traditional open-ended production units include, but are not limited to, open pits, hot-tail kilns and brick-based Missouri kilns.

[2] Less than 50% of charcoal production activities comply in the country.

3. No relevant changes in greenhouse gas emissions other than methane occur as a consequence of the project activity and/or need to be accounted, except for the possibilities of leakage.

4. The implementation of the project activity shall not result in changes in the type and source of biomass raw material used for production of charcoal (e.g. if in the baseline charcoal was produced from coconut shells, the project activity will only produce charcoal from coconut shells).

5. Measures are limited to those that result in emission reductions of less than or equal to 60 kt CO_2 equivalent annually.

6. If the combustion facility is used for heat and electricity generation that component of the project activity shall use a relevant methodology under Type I.

Boundary

7. The project boundary is the physical, geographical sites:

(a) Where the charcoal is or would be manufactured in traditional open-ended production units and the avoided methane emission occurs in the absence of the proposed project activity;

(b) Where the charcoal manufacturing with recovery and flaring/combustion of methane takes place;

(c) And in the itineraries between them, where the transportation of raw material for charcoal manufacturing occurs.

Baseline

8. The baseline scenario is the situation where, in the absence of the project activity, charcoal is produced through traditional open-ended methods within the project boundary and methane is emitted to the atmosphere. The baseline emissions are the amount of methane that would have been produced from traditional open-ended methods to process the equivalent quantity of raw material used in the project activity to produce charcoal. Only dry mass of the biomass raw material shall be considered for the calculations.

The baseline emissions shall be estimated using the equation below:

$$BE_y = Q_{y,raw} * (SMG_b - M_d) * GWP_{CH4} \quad \textbf{(1)}$$

Where:

BE_y	Baseline emissions (tCO_2e)
$Q_{y,raw}$	Quantity of raw material used in the project facility in the year *y* on a dry basis (tonnes)
SMG_b	Specific methane generation ~~emission~~ factor for the baseline charcoal producing

process (tonnes of CH_4/tonne raw material used). SMG_b shall be determined from experiments using relevant statistical methods. Examples of generic procedures are provided in Annex I, II and III

M_d — Factor to account for any legal requirement for capture and destruction of methane in the charcoal production facility (tonnes of CH_4/tonne of raw material)

GWP_{CH4} — GWP of CH_4 (a value of 21)

Project activity emissions

9. Project activity emissions consist of:

(a) CO_2 emissions due to incremental transportation distances ($PE_{y,transp}$);

(b) CO_2 emissions from electricity and/or fossil fuel consumption by the project activity facilities ($PE_{y,power}$);

(c) Fugitive methane emissions due to capture inefficiency ($PE_{y,fugitive}$);

(d) Methane emissions due to incomplete flaring, where applicable ($PE_{y,flaring}$).

$$PE_y = PE_{y,transp} + PE_{y,power} + PE_{y,fugitive} + PE_{y,flaring} \quad \textbf{(2)}$$

Where:

PE_y — Project activity emissions in the year y (tCO_2e)

$PE_{y,transp}$ — Emissions from incremental transportation from raw material collection points in the year y (tCO_2e)

$PE_{y,power}$ — Emissions from electricity and/or fossil fuel consumption in the year y (tCO_2e)

$PE_{y,fugitive}$ — Fugitive emissions from operation of charcoal producing facility (physical leakage) in the year y (tCO_2e)

$PE_{y,flaring}$ — Emissions due to the flare inefficiencies (if applicable) in the project charcoal manufacturing plant in the year y (tCO_2e)

10. Project emissions due to incremental transport distances ($PE_{y,transp}$) are calculated based on the incremental distances between:

(i) The charcoal producing facility(ies) to the consumption points in comparison to the baseline case;

(ii) The raw material collection points to the project charcoal producing facility(ies) in comparison to the baseline case.

$$PE_{y,transp} = (Q_{y,raw} / CT_{y1}) * DAF_{w1} * EF_{CO2} + (Q_{y,prod} / CT_{y2}) * DAF_{w2} * EF_{CO2} \quad \textbf{(3)}$$

Where:

$Q_{y,raw}$	Quantity of raw material used in the year *y* (tonnes)
CT_{y1}	Average truck capacity for raw material transportation (tonnes/truck)
DAF_{w1}	Average incremental distance for raw material transportation (km/truck)
EF_{CO2}	CO_2 emission factor for the fuel used (tCO2/km). Local values or IPCC default values can be used
$Q_{y,prod}$	Quantity of charcoal produced in the year *y* (tonnes)
CT_{y2}	Average truck capacity for charcoal transportation (tonnes/truck)
DAF_{w2}	Average incremental distance for charcoal transportation (km/truck)

11. Fugitive emissions due to the physical leakage from the charcoal producing facility ($PE_{y,fugitive}$) are determined by the following equation:

$$PE_{y,fugitive} = (1 - CFE_{project}) * ME_{y,project} * GWP_{CH4} \quad \textbf{(4)}$$

Where:

$CFE_{project}$	Capture efficiency of the methane recovery equipment in the project charcoal producing facility (a default value of 0.9 shall be used, given no other appropriate value)
$ME_{y,project}$	Methane emission potential of the project charcoal producing process in the year *y* (tonnes)

$$ME_{y,project} = Q_{y,raw} \times SMG_{y,p} \quad \textbf{(5)}$$

Where:

$Q_{y,raw}$	Quantity of raw material (biomass) input in the year *y* (tonnes, dry basis)
$SMG_{y,p}$	specific methane generation for the project charcoal producing facility in the year *y* (tonnes CH_4/t raw material, dry basis)

12. $SMG_{y,p}$ shall be determined based on specific values of methane generation per ton of raw material (biomass) input as per the procedure in one of the methods described in the Annexes I, II or III, particularly the following requirement will apply:

(a) If statistical correlation method of Annex I is used, the average charcoaling temperatures and the gravimetric charcoal yield for each batch of charcoal production shall be monitored according to the method to determine the $SMG_{y,p}$;

(b) If the method of Annex II or III is used, the parameter $SMG_{y,p}$ is determined once after project kiln is installed under typical operating conditions (e.g. raw material, sealing conditions, temperature profile) and it is applicable and fixed for all the kilns of the same manufacturer and design, when operated according to the manufacture's requirement/instruction.

13. For *ex ante* estimations, the default value of $SMG_{y,p}$ from nationally approved data or IPCC default value of 4.5 kg CH_4/t of wood input may be used.[3]

14. In case captured pyrolysis gas is gainfully used (i.e. as fuel for pre-heating the facility, or for wood drying, or used for production of heat and/or power), then $PE_{y,flaring}$ can be taken as zero, i.e. a methane destruction efficiency of 100% will apply. In such a case, the energy production equipment where the pyrolysis gas is burned shall be included into the project boundary and its operation shall be monitored.

