Draft consolidated baseline and monitoring methodology ACM00XX

"Reduction of emissions from charcoal production by improved kiln design and/or abatement of methane"

I. SOURCE, DEFINITIONS AND APPLICABILITY

Sources

This consolidated baseline and monitoring methodology is based on the following approved baseline and monitoring methodology and proposed new methodology:

- AM0041 "Mitigation of Methane Emissions in the Wood Carbonization Activity for Charcoal Production";
- NM0341 "Mitigation of methane emissions from charcoal production by recovering and burning carbonization gases" prepared by Arcelor Mittal.

This methodology also refers to the latest approved versions of the following tools:

- "Combined tool to identify the baseline scenario and demonstrate additionality";
- "Tool to determine the remaining lifetime of equipment";
- "Tool to calculate baseline, project and/or leakage emissions from electricity consumption";
- "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion";
- "Assessment of the validity of the current/original baseline and update of the baseline at the renewal of the crediting period".

For more information regarding the proposed new methodologies and the tools as well as their consideration by the CDM Executive Board please refer to <http://cdm.unfccc.int/methodologies/PAmethodologies/index.html>.

Selected approach from paragraph 48 of the CDM modalities and procedures

"Existing actual or historical emissions, as applicable"

"Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment".

Definitions

For the purpose of this methodology, the following definitions apply:

Biomass is non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms. This shall also include products, by-products, residues and waste from agriculture, forestry and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal wastes. Biomass also includes gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material.

Carbonization is the process whereby charcoal is produced through the pyrolysis of woody biomass in charcoal kilns. Through the carbonization, complex carbonaceous substances contained in wood or agricultural residues, mainly cellulose, hemicelluloses and lignin, are broken down by heating into elemental carbon and chemical compounds which may also contain some carbon in their chemical structure. The end products of carbonization under controlled conditions are pyroligneous acid, tar, residual gas and charcoal. More information about carbonization process is provided in Appendix 1.

Residual gas is the gas produced in the carbonization process. The residual gas contains several compounds that can be divided in two categories: condensable organic gases (that after condensation will be present in pyroligneous acid and tar) and the non-condensable gases. The non-condensable gases are composed mainly of CO, CO_2, H_2 and CH_4, with the prevalence of CO and CO_2.

Gravimetric yield is the mass of charcoal produced during carbonization divided by the mass of biomass used for charcoal production, both on dry basis.

Carbonization cycle. The time needed by a kiln to manufacture charcoal. It is expressed in hours, begins with ignition of the kiln and finishes when the kiln is sealed for cooling.

Methane abatement unit. A destruction facility designed to burn the residual gas from the carbonization process.

Applicability

This methodology applies to project activities that reduce methane emissions in the residual gas from the carbonization process at existing and/or new charcoal kilns. A kiln is considered to be existing, if it has been in operation for at least a year prior to the implementation of the project activity. At existing charcoal kilns, the project activity shall avoid or abate methane emissions by the installation of charcoal kilns of enhanced design, and/or by the installation of methane abatement units. At new kilns constructed to provide capacity additions to existing charcoal kilns, or at Greenfield kilns, the project activity shall mitigate methane emissions by the installation of methane abatement units.

Emission reductions due to the installation of methane abatement units can be claimed only if the abatement units are monitored. The abatement units can be of the following types: enclosed flares, or other gas combustion facilities that would contain a combustion chamber. The energy produced by the abatement process can be used for heat and/or electricity generation, but no emission reductions can be claimed until a revision request in this regard is accepted;

The methodology is applicable under the following conditions:

- The implementation of the project shall not result in any changes in the type and source of inputs (e.g. wood source, adoption of fossil-fuel based inputs, etc.) for the production of charcoal;
- The project activity is implemented by charcoal producers that supply charcoal to a market or that are an integral part of another industrial activity, e.g. part of an iron and steel industry;
- There are no regulations that prevent venting of methane gas generated from charcoal production facility;
- If the project activity is implemented for existing kilns and no methane abatement unit is installed for these kilns, design and operations of the existing kilns shall be improved through the adoption of technologies and processes for advanced kiln, which avoid or diminish the production of methane emissions in the carbonization process.
- All the kilns in the project boundary are operated in batch mode and each carbonization cycle can be clearly distinguished with its start time and end time marked by the ignition of the kiln and the seal of the kiln;
- Only kilns for which a gravimetric yield relation was derived are used in the baseline and/or project situation;

- All the existing kilns to be improved or replaced by the project activity shall have the same mechanical design (volume, insulation type, net capacity, flows of combustion gases, burner type) with a maximum deviation of 10%;
- The new capacity or Greenfield kilns constructed by the project activity shall have the same mechanical design (volume, insulation type, net capacity, flows of combustion gases, burner type) with a maximum deviation of 10%;
- For projects that consider increase in the existing rated capacity of carbonization or for Greenfield projects, the renewable raw material supplies used in the project activity should originate from sustainable sources of biomass. The sustainability of the sources should be demonstrated in one of the following ways:
    - Official or independent certification agencies demonstrating that the charcoal from renewable sources of biomass originates from sustainably managed plantations and/or
    - The project participant shall demonstrate that the plantations that supply renewable biomass are established in one or more of the following categories of land by providing suitable evidence (e.g. official land use maps, satellite images /aerial photographs, cadastral information, official land use records):
        - (i) Extensively managed grasslands,
        - (ii) Exhausted plantations;
        - (iii) Lands not under agricultural use;
        - (iv) Degraded lands.[1]
- If the project involves the installation of methane abatement unit(s), the following applicability conditions are required:
    - The methane abatement units destroy the methane in the residual gas through combustion; the DOE shall validate using design specifications that the methane abatement unit is designed for this application and that there are requirements for maintenance and cleaning. In addition, for each methane abate unit, at least one campaign shall be conducted to measure the methane concentration in the exhaust of the methane abatement unit m and to demonstrate that $C_{CH4,m,n}$ the methane concentration is below 0.1% on average for each hour n during this period: from 5 hours after the temperature of residual gas initially reaches 100°C after the start of a carbonization cycle, to the end of the carbonization cycle;
    - The combustion chamber of each methane abatement unit shall be continuously monitored by a flame detector during the operation of a kiln;
    - The flow of the residual gas can not be diverted away from the combustion chamber of the methane abatement units; and
    - No gas flow enters the methane abatement units other than the residual gas from charcoal kiln, ambient air, the gas supplied to the pilot flame system, and any other start-up/auxiliary fossil fuels.

In addition, the applicability conditions included in the tools referred to above apply.

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[1] Degraded lands are lands that can be identified as degraded as per the “Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities”.

Finally, this methodology is only applicable if the most plausible baseline scenario determined as per the "Procedure for the identification of the most plausible baseline scenario and assessment of additionality" is as indicated in Table 1.

II. BASELINE METHODOLOGY PROCEDURE

Procedure for the identification of the most plausible baseline scenario and assessment of additionality

Project participants shall determine the most plausible baseline scenario through the application of the steps prescribed by the latest approved version of the "Combined tool to identify the baseline scenario and demonstrate additionality." The following methodology-specific requirements shall be fulfilled in the application of the tool.

Step 1: Identification of alternative scenarios

The identification of the alternative scenarios shall be based on the total output of charcoal in the project scenario. For that reason, if the project activity involves capacity increase of charcoal production as compared to an existing capacity, the choice of alternative scenarios shall be determined for the existing production and for the expanded production, respectively.