15. In case the captured pyrolysis gas is flared, then project emissions due to the inefficiency of the flare shall be accounted for and monitored. For that purpose, a continuous measurement and recording of the flare temperature shall be undertaken. The amount of methane destroyed by the flare may be calculated using one of the following options:

(a) The pyrolysis gas flow and methane content are continuously measured and recorded. These measurements are at same or at close locations in the gas line, and at the same condition (dry or wet), simultaneously with the flare temperature. The methane emissions is calculated through numeric integration of the flow and methane content of the flared gases, for the time intervals (dt) where the flare is operational (temperature above 500°C), and for the time intervals where the flare is off (temperature lower than 500°C);

$$PE_{y,flaring} = \int_{t,on} F_{g,t} * C_{CH4,t} * (1 - FE) * GWP_{CH4} . \partial t + \int_{t,off} F_{g,t} * C_{CH4,t} * GWP_{CH4} * \partial t \quad \textbf{(6)}$$

Where:

$F_{g,t}$ Flow rate of gases containing methane to the flare at the time t (m^3/h, at norm conditions)[4]

[3] "Revised 1996 IPCC guidelines for National Greenhouse Gas Inventories: Reference Manual", TABLE I-14, assuming 30 MJ/kg charcoal and 15 MJ/kg wood. Respective output value: 30 kg CH4/t charcoal. <http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ref3.pdf>.

$C_{CH4,t}$ Methane content of the gas at the time t (t/m^3, norm conditions)[4]

FE Flare efficiency. It may be considered to be 50% for open flare and 90% for enclosed flare, whenever the open/enclosed flare is operational (temperature above 500°C) and zero when it is not operating (temperature below 500°C)

∂t Time interval for integration (h). The measurements of flow, methane concentration and flare temperature shall be recorded simultaneously as average values for each five minutes or shorter intervals. The integration methods for daily, monthly, and annual values shall be described in the PDD

(b) Methane emission potential of the project charcoal producing process in the year y ($ME_{y,project}$) is corrected for the fraction of the time where the flare is operational (temperature above 500°C), and for the fraction of the time where the flare is off (temperature lower than 500°C):

$$PE_{y,flaring} = ME_{y,project} * \left[f_{time,on}(1 - FE) + f_{time,off} \right] * GWP_{CH4} \quad \textbf{(7)}$$

Where:

$f_{time,on}$ Fraction of the time where the flare is "on" (temperature above 500°C)

$f_{time,off}$ Fraction of the time where the flare is "off" (temperature below 500°C). The flare temperature will be recorded at five minutes or shorter time intervals. The integration for daily, monthly and annual values will be described in the PDD. $f_{time,off} + f_{time,on} = 1.0$

16. For the calculation of project emissions from electricity and/or fossil fuel consumption by the project activity facilities ($PE_{y,power}$) the energy consumption of all equipment/devices installed by the project activity shall be included, e.g. the equipments for air pollution control required by regulations and fossil fuel used to support the flaring process. The procedure for determining project emissions from the consumption of electricity specified in AMS-I.D "Grid connected renewable electricity generation" and/or the "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion" shall be followed, respectively.

Leakage

17. If the charcoal producing technology is equipment transferred from another activity, leakage effects are to be considered.

[4] The flow measurement shall take into account those factors that may impact the accuracy of the flow meter, e.g. the gas temperature, condensables, impurities contained in the pyrolysis gas.

18. If the implementation of the project activity occurs in conjunction with other project activities directly related to the inputs and outputs associated with the carbonization process (e.g. coconut shell, eucalyptus or charcoal), the overall supply chain relationship of the respective baseline and project emissions of the individual project activities must be taken into account. In such cases, provisions to avoid double counting may be included in the CDM-PDD as per the EB guidance on double counting of emission reductions as outlined in the paragraph 38 of the EB 26 meeting report.

Emission reductions

19. The emission reduction achieved by the project activity will be measured as the difference between the baseline emission and the sum of the project emission and leakage.

$$ER_y = BE_y - PE_y - Leakage \quad \textbf{(8)}$$

Where:

ER_y Emission reduction in the year y (tCO_2e)

Monitoring

20. The following parameters shall be monitored and recorded under the project activity:

(a) Quantity of raw material ($Q_{y,raw}$) used each year and its moisture content through representative sampling;

(b) Quantity of charcoal produced ($Q_{y,prod}$) and its moisture content in each year;

(c) The average truck capacity ($CT_{y\,1}$ and CT_{y2}) and the distances over which the raw materials and charcoal are transported in the baseline and the project situation;

~~(d)~~ The electricity and/or fossil fuel consumption.

21. The project participants will demonstrate annually that the amount of charcoal raw material used in the project activity facilities would have been used in charcoal manufacturing sites using traditional open-ended methods without methane recovery in the absence of the project activity.

Project activity under a programme of activities

The following conditions apply for use of this methodology in a project activity under a programme of activities:

22. In case the project activity involves the replacement of equipment, and the leakage effect of the use of the replaced equipment in another activity is neglected, because the replaced equipment is scrapped, an independent monitoring of scrapping of replaced equipment needs to be implemented. The monitoring should include a check if the number of project activity equipment distributed by the project and the number of scrapped equipment correspond with each other. For

this purpose scrapped equipment should be stored until such correspondence has been checked. The scrapping of replaced equipment should be documented and independently verified.

Annex I

GENERIC PROCEDURE FOR ESTIMATING METHANE EMISSION FACTOR FOR OPEN-ENDED CHARCOAL MANUFACTURING PROCESSES
(SMG in the equation for estimating baseline emissions, or SMG for project activity facilities)

1. The procedures described here are based on the principles that charcoaling yield is inversely proportional to the temperature of carbonization, and the release of methane is directly proportional to the charcoaling temperature. Laboratory and field experiments are to be carried out to establish the relationship between the release of methane and charcoaling temperature. Experimental steps described below need to be repeated several times for data consistency purposes.

Procedure for laboratory trials

Step 1. Laboratory Rotary type kiln is used for the generation of lab-scale data. Crushed and dried samples of raw material are subjected to charcoaling at different temperatures ranging from 400 ^{0}C to 700^{0}C at different time intervals, varying from 1 to 10 hours of carbonization.

Step 2. The resulting solid masses are weighed and analyzed for their properties. The volatiles released are collected into gas sample bags and their volumes are measured.

Step 3. Using a calibrated gas chromatograph in a certified laboratory, the percentage composition of methane (volume basis) in the collected volatile gas samples is determined.

Step 4. Compute the total weight of methane released when processing 1 tonne of raw material.

Step 5. Conduct a regression analysis and establish a linear or non-linear regression equation that best demonstrates the relationship between the methane emissions and temperature of the carbonisation, consistent with the statistical procedures, the EB guidance on the use of regression in methodologies;

$$\mathbf{CH_4\ (kg/tonne\ of\ raw\ Material) = A \times Temperature\ (^0C) - B}$$

Procedure for field trials

2. The charcoaling cycle consists of four stages:

(a) Pyrolysis phase of over 12 hours when gases are released;

(b) Pacification phase of 12 hours when the pit is closed and hence no gases are released;

(c) Cooling phase of 12 hours;

(d) Unloading of the charcoal and loading of the fresh raw material for the next cycle.

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III.K. Avoidance of methane release from charcoal production (cont)

Step 1. Charcoaling temperature and gravimetric charcoal yield (mass of charcoal over mass of biomass raw material) are measured in selected pits or kilns. Temperature measurements are done throughout the pyrolysis phase at one-hour intervals in the selected pits or kilns.

Step 2. The projected methane release from the pits or kilns is calculated based on the temperature of the charcoaling zone using the co-relation derived using the laboratory testing. Temperature measured at pit/kiln locations is recorded in following format:

Location	Temperature (^{0}C)
	Charcoaling zone
1	
2	
3	
4	
Mean charcoaling Temperature (^{0}C)	XX
Standard deviation	X

If the laboratory charcoaling temperatures and the gravimetric charcoal yield are falling in the same range as the pit/kiln charcoaling, the correlation between temperature and methane emissions established is valid.

The selected pits or kilns should be representative of the industry by way of geographical location, raw material, and size of pits or kilns and duration of charcoaling. The measured temperature values are the average of a minimum five measurements covering the cross section of the pit or kiln.

Annex II

PROCEDURES FOR ESTIMATING METHANE EMISSION FACTOR FOR OPEN-ENDED CHARCOAL MAKING PROCESSES

(*Based on Sampaio, et al, 2006, Appendix I of the CDM Approved Methodology AM0041)*

The objective of this annex is to provide a step-wise approach for establishing a fixed methane emission factor in charcoal production for a given set of open-ended kilns functioning under the same relevant operational parameters. This experimental protocol is based upon the experimental protocol supporting the baseline determination in the approved methodology AM0041 which in turn is drawn upon the most up-to-date published literature on the carbonization process and on a pioneer research conducted in Brazil, triggered by the CDM incentive.

Contrary to the AM0041 methodology, in the present case, no study of the correlation between gravimetric yield and methane emissions will be conducted. This is justified by the fact that, this small-scale methodology only targets projects, which incinerate the methane produced during carbonization process. Moreover, the adoption of a fixed emission factor finds justification in the nature of the improvement brought on by the proposed project activity, which is the substitution of a precisely defined production unit (set of open-ended kilns) that has historically operated under fairly constant conditions.

The experimental procedures described below (such as carbonization tests and gas sampling) must be conducted on a representative sample of kilns to be replaced by the kilns equipped with flaring facility to ensure that the results obtained are statistically representative of the overall production process. These tests must also be in accordance with physical and operational features currently adopted by the project entity.

1.0 Abstract

The aim of this annex is to establish a fixed and representative ratio of methane emissions (kg CH_4) per tonne of raw material (Dry basis) processed (SMG_b) in the production of charcoal.

For this, it is necessary to perform a mass balance analysis on a representative sample of the existing kilns to assess the quantity of methane emitted during the carbonization process.

Basically, the operation performed for each run on each selected kiln consists of the following:

1. Measurement of the raw material mass (Dry basis) loaded into the kiln (Q_{RAW});
2. Ignition of the carbonization process;
3. Mass balance and determination of the total amount of methane emitted in the atmosphere during the total process (Q_{CH4});
4. Statistical treatment of the measured value of $SMG_b = Q_{CH4} / Q_{RAW}$.

2.0 Choice of the sample

Basically one unit of carbonization (e.g.: array of brick kilns) is linked to a given plantation. Because of transportation cost, catchment area for raw material procurement is limited. Thus, in situations where the implementation of the project activity implies on the deactivation of the pre-existing units, it is reasonable to consider the new kilns as a replacement of these units for the considered catchment area.

The baseline determination will focus on the kilns, which have a common catchment area with the project activity.

Once kilns of the baseline are identified, the project developer should take great care in selecting a representative sample among these kilns.

The selected kilns should be representative of actual practices by way of geographical location, raw material, size, operating conditions and operation protocol.

Once selected kilns are divided into homogeneous families with similar characteristics (same location, same operation and same design), then the project proponent select one kiln in each family and perform minimum 8 carbonization cycles on this selected kiln.

3.0 Operative protocol

3.1 Third party measurements

The mass balance on the kilns of the baseline shall be performed by an **independent party** which has the ability and the required certification to handle such operations.

3.2 Weighing of raw material

The project developer should use an industrial calibrated scale to measure the wood to be loaded into the kiln. Precision to be reached is +/- 2 %.

The measure of the wet material weight is recorded as Q_{wRAW}.

3.3 Raw material moisture content

In order to allow the calculation of a total mass balance, it is important to determine the moisture content of the wood logs, in addition to the wood weight. Preliminary research has demonstrated the existence of some variance in moisture, as a function of the wood log diameter, i.e. high moisture levels for pieces of greater diameter and low levels for pieces of shorter diameter. Therefore, this protocol adopts rigorous provisions to reduce the influence of uncertainties associated to the wood moisture measurement, by determining the sampling and stratification of wood into diameter classes, as per the procedure below:

1. Put the wood logs to be carbonized in a stack. The wood must come from the same sources currently used by the project entity;
2. Measure the diameter of all the pieces of wood log in the "stack" (a log pile whose width and volume of wood are approximately equivalent to the carbonization kiln (dimensions) with a pachymeter. The diameter shall be calculated as the mean of two perpendicular and center-crossing measurements of the log transversal section, taken at the middle-length of the log;
3. Determine the distribution histogram of the diameters of the entire population of wood logs in the "stack". The interval size of each diameter class shall not exceed 6.0 centimeters;
4. Choose 60 to 70 samples from the lot of wood logs. The pieces shall follow the proportions of diameter classes of wood logs as shown in the histogram. The samples shall be taken in 3 different vertical areas, covering at least the width equivalent to four average diameters (as measured in Step 2);
5. Cut a 5 to 7 cm thick transversal slice (wood disks), removed from the point that represents 1/3 of total length of each wood log sample, starting from the extremity;