- The realistic and credible alternative scenarios for charcoal production at existing kilns shall include, *inter alia*:

  M1: Use of the kiln design existing at the project activity site prior to the implementation of the project activity, without methane abatement units at the project site;

  M2: Use of a kiln design which are the common practice in the project geographical area, without methane abatement units at the project site;

  M3: Adoption of improved kiln design as implemented in the project activity, without methane abatement units;

  M4: Use of the kiln design existing in the project activity site prior to the implementation of the project activity, with methane abatement units at the project site;

  M5: Use of a kiln design which are the common practice in the project geographical area, with methane abatement units at the project site;

  M6: Adoption of improved kiln design as implemented in the project activity, with methane abatement units;

  M7: Investment in carbonization technologies and equipment that are based on sophisticated industrial processes for charcoal production, such as carbonization retorts, or best available technologies;

  M8: The proposed project activity undertaken without being registered as a CDM project activity.

The project geographical area referred to in alternative M2 above should be the same geographical area applicable in the common practice analysis.

- The realistic and credible alternative scenarios for the expanded capacity of charcoal production at existing kilns and the total capacity of charcoal production at Greenfield kilns shall be limited to

  G1: The proposed project activity undertaken without being registered as a CDM project activity;

G2: The use of the kiln design as implemented in the project activity, but without the installation of the methane abatement units at the project site; and

G3: The use of the kiln design as implemented in the project activity, but with the installation of a different type of methane abatement unit at the project site.

Step 3 Investment Analysis

The additional revenues from the productivity improvement compared to the baseline kilns and the savings from the production of useful energy from the methane abatement unit, where applicable, shall be taken into account.

Step 4 Common practice analysis

The concept of "different technologies" shall be interpreted in the context of this methodology as follows:

- All types of equipment installed for charcoal kilns to abate methane through combustion are considered to be the same technology and
- The installation of such methane abatement units and the absence of such methane abatement units are considered to be two different technologies.

The following table presents the combinations of projects and baseline scenarios to which this methodology is applicable. If the project activity involves capacity increase of charcoal production as compared to an existing capacity, different baseline scenarios shall be applicable to the existing production capacity and for the expanded capacity, respectively.

Table 1: Combinations of baseline and project scenarios to which the methodology is applicable

	Project type	**Baseline scenario**
A	Replacement of existing charcoal production capacity by installation of charcoal kilns of enhanced design, without methane abatement units	M1
B	Replacement of existing charcoal production capacity by installation of charcoal kilns of enhanced design, with methane abatement units	M1 or M3
C	Expansion of existing charcoal production capacity by installation of charcoal kilns of enhanced design, with methane abatement units	G2
D	Installation of Greenfield charcoal kilns, with methane abatement units	G2

Project boundary

The spatial extent of the project boundary encompasses the area of the charcoal kilns. The DOE shall verify the number and location of charcoal kilns included in the project boundary. The greenhouse gases included in or excluded from the project boundary are shown in Table 2.

Table 2: Emissions sources included in or excluded from the project boundary

Source		Gas	Included?	Justification / Explanation
Baseline	Carbonization	CO_2	No	Not accounted. This emission is from the renewable biomass sources
		CH_4	Yes	The major source of emissions in the baseline
		N_2O	No	Not applicable to the process
Project activity	Carbonization	CO_2	No	Not accounted. This emission is from the renewable biomass sources
		CH_4	Yes	Major source of emissions
		N_2O	No	Not applicable to the process
	Electricity consumption due to the project activity	CO_2	Yes	May be an important emission source
		CH_4	No	Excluded for simplification. This emission source is considered very small
		N_2O	No	Excluded for simplification. This emission source is considered very small
	Fossil fuel consumption due to the project activity	CO_2	Yes	May be an important emission source
		CH_4	No	Excluded for simplification. This emission source is considered very small
		N_2O	No	Excluded for simplification. This emission source is considered very small

Project emissions

Project emissions include:

- CH_4 emissions from vented or unabated residual gas from the kiln;
- CO_2 emissions from on-site electricity consumption due to the project activity; and
- CO_2 emissions from on-site fossil fuels consumption due to the project activity.

Project emissions are calculated as follows:

$$PE_y = PE_{gas,y} + PE_{elec,y} + PE_{fuel,y} \tag{1}$$

Where:

PE_y	=	Project emissions in year *y* (tCO_2e/yr)
$PE_{gas,y}$	=	Project emissions from vented or unabated methane in the residual gas in year *y* (tCO_2e/yr)
$PE_{elec,y}$	=	Project emissions from electricity consumption on-site due to the project activity in year *y* (tCO_2/yr)
$PE_{fuel,y}$	=	Project emissions from fuel consumption on-site due to the project activity in year *y* (tCO_2/yr)

Step 1: Project emissions from vented or unabated methane in the residual gas ($PE_{gas,y}$)

If destruction by methane abatement unit(s) is implemented in the project activity, the DOE shall ensure that the operation and maintenance of the methane abatement unit(s) conforms to the requirements as per its design, by reviewing maintenance records (including cleaning of the units) and by observing on-site or photos of the methane abatement unit(s).

Project emissions from vented or unabated methane in the residual gas are calculated as:

$$PE_{gas,y} = GWP_{CH4} \times \mathrm{f}_{\mathrm{PJ}}\left(Y_{PJ,y}\right) \times P_{char,y} \times \left[\frac{B_{total,y} - B_{qual,b,y} - B_{qual,c,y}}{B_{total,y}} + \frac{B_{qual,b,y}}{B_{total,y}} \times \left(1 - \eta_{PJ,b}\right) + \frac{B_{qual,c,y}}{B_{total,y}} \times \left(1 - \eta_{PJ,c}\right)\right] \tag{2}$$

Where:

$PE_{gas,y}$ = Project emissions from vented or unabated methane in the residual gas in year *y* (tCO_2e/yr)

GWP_{CH4} = Global warming potential of methane (tCO_2e/tCH_4)

$F_{PJ}(.)$ = Project regression equation (tCH_4/tonnes of charcoal)

$Y_{PJ,y}$ = Project gravimetric yield during year *y* (tonnes of charcoal/tonne of biomass, both on dry basis)

$P_{char,y}$ = Production of charcoal during year *y* (tonnes/yr on dry-basis)

$B_{total,y}$ = The number of all the carbonization batches operated by the project plant in year *y* (-)

$B_{qual,b,y}$ = The number of qualified carbonization batches abated by the batch operation of a methane abatement unit in year *y* (-). If no methane abatement device is installed by the project activity, the number of qualified batches is set at zero (dimensionless)

$B_{qual,c,y}$ = The number of qualified carbonization batches abated by the continuous operation of a methane abatement unit in year *y* (-). If no methane abatement device is installed by the project activity, the number of qualified batches is set at zero (dimensionless)

$\eta_{PJ,b}$ = The destruction efficiency of the batch operation of a methane abatement unit (if any) (fraction)

$\eta_{PJ,c}$ = The destruction efficiency of the continuous operation of a methane abatement unit (if any) (fraction)

a. Determine the project regression equation (f_{PJ})

The relationship between the methane emission factor and the gravimetric yield of the carbonization process for the kilns implemented by the project shall be established based on experimental data, obtained as described in Appendix 1, followed by a statistical analysis of those data as described in Appendix 2.

An independent third party shall implement or audit the experiment and review the statistical analysis. A detailed report describing the implementation of each step of Appendices 1 and 2 should be attached to the PDD at the validation stage. The report must contain a detailed description of test facility and test procedures (including assumptions and simplifications), all data, calculations and conclusions reached as a result of the required procedures.

The following steps summarize the procedures described in Appendices 1 and 2:

(1) Set up the experimental apparatus at a project kiln, with all the equipment that will enable experimental analysis of the carbonization process, as described in Appendix 1;

(2) Run at least six (as specified in section 3.4 of Appendix 1) carbonization cycles using the experimental kiln, under different operational conditions, following the experimental procedures described in Appendix 1. Collect all necessary input and output data, e.g. biomass and charcoal weights, gas flows, gas composition, and calculate the gravimetric yields and methane emission factors for each carbonization cycle, $Y_{PJ,f,n}$ and $EF_{CH4,PJ,f,n}$;

(3) Conduct a statistical analysis of the data using the procedures described in Appendix 2. Establish a regression equation that best demonstrates the relationship between the gravimetric yield $Y_{PJ,f,n}$ and the methane emission factor $EF_{CH4,PJ,f,n}$.

After the experiment and the statistical analysis are conducted, a regression equation $f_{PJ}(Y)$, which expresses the methane emissions factor as a function of the gravimetric yield, should be obtained.

b. Determine the project gravimetric yield ($Y_{PJ,y}$)

The project gravimetric yield ($Y_{PJ,y}$) is determined as the average of the gravimetric yield of sampled project kiln *j* ($Y_{PJ,y,j}$). The samples are collected from the project kilns, and the measurements are conducted in accordance with the protocols presented in Appendix 3. The sample size should be estimated in accordance with the requirement of confidence and precision from the latest version of the *Standard for sampling and surveys for CDM project activities and programme of activities*. If the approach of stratified random sampling is adopted, one charcoal production farm or a group of charcoal kilns could be a stratum within which the carbonization kilns shall be homogeneous with respect to the operation of the carbonization process; between the different strata, heterogeneity in operation may be observed.

c. Determine the number of qualified batches abated by the batch operation of a methane abatement unit ($B_{qual,b,y}$)

The residual gas from a charcoal batch is considered to be successfully mitigated by the batch operation of a methane abatement unit and that batch is included in the number of qualified batches abated by the batch operation of a methane abatement unit ($B_{qual,b,y}$) only if the following conditions are met:

- When the temperature of residual gas initially reaches 100°C after the start of a carbonization cycle, the methane abatement unit for that kiln is ignited within 5 hours;
- After the 5 hours of the ignition process and before the end of the carbonization cycle, the flame is detected for at least 55 minutes out of each hour, through a flame detection system reporting electronically for each minute.

The project participant shall ensure that these conditions can be demonstrably satisfied through the documentation and implementation of operating procedures for the methane abatement units and the continuous operation of the relevant flame detector and temperature measurement device throughout each carbonization cycle. For the evaluation of the conditions, the start time and the end time of each carbonization cycle, as marked by the ignition and the seal of the kiln, shall also be monitored and recorded.

d. *Determine the number of qualified batches abated by the continuous operation of a methane abatement unit ($B_{qual,c,y}$)*

The residual gas from a charcoal batch is considered to be successfully mitigated by the continuous operation of a methane abatement unit and that batch is included in the number of qualified batches abated by the continuous operation of a methane abatement unit ($B_{qual,c,y}$) only if the following condition is met:

- Throughout the entire carbonization cycle, the flame is detected for at least 55 minutes out of each hour, through a flame detection system reporting electronically for each minute.

The project participant shall ensure that these conditions can be demonstrably satisfied through the documentation and implementation of operating procedures for the methane abatement units and the continuous operation of the relevant flame detector throughout each carbonization cycle. For the evaluation of the conditions, the start time and the end time of each carbonization cycle, as marked by the ignition and the seal of the kiln, shall also be monitored and recorded.

e. *Determine the destruction efficiency of the batch operation of a methane abatement unit ($\eta_{PJ,b}$)*

As each charcoal kiln is operated as a batch process, the batch-operating abatement unit is not continuously lit and has to be manually ignited when the concentration of the combustibles (including CH_4, CO and H_2 etc.) in the residual gas rises above a threshold. Therefore, even if a carbonization batch meets the conditions for qualified batches, some of the methane in the residual gas will pass through the batch-operating abatement unit unmitigated, when the combustible concentration is relatively low, when part of flow does not pass through the combustion zone, or when the batch-operating abatement unit is not lit.

A default value of the destruction efficiency is provided for charcoal batches that are considered to be successfully mitigated by the batch operation of methane abatement units. It is set at 50% to be conservative, due to uncertainties associated with the manual and intermittent operation of the methane abatement units. [2]

f. *Determine the destruction efficiency of the continuous operation of a methane abatement unit ($\eta_{PJ,c}$)*

During the continuous operation of a methane abatement unit, where the flame can be detected for at least 55 minutes in each hour, a default destruction efficiency of 80% is provided for charcoal batches that are considered to be successfully mitigated by the continuous operation of methane abatement units.[3]

Step 2: Project Emissions from electricity consumption on site due to the project activity ($PE_{elec,y}$)

If the project activity involves electricity consumption, corresponding emissions $PE_{elec,y}$ (tCO_2/yr) should be calculated as per the parameter $PE_{EC,y}$ in the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption". For the electricity which is produced on-site using

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[2] Procedures may be proposed to revise this methodology to allow each project to reliably determine a more accurate destruction efficiency through experiments. Additional procedures should be provided on how to ensure that the abatement unit operates the same as in the experiments.

[3] The destruction efficiency of the unit is assumed to be slightly lower than the default of an enclosed flare (90%) adopted in the "Tool to determine project emissions from flaring gases containing methane", because the flame may go out for up to 5 minutes per hour.

fossil fuels, the corresponding emissions need not be accounted for, as they are already considered as part of the emissions from fuel consumption on-site ($PE_{fuel,y}$), see below.

Step 3: Project Emissions from fuel consumption on-site due to the project activity ($PE_{fuel,y}$)

If the project activity involves on-site fossil fuel consumption, corresponding emissions $PE_{fuel,y}$ (tCO_2/yr) should be calculated as per the parameter $PE_{FC,j,y}$ in the "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion".

Baseline emissions

Baseline emissions include only methane emissions from the carbonization process in the baseline scenario and are calculated as follows:

$$BE_y = GWP_{CH4} \times f_{BL}\left(Y_{BL,y}\right) \times P_{char,BL,y} + GWP_{CH4} \times f_{PJ}\left(Y_{PJ,y}\right) \times \left(P_{char,y} - P_{char,BL,y}\right) \qquad \textbf{(3)}$$

Where:

BE_y = Baseline emissions during year y (tCO_2e/yr)

GWP_{CH4} = Global warming potential of methane (tCO_2e/tCH_4)

$F_{PJ}(.)$ = Project regression equation (tCH_4/tonnes of charcoal)

$Y_{PJ,y}$ = Project gravimetric yield during year y (tonnes of charcoal/tonne of biomass, both on dry basis)

$f_{BL}(.)$ = Baseline regression equation (tCH_4/tonne of charcoal)

$Y_{BL,y}$ = Baseline gravimetric yield during year y (tonnes of charcoal/tonne of biomass, both on dry basis)

$P_{char,BL,y}$ = Production of charcoal by existing kilns during year y (tonnes/yr, on dry-basis)

$P_{char,y}$ = Production of charcoal during year y (tonnes/yr, on dry-basis)

Step 4: Determine the baseline regression equation (f_{BL})

The project regression equation shall be applied for the existing kilns, i.e. $f_{BL} = f_{PJ}$, if one of the following conditions is met,

- The kiln design in the project activity are the same as the design of the kilns in the baseline scenario (i.e. emission credits are claimed only for the destruction of methane in the residual gas);
- The end of the lifetime of at least 5% of the existing kilns is reached during the first crediting period, determined ex ante as per the "Tool to determine the remaining lifetime of equipment";
- It is in the second or the third crediting period.

If none of the conditions above are met, the relationship between the methane emission factor and the gravimetric yield of the carbonization process for the existing kilns shall be established based on experimental data, obtained as per the procedures in Appendix 1, followed by a statistical analysis of those data as described in Appendix 2.

An independent third party shall implement or audit the experiment and review the statistical analysis. A detailed report describing the implementation of each step of Appendices 1 and 2 should be attached to the PDD at the validation stage. The report must contain a detailed description of test facility and test procedures (including assumptions and simplifications), all data, calculations and conclusions reached as a result of the required procedures.