Figure 1 provides an example of the sampling collection:

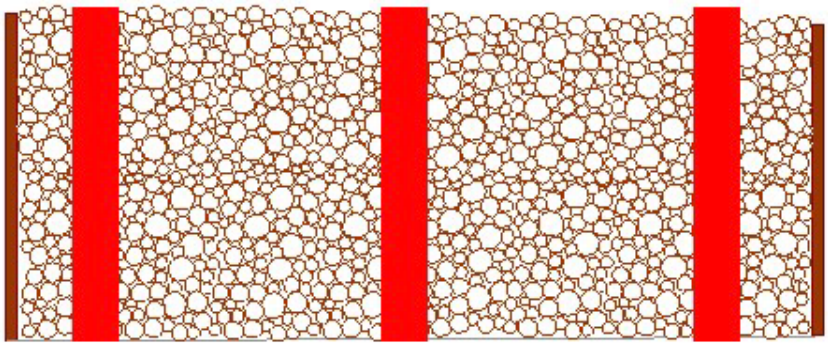

Figure 1: Example of sampling collection in a stack

6. Weigh each disk immediately on the laboratory scale and note the mass;
7. Note the sample number on the wooden disk itself;
8. Place the wooden disks in the oven to dry;
9. Set the oven to 103 ±2ºC;
10. Dry until they reach constant weight, after three consecutive weighing processes indicate constant weight.
11. Weight the wooden disks and note the weights;
12. Calculate the dry basis moisture content (W_{db}) of each disk:

$$W_{db} = \frac{\text{Wet Mass - Dry Mass}}{\text{Dry Mass}} (\text{kg/kg})$$

13. Calculate the mean moisture content of each diameter class;
14. The mean moisture content of the logs in the entire "stack" shall be calculated by the mean moisture content of each diameter class multiplied by its frequency in the diameter distribution histogram.

Q_{RAW} the quantity of raw material on dry basis is given by:

$$Q_{RAW} = \frac{Q_{wRAW}}{(1 + W_{db})}$$

3.4 Experimental Apparatus for mass balance during the carbonization process

3.4.1 Weighing and Temperature Measurement Apparatus

- Two (2) industrial thermometers with range 0-1100°C, and precision of +/- 2.0°C for the temperature measurement on the top and chimneys.

3.4.2 Gas Sampling

- One (1) constant volume peristaltic pump;
- One (1) water cooled gas condenser;
- One (1) oil filter;
- One (1) 100-liter-gasometer;
- Glass bottles or Tedlar bags.

3.4.3 Gas Analysis

- Calibrated Gas Chromatography apparatus for CH_4, CO_2, CO, O_2, and N_2;
- Wood and Charcoal Elementary Analysis;
- Elementary analysis of wood (C, H, O, N, S, Ash and Moisture);
- Elementary analysis of charcoal produced (C, H, O, N, Ash and moisture).

3.4.4 Technical Staff

- One (1) carbonization expert (to conduct the carbonization tests);
- One (1) chemistry technician (to make the measurements);
- One (1) team assistant;
- One (1) carbonization operator for each carbonization test.

3.5 Carbonization procedures

The carbonization procedures conducted under this protocol, also referred as "carbonization tests", shall accurately reflect the physical and operational features of the charcoal manufacturing process currently adopted by the project entity, allowing the assessment the actual carbonization emissions observed in the absence of the cleaner mechanized process. The following procedures shall be followed for the carbonization tests:

1. Carefully load the kiln with the wood;
2. Close and seal the kiln's door;
3. Ignite the kiln;
4. Keep track of temperature measurements, off gas removals, measurement and sampling of the condensable gases, and gaseous fractions generated in each hour;
5. Seal the kiln at the end of carbonization process;
6. Stop the gas sampling procedure;
7. Wait for natural cooling;
8. Open the kiln;
9. Take off the charcoal;

10. Set up the scale for zero weight for taring purposes;
11. Measure the weight of the charcoal immediately after unloading the kiln ($M_{charcoal}$);
12. Remove all brands (large partly charred pieces of wood, not usable as fuel);
13. Measure the weight of all brands removed (M_{brands}).

3.6 Gas sampling procedures

High variations in temperature, composition and density of the volatile materials released make the determination of the flow of non-condensable gases, where methane is present, a relatively complex task. Nevertheless, it is possible to get representative samples of these volatiles during the carbonization process to measure the mass proportions of condensable and non-condensable materials produced. The non-condensable gas fraction shall also be analyzed by chromatography, so as to determine its methane content. Therefore, in order to evaluate the specific methane emissions (in kg CH_4/kg charcoal produced), this protocol is based on the measurement of the volatile mass released (condensable and non-condensable), resulting in the measurement of the amounts of methane released with the non-condensable gases.

In light of the above, the implementation of the following operational procedure, illustrated by scheme below, is required for measuring methane emissions:

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III.K. Avoidance of methane release from charcoal production (cont)

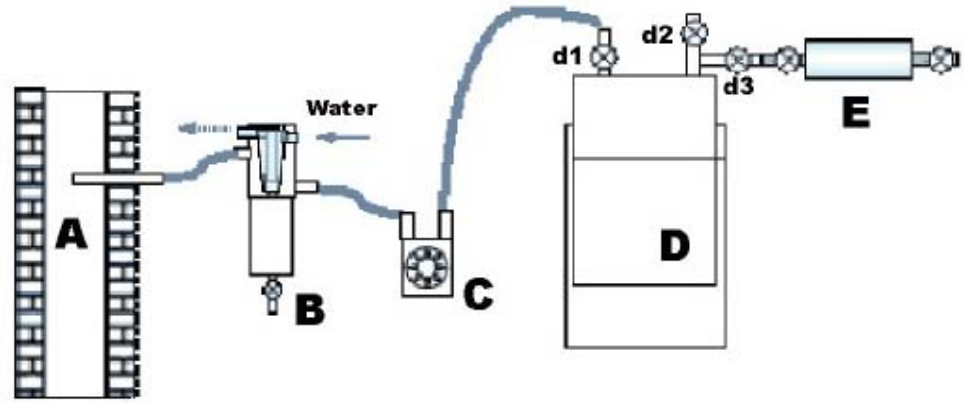

Figure 2: A schematic view of the assembly for collecting gas samples. An intake with a stainless steel tip (A) is installed in the central point of the chimney's transversal section. The suctioned gas passes through the condenser and oil filter (B), through the pump (C), and is released by the gasometer (D). The pump shall be turned on every hour for 10 minutes, suctioning in the gas. After 6 intake periods, covering an operating period of 6 hours, a gas sample shall be collected in a (E) glass cylinder with a double valve, or a Tedlar bag.