The following steps summarize the procedures described in Appendices 1 and 2:

(1) Set up the experimental apparatus, including a real size charcoal kiln (experimental kiln), with all the equipment that will enable experimental analysis of the carbonization process, as described in Appendix 1. The definition of the experimental kiln depend on the baseline scenario identified as per the "Procedure for the identification of the most plausible baseline scenario and assessment of additionality";

(2) Run at least four (as specified in section 3.4 of Appendix 1) carbonization cycles using the experimental kiln, under different operational conditions, following the experimental procedures described in Appendix 1. Collect all necessary input and output data, e.g. biomass and charcoal weights, gas flows, gas composition, and calculate the gravimetric yields and methane emission factors for each carbonization cycle, $Y_{BL,f,m}$ and $EF_{CH4,BL,f,m}$;

(3) Conduct a statistical analysis of the data using the procedures described in Appendix 2. Establish a regression equation that best demonstrates the relationship between the gravimetric yield $Y_{BL,f,m}$ and the methane emission factor $EF_{CH4,BL,f,m}$.

After the experiment and the statistical analysis are conducted, a regression equation $f_{BL}(Y)$, which expresses the methane emissions factor as a function of the gravimetric yield, should be obtained.

Step 5: Determine the baseline gravimetric yield ($Y_{BL,y}$)

The gravimetric yield of the existing kilns ($Y_{BL,y}$) shall be the same as the project gravimetric yield in year *y*, i.e. $Y_{BL,y} = Y_{PJ,y}$, if one of the following conditions is met,

- The kiln design of the kilns in the project activity are the same as the design of the kilns in the baseline scenario (i.e. emission credits are claimed only for the destruction of methane in the residual gas);
- The end of the lifetime of at least 5% of the existing kilns is reached during the first crediting period, determined ex ante as per the "Tool to determine the remaining lifetime of equipment";
- It is in the second or the third crediting period.

Until one of the conditions above is met, the baseline gravimetric yield ($Y_{BL,y}$) shall be fixed as the average of the gravimetric yield of sampled existing kiln *i* ($Y_{BL,i}$) during a baseline campaign or based on historical values for the year prior to the implementation of the project activity if available.

The samples are collected from the kilns applying the kiln design in the baseline scenario, and the measurements are conducted in accordance with the protocols presented in Appendix 3. The sample size should be estimated in accordance with the requirement of confidence and precision from the latest version of *the Standard for sampling and surveys for CDM project activities and programme of activities*. If the approach of stratified random sampling is adopted, one charcoal production farm or a group of charcoal kilns could be a stratum within which the carbonization kilns shall be homogeneous with respect to the operation of the carbonization process; between the different strata, heterogeneity in operation may be observed.

Leakage

No leakage sources are considered.

Emission reductions

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y \tag{4}$$

Where:

ER_y = Emission reductions in year y (t CO_2e/yr)
BE_y = Baseline emissions in year y (t CO_2e/yr)
PE_y = Project emissions in year y (t CO_2e/yr)

Changes required for methodology implementation in 2nd and 3rd crediting periods

The required changes should be assessed using the tool for "Assessment of the validity of the current/original baseline and update of the baseline at the renewal of the crediting period".

Data and parameters not monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Parameter:	$C_{CH4,m,n}$
Data unit:	Volumetric fraction
Description:	Methane concentration in the exhaust of methane abatement unit m, for hour n during one carbonization cycle
Source of data:	--
Measurement procedures (if any):	Continuous monitoring from 5 hours after the temperature of residual gas initially reaches 100°C after the start of a carbonization cycle, to the end of the carbonization cycle
Any comment:	--

Parameter:	$Y_{BL,i}$
Data unit:	Tonnes of charcoal/tonnes of biomass, both on dry basis
Description:	Baseline gravimetric yield of sampled kiln *i*
Source of data:	Historical values for the year prior to the implementation of the project activity if available, or experimental data during a baseline campaign as per Appendix 3
Measurement procedures (if any):	See Appendix 3
Any comment:	--

Parameter:	$Y_{BL,f,m}$
Data unit:	Tonnes of charcoal/tonnes of biomass, both on dry basis
Description:	Baseline gravimetric yield of carbonization cycle *m* used to determine the baseline regression equation f_{BL}
Source of data:	Experimental data as per Appendix 3
Measurement procedures (if any):	See Appendix 3
Any comment:	The selection of kiln *m* shall ensure that its design and operating conditions are the same as the baseline scenario

Parameter:	$EF_{CH4,BL,f,m}$
Data unit:	Tonnes of CH_4/tonnes of charcoal
Description:	Methane emission factor of carbonization cycle *m* used to determine the baseline regression equation f_{BL}
Source of data:	Experimental data as per Appendix 1
Measurement procedures (if any):	See Appendix 1
Any comment:	The selection of kiln *m* shall ensure that its design and operating conditions are the same as the baseline scenario

Parameter:	$Y_{PJ,f,n}$
Data unit:	Tonnes of charcoal/tonnes of biomass, both on dry basis
Description:	Project gravimetric yield of kiln *n* used to determine the project regression equation f_{PJ}
Source of data:	Experimental data as per Appendix 3
Measurement procedures (if any):	See Appendix 3
Any comment:	The selection of kiln *n* shall ensure that its design and operating conditions are the same as the project scenario

Parameter:	$EF_{CH4,PJ,f,n}$
Data unit:	Tonnes of CH_4/tonnes of charcoal
Description:	Methane emission factor of kiln *n* used to determine the project regression equation f_{PJ}
Source of data:	Experimental data as per Appendix 1
Measurement procedures (if any):	See Appendix 1
Any comment:	The selection of kiln *n* shall ensure that its design and operating conditions are the same as the project scenario. If the project scenario includes the installation of a methane abatement unit, this emission factor is based on the emissions prior to the destruction by the abatement unit

Parameter:	GWP_{CH4}
Data unit:	tCO_2e /tCH4
Description:	Global warming potential of methane
Source of data:	IPCC
Measurement procedures (if any):	21 for the first commitment period. Shall be updated according to any future COP/MOP decisions
Any comment:	--

III. MONITORING METHODOLOGY

All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

In addition, the monitoring provisions in the tools referred to in this methodology apply.

As part of monitoring, the relevant changes to charcoal kilns must be recorded, including the number of kilns and their start date under the project activity. The changes in the number of kilns shall be reflected in the monthly data on kiln operations.

The operational procedures shall be periodically verified by the supervisory personnel to ensure the integrity of the data monitored and collected.

The monitoring plan of the project should outline the management and operational structure of the project and the monitoring protocols, standard operating procedures and responsibilities of the personnel involved in the charcoal production process shall be outlined in order to ensure the effective implementation of the monitoring plan.

Data and parameters monitored

Data / Parameter:	$P_{char,y}$
Data unit:	Tonnes, on dry basis
Description:	Production of charcoal during year *y*
Source of data:	On-site production data logs
Measurement procedures (if any):	Measure the production of charcoal and correct for moisture content as explained in Appendix 3
Monitoring frequency:	Monthly and aggregated annually
QA/QC procedures:	Scales in use must be accurately monitored and regulated. Check against production and delivery records at the charcoal kilns. Also check against the capacity of the kilns and the number of carbonization batches
Any comment:	Charcoal must be weighted at delivery

Data / Parameter:	$P_{char,BL,y}$
Data unit:	Tonnes, on dry basis
Description:	Production of charcoal by existing kilns during year *y*
Source of data:	On-site production data logs
Measurement procedures (if any):	Measure the production of charcoal and correct for moisture content as explained in Appendix 3
Monitoring frequency:	Monthly and aggregated annually
QA/QC procedures:	Scales in use must be accurately monitored and regulated. Check against production and delivery records at the charcoal kilns. Also check against the capacity of the kilns and the number of carbonization batches
Any comment:	Charcoal must be weighted at delivery