A. Set up

1. Connect the stainless steel tip in the central point of the chimney's transversal section before the beginning of the carbonization procedure;
2. Connect all collecting gas sample system;
3. Close the gasometer valves d1 and d3 open the valves d2 to purge the gasometer;
4. Close all gasometer valves;
5. Set the peristaltic pump to 1.3 to 1.5 liters per minute.

B. Purge the gas after one hour from the beginning of carbonization

1. Open the gasometer valves d1 and d2;
2. Turn on the pump for 1.0 minute to purge the gas system;
3. Close all gasometer valves;
4. Purge and close the condenser.

C. Gas sampling

1. Turn on the constant volume peristaltic pump for 10 minutes at every hour;
2. Take off a gas sample for analysis within each six-hour time interval (after six gas samples);

(i) Drain the condenser.

(ii) Measure the mass of condensed liquid (wood tar and pyroligneous water) $M_{cond;}$

(iii) Measure carefully the volume and temperature of the gasometer ($V_{gasometer}$, $T_{gasometer}$);

(iv) Connect the glass bottle or Tedlar bag to valve d3;

(v) Open the valve d3 to fill the glass bottle or Tedlar bag;

(vi) Close the valve d3;

(vii) Connect a second glass bottle or Tedlar bag to valve d3;

(viii) Open the valve d3 to fill the glass bottle or Tedlar bag;

(ix) Close the valve d3;

(x) Take note of date and time on glass bottle or Tedlar bag;

(xi) The glass bottles or Tedlar bags must be send to a laboratory to gas chromatography analysis of CH_4, CO_2, CO, O_2, and N_2;

(xii) Open the gasometer valve d2 to drain all gas;

(xiii) Close the gasometer valve d2;

(xiv) This gas sampling procedure shall be repeated during the entire carbonization process;

(xv) The glass bottles or Tedlar bags must be expeditiously send to an laboratory for chromatographic analysis of CH_4, CO_2, CO, O_2, and N_2. The recipients must be carefully packed and transported in order to ensure that the samples be adequately preserved.

Note 1*: It is necessary to fill and purge the glass bottle or Tedlar bag 2 times to ensure that all remaining air inside be removed.*

Note 2*: Researchers may connect a gas chromatography apparatus directly to valve d2 to make the chromatography analysis.*

3.7 Mass balance analysis

Based on the experimental results, the mass balance to obtain the mass of methane released for each dry ton of processed raw material shall be calculated. Figure 3 illustrates the mass inputs and outputs within the experimental apparatus:

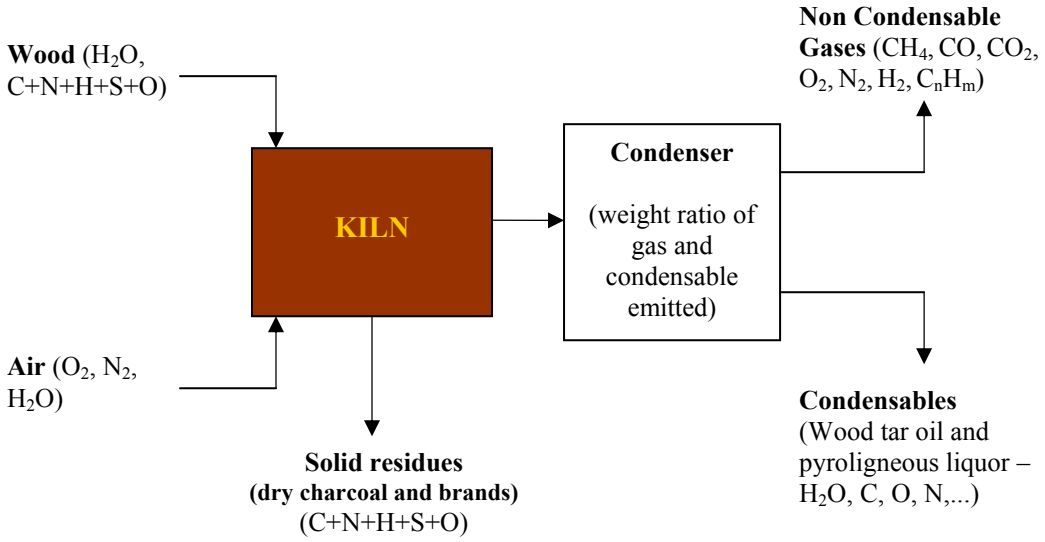

Figure 3 – Major inputs and outputs of the mass balance

The measurement technician shall start the peristaltic pump every hour, read the temperatures, and wait ten minutes to stop the pump until the following hour. After a six-hour-period, the gasometer volume shall be measured and the gas samples shall be taken for analysis purposes (by chromatography and Orsat, if applicable).

INPUT = [mass of wood] + [mass of air]

The mass of wood is a measured value and the mass of air is determined from other measured data and the mass balance:

[mass of wood] = [mass of dry wood] + [mass of water from moisture in wood]

[mass of air] = [mass of O_2 from air] + [mass of N_2 from air] + [mass of H_2O from air]

OUTPUT = [mass of solid residue] + [mass of non-condensable gases] + [mass of condensable volatile]

[mass of solid residues] = weight of the materials left inside the kiln at the moment of measurement, e.g. the carbonizing biomass. When the entire carbonization procedure is finished, it results in the weight of dry charcoal produced.

The volatile material mass leaving the kiln cannot be directly measured, since it contains part of the air that was introduced into the kiln during the carbonization process. The mass of air is an indirectly measured value of the input equation. Nevertheless, the ratio of condensed and non-condensed materials (K_{fu}) can be obtained, as follows:

K_{fu} = the weight ratio between the collected samples of condensed material (water, wood tar, and pyroligneous liquor) and the gases in the gasometer. It is one of the critical measured values of the experiment because it permits one to calculate, for every time interval, the real total amounts of condensable and non-condensable materials. Therefore,

$K_{fu,t}$ = [mass of condensable volatile sampled at time interval t]/ [mass of non-condensable gases sampled at time interval t].

When the entire carbonization process is over, the value of K_{fu} is a mass proportional value of all the K_{fu} measured at each six-hour-time-interval.

[mass of condensable volatile sampled at time interval t] = a measured value at each time interval when the volatiles sample is taken from the kiln chimney.

Through direct weighing, alternatively, the volume in milliliters shall be recorded during the experiments for each timed interval and its density shall be measured to calculate the weight.

[mass of non-condensable gases sampled at time interval t] = the measured and analyzed gas sample volume accumulated in the gasometer at each time interval. The mass value is determined by assuming ideal gas under the experimental conditions (Temperature and Pressure) and using the chromatographic gas analysis to convert the gas analysis from molar base to weight fraction. This procedure also provides the amount of CH_4 released in each time interval *t*. Some minor components of the gas are not analyzed and shall be referred as others.

The values for each six-hour time interval are assumed to be proportional to the whole mass lost at that time interval. Therefore, for the ten-minute samples taken every hour when the six hours are reached, the samples are collected and analyzed for CH_4, CO, CO_2, N_2 and O_2. In that time interval, the precise weight of the material released to the volatile phase is measured and is separated into two phases: non-condensable gases and condensable liquids have their mass ratios measured.

To calculate the mass of air introduced in the kiln at time interval t (six hours), a nitrogen balance shall be conducted:

[mass of nitrogen in output volatile gas] = [mass of nitrogen from air] + [mass of nitrogen in the dry wood] – [mass of nitrogen in solid residues]

The wood nitrogen is either retained in the solid residues or released in the form of non-condensable gases. Thus, by knowing the nitrogen content of the non-condensable gases and the nitrogen from the dry wood and the charcoal, the balance can be calculated based on the infiltrated air. The values of nitrogen present in the wood and in the residue product can be obtained for the initial (dry wood = $M_{DryWood}$) and the final product (charcoal =$M_{charcoal}$).

As above, the following data and calculations are required to perform the mass balance:

4.0 Calculations

4.1 Initial Data

Wood Mass M_{Wood} =	[kg]
Dry basis moisture content of Wood W_{db} =	[kg/kg]
Dry Wood Mass $M_{DryWood} = M_{Wood} / (1 + W_{db})$ =	[kg]
Mass of Charcoal Produced $M_{Charcoal}$ =	[kg]
Mass of Brands Produced M_{Brand} =	[kg]
Nitrogen Content in Wood N_{Wood} =	[kg/kg]
Nitrogen Content in Charcoal $N_{Charcoal}$ =	[kg/kg]

For each 6 hours interval, the following measurements and calculations shall be conducted:

4.2 Measured Data

Six-hour-interval-data:

- Mass of condensed liquid in condenser $M_{cond\Delta t}$ = [kg]
- Gasometer volume (dry non-condensable gases) $V_{gasometer\Delta t}$ = [m^3]
- Gasometer temperature $T_{gasometer}$ = [°C]
- Gasometer pressure $P_{gasometer}$ = [atm]
- Gas analysis (% molar basis):
  - X_{CO2} =
  - X_{CO} =
  - X_{O2} =
  - X_{H2} =
  - X_{N2} =
  - X_{CH4} =

Six-hour-interval-calculations

Specific mass of gasometer dry non-condensable gases

(NTP) = $\rho_{gas} = (44/0.224).X_{CO2} + (28/0.224).X_{CO} + (32/0.224).X_{O2} + 2/0.224).X_{H2} + (22/0.224) + (28/0.224).X_{N2} + (16/0.224).X_{CH4}$ [kg gas/m^3 gas]

Gasometer mass of dry non-condensable gases

$M_{gas\Delta t} = [273/(T_{gasometer} +273)]. P_{gasometer}. V_{gasometer} . \rho_{gas}$ [kg]

Mean 6 hours Methane mass fraction gas content

$P_{CH4\Delta t} = (16/0.224).X_{CH4} / \rho_{gas}$ [kg CH_4/kg gas]

Mean 6 hours Nitrogen mass fraction gas content

$P_{N2\Delta t} = (28/0.224).X_{N2} / \rho_{gas}$ [kg N_2/kg gas]

4.3 Final Mass Balance

Total gasometer mass of dry non-condensable gases

$M_{gas} = \Sigma M_{cond\Delta t}$ [kg]

Total Mass of condensed liquid in condenser

$M_{cond} = \Sigma M_{gas\Delta t}$ [kg]

Ratio of condensed and non-condensed effluents

$K_{FU} = M_{cond} / M_{gas}$ [kg/kg]

Mean Methane mass fraction content of carbonization run

$P_{CH4} = \Sigma P_{CH4\Delta t}$ /NumberAnalysis [kg CH_4/kg gas]

Mean Nitrogen mass fraction content of carbonization run

$P_{N2} = \Sigma P_{N2\Delta t}$ /NumberAnalysis [kg N_2/kg gas]

Mass of dry non-condensed effluents of carbonization run

$MNC = \{M_{DryWood} (1+W_{db}) - M_{Charcoal} - [N_{Wood}.M_{DryWood} + N_{Charcoal}.M_{Charcoal}] /0.769\} /[K_{FU} + 1 + P_{N2} / 0.769]$ [kg non-Cond Gas/run]

Methane emission of carbonization run

$M_{CH4} = P_{CH4} . MNC$ [kg CH_4 /run]

5.0 Specific emission factor determination

Specific emission factor will be calculated for each run (i) as:

$SE_i = M_{CH4} / Q_{RAW}$ [kg CH_4 / kg of raw material]

A final report on the implementation of each step of this protocol shall be presented and attached to the Project Design Document of the respective project activity. The report must contain all data, calculations and conclusions reached as a result of the proposed procedures.

6.0 Statistical Treatment

After conducting minimum eight cycles on each homogeneous family of kilns to be replaced, a conservative statistical treatment of the result is performed in order to calculate the fix emission factor of each family.

Indicative simplified baseline and monitoring methodologies
for selected small-scale CDM project activity categories

III.K. Avoidance of methane release from charcoal production (cont)

This approach is based on the standard deviation of the sample.

Hypothesis:

- *EFi* the Emission factors (kg CH_4/Kg raw material) obtained for the family *k;*
- SD the standard deviation of the sample of *EFi;*
- CV = SD/Average (*EFi*).

Then EF_k emission factor of the given family k of kilns, is equal to:

- Case 1 - If CV (*EFi*)≤ 10% → take average of *EFi;*
- Case 2 - If 10% < CV (*EFi*)≤ 20% → take average of *EFi* ≤ Q3.

Where:

Q3 is the third quartile of the distribution of *EFi.* The average is over all the values of *EFi* that are lower than the third quartile.

- Case 3 - If 20% < CV (EFi)≤ 30% → take average of EFi ≤ Q2.

Where:

Q2 is the second quartile of the distribution of *EFi*. The average is for all the values of *EFi* that are lower than the second quartile value.

- Case 4 - If 30% < CV (EFi) ≤ 40% → take average of *EFi* ≤ Q1.