Data / Parameter:	Location/site description
Data unit:	Location of the carbonization unit that typically comprises a group of several charcoal kilns
Description:	Production department /farm maps
Source of data:	Monthly data and their correspondent changes on kiln number, including start date under the project activity
Measurement procedures (if any):	Monthly
Monitoring frequency:	Location of kilns are physically verifiable and registered in production registries subjected to monitoring provisions under this methodology
QA/QC procedures:	Location/site description
Any comment:	Location of the carbonization unit that typically comprises a group of several charcoal kilns

Data / Parameter:	$Y_{PJ,y,j}$
Data unit:	Tonnes of charcoal/tonnes of biomass, both on dry basis
Description:	Project gravimetric yield of sampled kiln *j* in year *y*
Source of data:	Experimental data as per Appendix 3
Measurement procedures (if any):	See Appendix 3
Monitoring frequency:	Annually
QA/QC procedures:	--
Any comment:	--

Data / Parameter:	$B_{total,y}$
Data unit:	--
Description:	The number of all the carbonization batches operated by the project plant in year *y*
Source of data:	Operating records of the kilns
Measurement procedures (if any):	--
Monitoring frequency:	Annually
QA/QC procedures:	To cross check against the capacity of the kilns per batch and the total production of the kilns
Any comment:	--

Data / Parameter:	$B_{qual,b,y}$
Data unit:	--
Description:	The number of qualified carbonization batches abated by the batch operation of a methane abatement unit in year *y*
Source of data:	Operating records of the kilns, according to the criteria given for qualified carbonization batches in Step 1 of the Project Emissions section
Measurement procedures (if any):	--
Monitoring frequency:	Annually
QA/QC procedures:	--
Any comment:	If no methane abatement device is installed by the project activity, the number of qualified batches is set at zero

Data / Parameter:	$B_{qual,c,y}$
Data unit:	--
Description:	The number of qualified carbonization batches abated by the continuous operation of a methane abatement unit in year *y*
Source of data:	Operating records of the kilns, according to the criteria given for qualified carbonization batches in Step 1 of the Project Emissions section
Measurement procedures (if any):	--
Monitoring frequency:	Annually
QA/QC procedures:	--
Any comment:	If no methane abatement device is installed by the project activity, the number of qualified batches is set at zero

Data / Parameter:	Combustion status of each methane abatement unit
Data unit:	--
Description:	--
Source of data:	From a flame detection system reporting electronically for each minute
Measurement procedures (if any):	--
Monitoring frequency:	Every minute
QA/QC procedures:	The detector and the electronical reporting system will be checked after monthly to ensure that it is operational and functioning correctly
Any comment:	Applicable only if a methane abatement unit(s) is installed as part of the project activity

Data / Parameter:	Start time and end time of each carbonization cycle of each kiln
Data unit:	--
Description:	--
Source of data:	Recorded by the project participant
Measurement procedures (if any):	The start time and end time of each carbonization cycle shall be recorded as part of the standard operating procedure of the kilns. The standard operating procedure will be validated by the DOE
Monitoring frequency:	Every carbonization batch
QA/QC procedures:	The time recording system should be in sync with the time system of the flame detection system
Any comment:	The start and end time of each carbonization cycle of each kiln marked by the ignition and the seal of the kiln. Applicable only if a methane abatement unit(s) is installed as part of the project activity

Data / Parameter:	Temperature of the residual gas from each kiln
Data unit:	Degree C
Description:	--
Source of data:	Temperature measurement device with automatic electronic reporting system
Measurement procedures (if any):	--
Monitoring frequency:	At least every half an hour during each carbonization cycle
QA/QC procedures:	The time recording system should be in sync with the time system of the temperature measurement device.
Any comment:	Applicable only if a methane abatement unit(s) is installed as part of the project activity. If one methane abatement unit mitigates the methane from a group of several charcoal kilns, the measurement of the temperature of residual gas from each of these kilns shall be conducted at a location where no significant interference by the carbonization process of any other kiln may occur

Data / Parameter:	Combustion status of each methane abatement unit
Data unit:	--
Description:	--
Source of data:	From a flame detection system reporting electronically for each minute
Measurement procedures (if any):	--
Monitoring frequency:	Every minute
QA/QC procedures:	The detector and the electronic reporting system will be checked after monthly to ensure that it is operational and functioning correctly
Any comment:	Applicable only if a methane abatement unit(s) is installed as part of the project activity. Each monitoring report shall specify the assignment of each charcoal kiln to one of the methane abatement units for the monitoring period

Data / Parameter:	Maintenance of each methane abatement unit
Data unit:	--
Description:	--
Source of data:	Maintenance records (including cleaning of the units) and site visit or photos of the methane abatement unit(s)
Measurement procedures (if any):	--
Monitoring frequency:	Every monitoring period
QA/QC procedures:	--
Any comment:	Applicable only if a methane abatement unit(s) is installed as part of the project activity. DOE shall ensure that the operation and maintenance of the methane abatement unit(s) conforms to the requirements as per its design

Data / Parameter:	$PE_{elec,y}$
Data unit:	tCO_2
Description:	Emissions from electricity use on site
Source of data:	As per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”
Measurement procedures (if any):	As per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”
Monitoring frequency:	As per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”
QA/QC procedures:	As per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”
Any comment:	For the electricity which is produced on-site using fossil fuels, the corresponding emissions need not be accounted for as they are already considered as part of the emissions from fuel use on-site ($PE_{fuel,y}$), see below

Data / Parameter:	$PE_{fuel,y}$
Data unit:	tCO_2
Description:	Emissions from fuel use on-site
Source of data:	As per the “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”
Measurement procedures (if any):	As per the “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”
Monitoring frequency:	As per the “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”
QA/QC procedures:	As per the “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”
Any comment:	-

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Appendix 1: Experimental protocol for measuring methane emissions in the charcoal-making process

SUMMARY

INTRODUCTION……………………………………………………………………......

1.) The overall behaviour of carbonization cycle and methane emissions………..

2.) Experimental protocol for measuring methane emissions in charcoal production with the objective of establishing a parametric relationship between both variables:………………………………………………………………………

1. Experimental apparatus………………………………………………………...
2. Wood moisture content measurement…………………………………………….
3. Carbonization procedure……………………………………………………….
4. Gas sampling and analysis……………………………………………………..
5. Mass balance…………………………………………………………………...
6. Determining the relationship between methane emissions and carbonization gravimetric yield……………………………………………………………………..
7. Final report……………………………………………………………………..

INTRODUCTION

The objective of this document is to provide a step-wise approach for the implementation of applied carbonization research, aimed at establishing a relationship between methane emissions and carbonization gravimetric yield (mass of charcoal resulting from mass of wood). This experimental protocol is draws 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. By means of such a research, it has been possible to scientifically unveil and to statistically measure the negative relationship between gravimetric yield and methane emissions. The conclusion of the research pointed to substantial opportunities of reducing methane emissions, by improving the efficiency of the carbonization process, with the implementation of physical and operational changes within charcoal manufacturing units.

Before this protocol, there was no specified method or norm that considered the gas sampling and analysis from carbonization kilns off gases and, especially, from the surface brick kiln.. The previous tests for methane evaluation taken by Smith et al (www.energy.demon.nl/GHG/kilns.htm) have only evaluated the average time-dependent content of methane in the gas involved during the whole carbonization process.

In Smith's measurements small off gas samples have been collected and removed from the openings of the kilns during the carbonization cycle at certain time intervals. With the estimation of the total mass input and output of the solids produced in a complete cycle, they calculated the emission factors for the products of incomplete combustion. It has not provided the total mass of methane emitted during the carbonization process, nor did it provide any hints and means as to how the emissions could be reduced by kiln and operational processing improvements.

The rate of methane emissions is a function of the rate of mass loss and both are time, temperature, and air input dependent. Within the measurements conducted by Smith et al, the wood moisture measurement technique was not well explained and the quality of the charcoal produced did not receive the necessary attention. Wood moisture and total fixed carbon (and elemental carbon) in the final charcoal content play a major role in the conversion factor of dry wood into charcoal and, therefore, into the methane emissions factor.

Therefore, this experimental protocol becomes necessary to conduct precise mass loss measurements, in order to close, as accurately possible, the mass balance for the carbonization process, especially the amount of CH_4 emitted by ton of charcoal produced. Even though this protocol is based on brick-based carbonization kilns, it can also be applicable to other types of kilns, provided that the same measurement, weighing, gas analysis and mass balance requirements be adequately observed.

In Section 1, the main features of traditional carbonization processes are presented, as to provide an example and introductory basis for the applied carbonization research on methane emissions and gravimetric yield. In turn, Section 2 provides a step-wise approach to guide the implementation of the research activities necessary to establish and measure the relationship between both variables, within a given organization.

1.) THE OVERALL BEHAVIOUR OF CARBONIZATION CYCLE AND METHANE EMISSIONS

The transformation of wood into charcoal, by means of carbonization is a heterogeneous process. There are different phases, each one with its own characteristics. These phases occur at different processing times and the emissions in each phase are very distinct (mass released, volume and gas composition) and vary during the carbonization process. As an example, the following phases illustrate the usual behaviour of the carbonization process in brick-based kilns:

Ignition Period: Normally it takes 6 to 12 hours to ignite the kiln (from the air inlets at the kiln top) and, during this time interval, the ignition chamber and the small air inlet at the door bottom of the kiln is maintained in its higher opening capacity. Once the ignition is completed, the top air inlets are gradually closed. From this moment on, only the small air inlet at the bottom of the kiln door and the chimney are maintained open. At this moment, the carbonization process is beginning.

Carbonization Period: The carbonization process begins when the temperature reaches 180 °C and above (wood distillation). Within the previous a range of temperatures (from 25 to 180 °C) the moisture represents nearly all the mass lost. During the carbonization period, most of the exothermic heat is released, higher temperatures are reached and significant amounts of methane are produced. The temperature plays a major role in the process and the control of such variable is key to the efficiency of any carbonization process, providing the underlying basis for the implementation of efficiency improvements.

Cooling Period: The off gases color and small flows after the two-three day carbonization period define the moment to completely close the kiln. With the kiln fully sealed, the cooling period begins and may last up to three days. When the temperature inside the kiln is low, the kiln is open, and the charcoal is withdrawn.

The mass loss rate varies during the carbonization cycle. The mass loss increases with increasing carbonization temperature (also carbonization time). The Figure 1 shows an example of thermal gravimetric profile for six Eucalyptus types measured by lab scale.

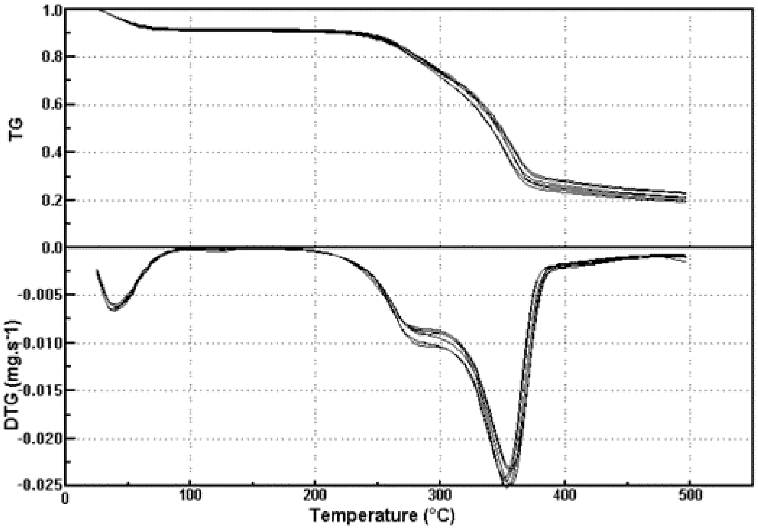

Figure 1: Eucalyptus Wood Pyrolysis (Pinheiro, P.C.C. et al, 2001)

Methane Emissions in the Carbonization Cycle: The figure 2 shows a gas analysis profile as a function of the carbonization temperature measured in a laboratory kiln without the participation of partial combustion from the air oxygen. Note that the CH_4 emissions occur at higher temperatures. Due to lack of proper process control measures most traditional carbonization processes undergo significant amounts of air infiltration during the whole cycle, thus increasing the temperature and methane formation. The rate of gas emissions during the carbonization process is mostly dependent on the carbonization temperature, which results from variables such as the heating rate, amount and control of air inlets, etc.

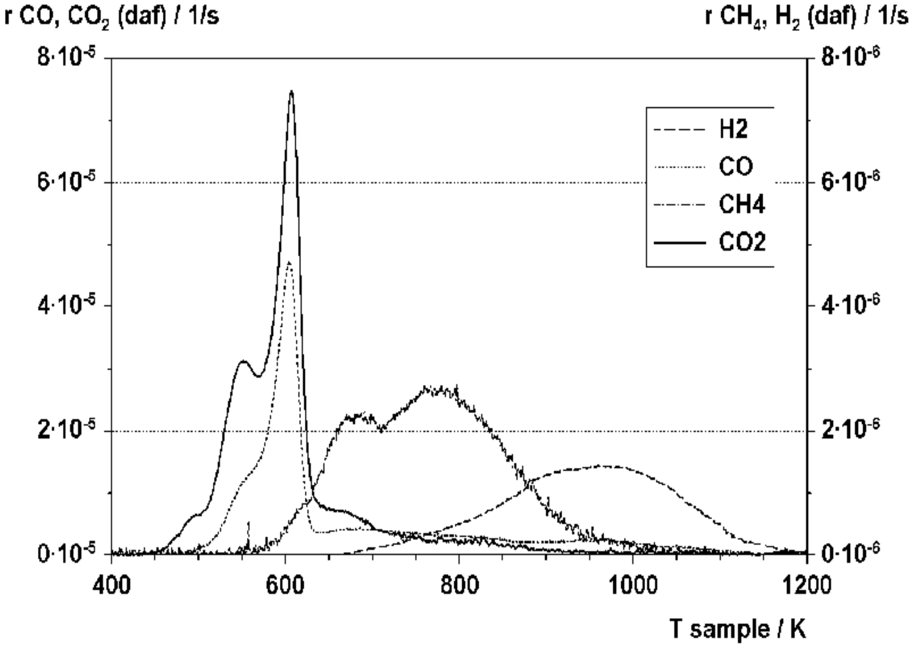

Figure 2: Aspen Pyrolysis Gases (Klose, W. et al, 2000)

2.) EXPERIMENTAL PROTOCOL FOR MEASURING METHANE EMISSIONS IN CHARCOAL PRODUCTION WITH THE OBJECTIVE OF ESTABLISHING A PARAMETRIC RELATIONSHIP BETWEEN BOTH VARIABLES

1. EXPERIMENTAL APARATUS

1.1 - Wood Moisture Content

- 1.1.1 - One (1) 300mm pachymeter.
- 1.1.2 - One (1) laboratory scale capable of measuring weight variations up to 2.5 kg with precision of +/- 1.0 g.
- 1.1.3 - One (1) Drying furnace.

1.2 - Weighing and Temperature Measurement Apparatus

- 1.2.1 - One (1) Real size charcoal kiln.

1.2.2 - One (1) Industrial scale capable of measuring weight up to 5,000 kg with precision of +/- 2.0 kg.

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

1.3 - Gas Sampling

1.3.1 - One (1) constant volume peristaltic pump.

1.3.2 - One (1) water cooled gas condenser.

1.3.3 - One (1) oil filter.

1.3.4 - One (1) 100-liter-gasometer.

1.3.5 - Glass bottles or Tedlar bags.

1.4 - Gas Analysis

1.4.1 - Calibrated Gas Chromatography apparatus for CH_4, CO_2, CO, O_2, and N_2.