Where:

Q1 is the first quartile of the distribution of *EFi*. The average is for all the values of *EFi* that are lower than the first quartile value.

- Case 5 - If CV (EFi) > 40% → take 0 as emission factor.

Once emission factor of each family is calculated, the fixed emission factor SMG_b of the baseline is obtained by calculating the weighted average of the various *EF* of each family (weighted according to the annual production of each family before project implementation).

$$SMG_b = \frac{\sum_{family\_k} EF_k * P_k}{P} \quad \textbf{(1)}$$

Where:

SMG_b	is the emission factor to be used in the baseline scenario
EF_k	is the emission factor calculated for the family *k*
P_k	is the annual production of the family *k*

P	is the total production of the kilns to be replaced

Annex III

PROCEDURES FOR ESTIMATING METHANE EMISSION FACTOR FOR OPEN-ENDED CHARCOAL MAKING PROCESSES USING HELIUM TRACING[5]

The objective of this annex is to provide a step-wise approach for establishing a fixed methane emission factor in charcoal production for a given set of open-ended kilns functioning under the same relevant operational parameters. This experimental protocol describes a simple way to determine the methane content of flue gases from open-ended kilns. The methodology is based on Helium tracing, which is a method widely used in industrial facilities,[6] coupled with online gaseous chromatography.

This annex is only applicable to project activities, which involve the substitution of a precisely defined production unit (set of open-ended kilns) that has historically operated under constant conditions.

The experimental procedures described below (such as carbonization tests and gas sampling) must be conducted on a representative sample of kilns to be replaced by the kilns equipped with flaring facility, to ensure that the results obtained are statistically representative of the overall production process. These tests must be in accordance with the historical physical and operational features of the kilns replaced in the project activity.

1.0 Abstract

The objective of this annex is to establish a fixed and representative ratio of methane emissions (kg CH_4) per tonne of raw material (Dry basis) processed (SMG_b) in the production of charcoal. To do so, it is necessary to determine the quantity of methane emitted during the carbonization process on a representative sample of the existing kilns.

Basically, the operation performed run per run on each selected kiln consists of the following:

1. Measurement of the raw material mass (Dry basis) loaded into the kiln (Q_{RAW});

[5] This method is not fully equivalent to the previous ones. The statistical correlation method (Annex 1) and mass balance method (Annex 2) allow the direct estimation of methane generation potential of the carbonization process. Annex 3 assumes that the fugitive emissions in the walls/seals, etc. of the kiln are negligible, and that all gases produced in the carbonizations leave the reactor through the stack. In case the method described in this Annex 3 is used, the test shall be done using the best practices for enclosure/sealing of the reactor/kiln such as to avoid fugitive emissions. The value of the specific methane generation (SMG) obtained using this method shall be multiplied by 1.10 to take into account the fugitive losses.

[6] That is 1) D.BEMER, JM.DESSAGNE, G.AUBERTIN - Determination of emission rate of gas source. Development of a helium tracer method - Service Thermique – INRS – Nancy, France - 1995. 2) O.HAVELANGE, G.DANLOY, R.FRANSSEN, L.BONTE – Helium tracing: a new tool for gas distribution control in the blast furnace – La revue de Métallurgie – January 2000. 3) D.BEMER, JP.MULLER – Comparaison des efficacités de captage mesurées par traçages gazeux et particulaires - Service Thermique – INRS – Nancy,France - 1995.

2. Ignition of the carbonization process;
3. Determination of the total amount of methane emitted in the atmosphere during the total charcoal production process (GM_{CH4});
4. Statistical treatment of the measured value of $SMG_b = GM_{CH4}/Q_{RAW.}$

In case of application of the helium tracing method, the procedures in Annex II chapter 3.4.2, 3.4.4, 3.5, 3.6, 3.7, 4.2 and 4.3 shall be replaced by the procedures below.

2.0 Experimental Apparatus for measurement of methane content in flue gas during the carbonization process

Helium injection system

- Massic flowmeter;
- Helium tank;
- Standard precision of massic flowmeter: 1,5 %;
- Standard purity of Helium: 99,995 %.

3.0 Technical Staff

- One (1) carbonization expert (to conduct the carbonization tests);
- One (1) chemistry technician (to make the measurements);
- One (1) team assistant;
- One (1) carbonization operator for each carbonization test;
- One (1) operator for measurement of wood moisture.

4.0 Carbonization procedures

The carbonization procedures conducted under this protocol, also referred as "carbonization tests", shall accurately reflect the physical and operational features of the charcoal manufacturing process currently adopted by the project entity, allowing the assessment of the actual carbonization emissions observed in the absence of the cleaner mechanized process. The following procedures shall be followed for the carbonization tests:

1. Carefully load the kiln with the wood;
2. Close and seal the kiln's door;
3. Ignite the kiln;
4. Initiate helium injection and flue gases on-line chromatography analysis;
5. Start analysis results record (a minimum of one analysis each 15 minutes should be reached);
6. Seal the kiln at the end of carbonization process;

7. Stop Helium injection procedure;
8. Wait for natural cooling;
9. Open the kiln;
10. Take off the charcoal;
11. Measure the weight of the charcoal immediately after unloading the kiln (Mcharcoal);
12. Remove all brands (large partly charred pieces of wood, not usable as fuel);
13. Measure the weight of all brands removed (Mbrands).

5.0 Gas sampling procedure

Given the nature of flue gases, flue gases sample will be purified continuously (condensation and filtration) before analysis by the chromatograph.

6.0 Flue gases on-line chromatography

Based on the experimental results, the mass of methane released for each dry ton of processed raw material shall be calculated. Figure A3.1 illustrates the principle for determination of methane content in flue gases:

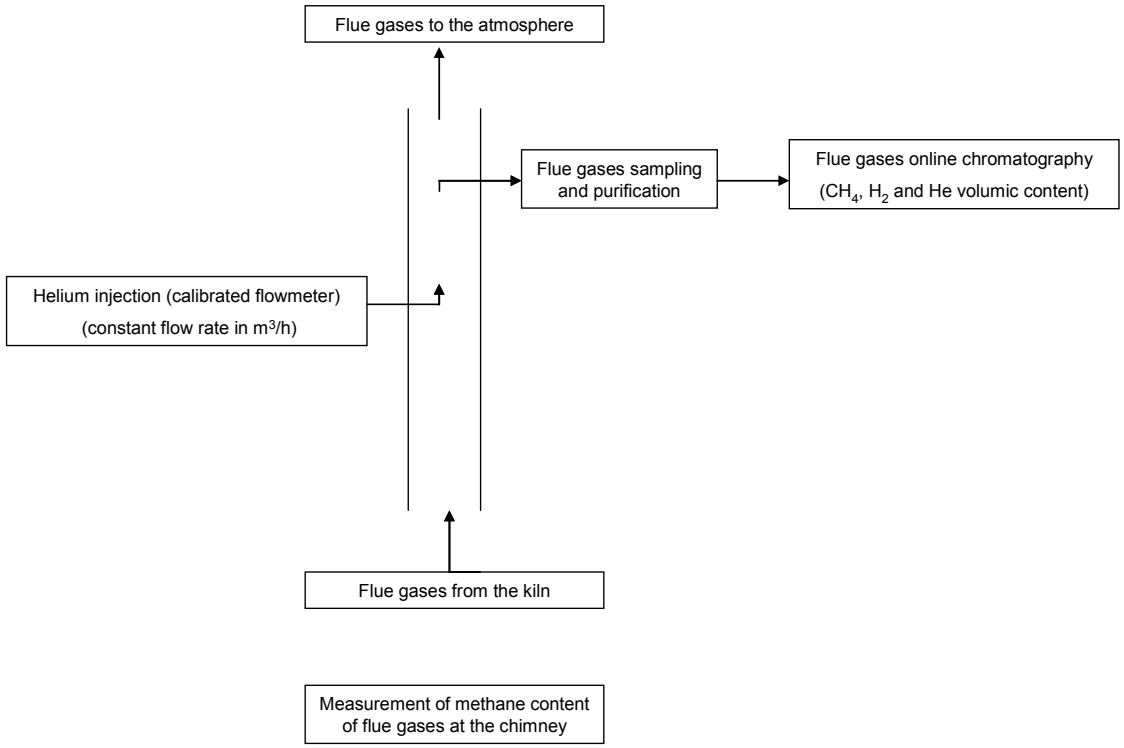

Figure A3.1 – Determination of methane mass content in flue gases

The main principle of this protocol is to inject a continuous mass flow rate of Helium in the chimney. Injection of helium will be realized near exhaust of flue gases at chimney with a stainless steel tip. The flow rate to inject should be at least 0,02% in volume to minimize uncertainty linked to helium content of the air (around 5 ppm). In order to take into account this helium content of air, 5 ppm will be deducted from flue gas analysis results. Moreover, volumes of helium injected per hour shall be negligible compared to flue gases flows.

Once injected, helium will be diluted with flue gases. Flue gases on-line chromatography analysis will determine CH_4 and He volumic content. The flow of flue gases and corresponding methane emissions will be determined by the dilution ratio of helium. Given the nature of flue gases, flue gases sample will be purified (condensation and filtration) before introduction in the chromatograph.

Inputs of the calculation are raw material (mass of wood) and helium injected. Output of this method is a massic flow of methane in flue gases, and then emissions of methane per ton of raw material processed.

7.0 Calculations

The following data and calculations are required to perform the specific emission factor calculation.

7.1 Initial data

Wood Mass Q_{wRAW} =	[kg]
Dry basis moisture content of Wood W_{db} =	[kg/kg]
Dry Wood Mass $Q_{RAW} = Q_{wRAW}/(1 + W_{db})$ =	[kg]
Flow of helium injected $F_{He\,inj}$ =	[m^3/s], NCPT
Volumic content of *He* in helium injected CHe_{inj}=	[$mol.m^{-3}$]

Volume content of *He* in helium injected will be calculated considering Helium content in injected gases (example given 99,995%). A mass flow meter calibrated for Helium (in normal conditions of pressure and temperature (NCPT), P= 1,013 □10 ^{5} Pa, T=0°C) will be used to inject the corresponding constant mass flow.

The following measurements and calculations shall be conducted:

7.2 Measured data

- Volumic content of He in flue gases: $C_{He\,fg}$ [$mol.m^{-3}$]
- Volumic content of CH_4 in flue gases: $C_{CH4\,fg}$ [$mol.m^{-3}$]
- Duration of a carbonization cycle: t_{carb} [s]

7.3 Calculated data

- Flow of flue gases: F_{fg} [m^3/s], NCPT

- Flow of methane emissions in flue gases: F_{CH4} [m^3/s], NCPT
- Massic flow: MF_{CH4} [g CH_4/s]
- Incremental time between two analysis: dt [s]

Considering volumes of helium injected per hour are negligible compared to flue gases flows, the flow of flue gases can be calculated as follows:

$$F_{fg} = F_{Heinj} * C_{Heinj} / C_{He\,fg}$$

As a result, the flow of CH_4 emissions (F_{CH4}) shall be calculated as follows:

$$F_{CH4} = F_{fg} * C_{CH4\,fg}$$

F_{CH4} will be transformed into a massic flow MF_{CH4} considering molecular weight of methane MW_{CH4} (16,043 g.mol^{-1}) and molar volume MV_{fg} (in NCTP, 22,413 l.mol^{-1}).

$$MF_{CH4} = F_{fg} * C_{CH4\ fg} * MW_{CH4} / MV_{fg}$$

7.4 Global methane emission of a carbonisation cycle

$$GM_{CH4} = (\int_{t=0}^{tcarb} MF_{CH4}\,dt) / 1000 \qquad \text{[kg } CH_4 \text{ /run]}$$

8.0 Specific emission factor determination

Specific emission factor will be calculated for each run (i) as:

$$EF_i = GM_{CH4} / Q_{RAW} \qquad \text{[kg } CH_4 \text{ / kg of raw material]}$$

A final report on the implementation of each step of this protocol shall be presented and attached to the PDD of the respective project activity. The report must contain all data, calculations and conclusions reached as a result of the proposed procedures.

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History of the document

Version	Date	Nature of revision
05	EB 65, Annex 25 25 November 2011	To expand the applicability of the methodology (e.g. retrofit of an existing facility is covered) and to provide more guidance on the determination of the fugitive emissions and project emissions from inefficient flaring. The title of the methodology has also been modified.
04	EB 44, Annex 19 28 November 2008	The revisions include a new approach involving helium tracing to determine the baseline methane emission factor in charcoal production.
03	EB 35, Annex 28 19 October 2007	To expand the applicability to include more traditional open-ended methods to produce charcoal such as hot tail kilns and brick based Missouri kilns. The revision also includes a new approach to determine the baseline emissions, which is based on approved methodology AM0041.
02	EB 33, Annex 38 27 July 2007	To allow for its application under a programme of activities (PoA).
01	EB 28, Annex 20 15 December 2006	Initial adoption.
Decision Class: Regulatory **Document Type**: Standard **Business Function**: Methodology		