1.5 - Wood and Charcoal Elementary Analysis

1.5.1 - Elementary analysis of wood (C, H, O, N, S, Ash and Moisture). 1.5.2 - Elementary analysis of charcoal produced (C, H, O, N, Ash and Moisture).

1.6 - Technical Staff

1.6.1 - One (1) carbonization expert (to conduct the carbonization tests).

1.6.2 - One (1) chemistry technician (to make the measurements).

1.6.3 - One (1) team assistant.

1.6.4 - One (1) carbonization operator for each carbonization test.

2. WOOD MOISTURE CONTENT MEASUREMENT

With the use of the gravimetric method to calculate the carbonization yield, it is important to determine the moisture content of the wood logs, in addition to the wood weight. Preliminary researches have 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:

2.1 - Put the wood logs to be carbonized in a stack. The wood must come from the same sources currently used by the project entity.

2.2 - 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.

2.3 - 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.

2.4 - 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 item 2.2). Figure 3 provides an example of the sampling collection:

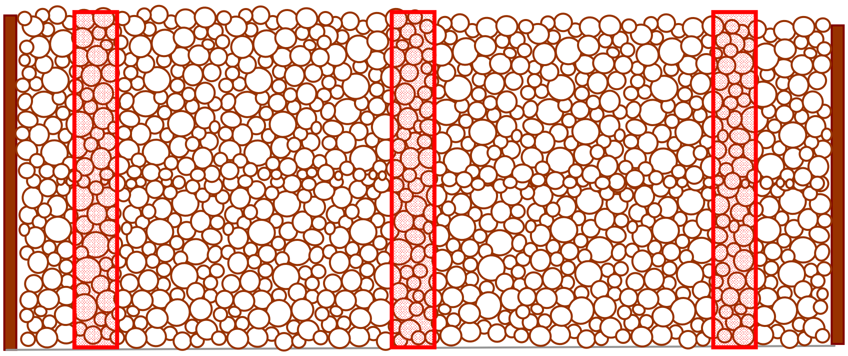

Figure 3: Example of sampling collection in a stack.

2.5- Cut a 5 to 7 cm thickness transversal slice (wood disks), removed from the point that represents 1/3 of total length of each wood log sample, starting from the extremity.

2.6 - Weigh each disk immediately on the laboratory scale and note the mass.

2.7 - Note the sample number on the wooden disk itself.

2.8 - Place the wooden disks in the oven to dry.

2.9 - Set the oven to 103±2ºC.

2.10 - Dry until they reach constant weight, after three consecutive weighing processes indicate constant weight.

2.11 - Weight the wooden disks and note the weights.

2.12 - Calculate the dry basis moisture content (W_{db}) of each disk:

$$W_{db} = \frac{\text{WET MASS - DRY MASS}}{\text{DRY MASS}} \quad \text{(kg/kg)}$$

2.13 - Calculate the mean moisture content of each diameter class.

2.14 - 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.

3. CARBONIZATION PROCEDURE

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. This is expected to express the actual efficiency observed in the organization, that is, the status of the carbonization process before the adoption of any efficiency improvements enabled by the project activity.

However, in order to ensure conservativeness in the establishment of the parametric relationship between methane emissions and gravimetric yield and, therefore, in the estimation of emission reductions, this experimental protocol also requires the incorporation of carbonization tests that encompass efficiency improvements, in comparison with the actual situation of the project entity. This requirement provides extreme conservativeness in the assessment of methane emission reductions, since it will result in a substantial inclusion of lower emissions - in comparison to the project entity's actual practices (basis for the baseline scenario) - in the regression equation to be established under the parameters of sub-item 7 and of Appendix 2.

The nature and type of improvements adopted in each case may vary, as more knowledge is developed. Considering intellectual property rights and the EB Guidance on information disclosure, project developers shall present a summary of the adopted improvements in the final report of the implementation of this experimental protocol (sub-item 8).

Having in mind the above, the following procedures shall be followed for the carbonization tests:

3.1 - Set up the scale for zero weight for taring purposes.3.2 – Measure the weight of the wood immediately before loading the kiln (**M_{Wood}**).

3.2 - Load carefully the kiln with the wood.

3.3 - Close and seal the kiln's door.

3.4 - Ignite the kiln.

3.5 - Conduct at least 10carbonization procedures, distributed within the following manner:

3.4.1 - Conduct at least four carbonization procedures in accordance with physical and operational features currently adopted by the project entity. In case more than four tests are conducted, they must represent at least one third of the total carbonization procedures to be considered in the regression analysis.

3.4.2 - Conduct at least six carbonization procedures that encompass efficiency improvements in comparison to the actual basis of the project entity. In case more than six tests are conducted, they must represent at least two thirds of the total carbonization procedures to be considered in the regression analysis.

Note: The carbonization practice is very much dependent on human sensitiveness and experience. Therefore, since a charcoal manufacturing company is likely to have several carbonization units, each one of the carbonization tests performed in the test kiln has to be managed by a different carbonization operator.

3.6 - Keep track of temperature measurements, off gas removals, measurement and sampling of the condensable gases (see separate item 4 for gas sampling), and gaseous fractions generated in each hour.

3.7 - Seal the kiln at the end of carbonization process,.

3.8 - Stop the gas sampling procedure.

3.9 - Wait for natural cooling.

3.10 - Open the kiln.

3.11 - Take off the charcoal.

3.12 - Measure the charcoal weight immediately after unloading the kiln ($\mathbf{M_{Charcoal}}$).

3.13 - Take off the brands.

3.14 - Measure the weight of brands immediately after unloading ($\mathbf{M_{Brand}}$).

4. GAS SAMPLING AND ANALYSIS

The high variation in the temperature, composition and density of the volatile materials released[4] makes 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, in view of determining its methane content.

Therefore, in order to evaluate the specific mass of methane emissions, 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. It is important to remind that the carbonization tests will also enable a precise charcoal-to-dry wood yield measurement, another critical factor in defining the CH_4 emission and charcoal-to-wood yield.

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

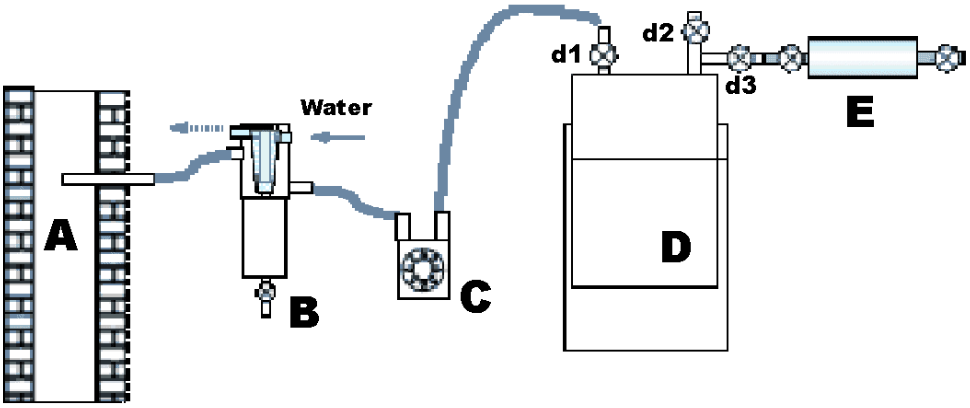

Figure 4: Schematic view of sampling equipment

Figure 4 offers 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.

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[4] Volatiles = [water vapor + (pyroligneous liquor ~ wood tar + acetic water) + non-condensable gases].

4.1 - Set up:

- 4.1.1 - Connect the stainless steel tip in the central point of the chimney's transversal section before the beginning of the carbonization procedure.
- 4.1.2 - Connect all collecting gas sample system.
- 4.1.3 - Close the gasometer valves d1 and d3 open the valves d2 to purge the gasometer
- 4.1.4 - Close all gasometer valves.
- 4.1.5 - Set the peristaltic pump to 1.3 to 1.5 liters per minute.

4.2 - Purge the gas after one hour from the beginning of carbonization

- 4.2.1 - Open the gasometer valves d1 and d2
- 4.2.2 - Turn on the pump for 1.0 minute to purge the gas system.
- 4.2.3 - Close all gasometer valves.
- 4.2.4 - Purge and close the condenser.

4.3 - Gas sampling

- 4.3.1 - Turn on the constant volume peristaltic pump for 10 minutes at every hour.
- 4.3.2 - Take off a gas sample for analysis within each six-hour time interval (after six gas samples):
  - 4.3.2.1 - Drain the condenser.
  - 4.3.2.2 - Measure the mass of condensed liquid (wood tar and pyroligneous water) $M_{cond.}$.
  - 4.3.2.3 - Measure carefully the volume and temperature of the gasometer ($V_{gasometer}$, $T_{gasometer}$).
  - 4.3.2.4 - Connect the glass bottle or Tedlar bag to valve d3.
  - 4.3.2.5 - Open the valve d3 to fill the glass bottle or Tedlar bag.
  - 4.3.2.6 - Close the valve d3.
  - 4.3.2.7 - Connect a second glass bottle or Tedlar bag to valve d3.
  - 4.3.2.8 - Open the valve d3 to fill the glass bottle or Tedlar bag.
  - 4.3.2.9 - Close the valve d3.
  - 4.3.2.10 - Take note of date and time on glass bottle or Tedlar bag.
  - 4.3.2.11 -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.
  - 4.3.2.12 - Open the gasometer valve d2 to drain all gas.
  - 4.3.2.13 - Close the gasometer valve d2.

4.3.2.14 - This gas sampling procedure shall be repeated during the entire carbonization process.

4.3.2.1.5 - 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.

Note 3: Researchers may also connect an Orsat apparatus directly to valve d2 to make the CO_2, and O_2 analysis.

5. MASS BALANCE

Based on the experimental results, the mass balance to calculate the mass of methane released for each dry ton of charcoal shall be calculated. The Figure 5 illustrates the mass inputs and outputs within the experimental apparatus:

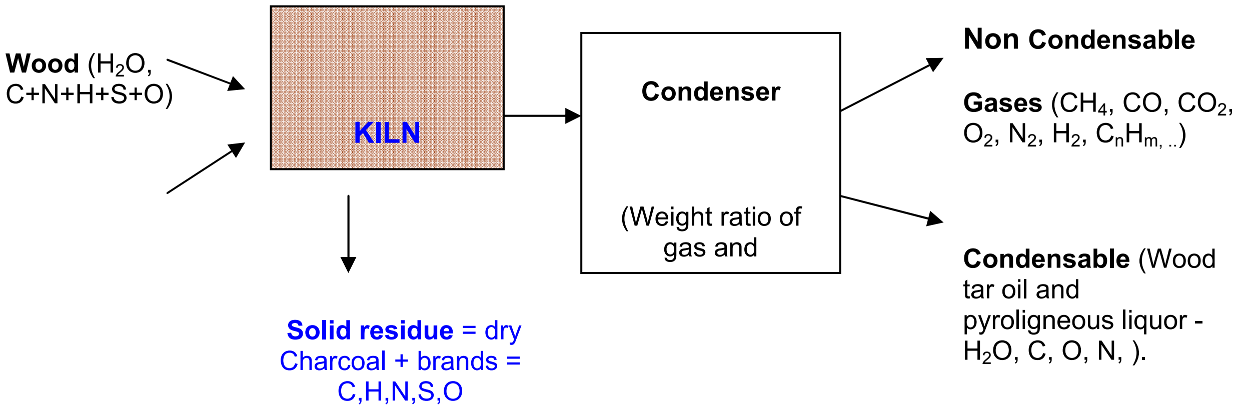

Figure 5: Major inputs and outputs of the mass balance

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 fished, 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 ($\mathbf{K_{fu}}$) can be obtained, as follows:

$\mathbf{K_{fu}}$ = 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,

$\mathbf{K_{fu\square t}}$ = [mass of condensable volatile <u>sampled</u> at time interval *t*]/ [mass of non-condensable gases <u>sampled</u> at time interval *t*].

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

[mass of condensable volatile <u>sampled</u> at time interval *t*] = a measured value at each time interval when the volatiles sample is taken from the kiln chimney. When the time interval is the total carbonization time, the ratio is the overall carbonization ratio for $\mathbf{K_{fu}}$. The volume in milliliters shall bee recorded during the experiments for each timed interval and its density shall be measured to calculate the weight.

[mass of non-condensable gases <u>sampled</u> 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 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[5] 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]

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[5] The interval could last for 20 minutes or for the whole six hours, provided a much larger gasometer is used.

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 = $\mathbf{M_{drywoo}}$) and the final product (charcoal = $\mathbf{M_{charcoal}}$).

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

5.1 - Initial Data:

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

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

5.2.1 - six-hour-interval-data:

- Mass of condensed liquid in condenser $\mathbf{M_{cond\Delta t}}$ = [kg]

- Gasometer volume (dry non-condensable gases) $\mathbf{V_{gasometer\Delta t}}$ = [m3]

- Gasometer temperature $\mathbf{T_{gasometer}}$ = [°C]

- Gasometer pressure $\mathbf{P_{gasometer}}$ = [atm]

- Gas analysis (% molar basis):

  - X_{CO2}=

  - X_{CO} =

  - X_{O2} =

  - X_{H2} =

  - X_{N2} =

  - X_{CH4} =

5.2.2 - six-hour-interval-calculations:

5.2.2.1 - Specific mass of gasometer dry non-condensable gases (NTP) =

$$\rho_{gas} = (44/0.224).X_{CO2} + (28/0.224).X_{CO} + (32/0.224).X_{O2} + (2/0.224).X_{H2} + (22/0.224) + (28/0.224).X_{N2} + (16/0.224).X_{CH4} \quad \text{[kg gas/m3 gas]}$$

5.2.2.2 - Gasometer mass of dry non-condensable gases

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

5.2.2.3 - Mean 6 hours Methane mass fraction gas content:

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

5.2.2.4 - Mean 6 hours Nitrogen mass fraction gas content:

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

5.3 - Final Mass Balance:

5.3.1 - Total gasometer mass of dry non-condensable gases $\mathbf{M_{gas} = \Sigma\ M_{cond\Delta t}}$ [kg]

5.3.2 - Total Mass of condensed liquid in condenser $\mathbf{M_{cond} = \Sigma\ M_{gas\Delta t}}$ [kg]

5.3.3 - Ratio of condensed and non-condensed effluents $\mathbf{K_{FU}} = \mathbf{M_{cond} / M_{gas}} =$ [kg/kg]

5.3.4 - Mean Methane mass fraction content of carbonization run

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

5.3.5 - Mean Nitrogen mass fraction content of carbonization run

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

5.3.6 - Mass of dry non-condensed effluents of carbonization run

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

5.3.7 - Methane emission of carbonization run

$\mathbf{M_{CH4} = P_{CH4}\ .\ M_{NC}}$ [CH_4 kg/run]

5.3.8 - Carbonization Gravimetric Yield

$\mathbf{Y = M_{Charcoal} / (M_{DryWood} - M_{Brand})}$ [kg charcoal / kg dry wood]

5.3.9 - Specific Methane emission

$\mathbf{EF_{CH4} = M_{CH4} / M_{Charcoal}}$ [CH_4 kg / charcoal kg]

6. DETERMINING THE RELATIONSHIP BETWEEN METHANE EMISSIONS AND CARBONIZATION GRAVIMETRIC YIELD

Based on the experimental results of the proposed protocol and considering the obtained data on methane emissions and carbonization gravimetric yield, the project developers shall establish a best-fit regression equation in order to determine the relationship between both variables. The regression equation must comply with all statistical provisions and tests outlined in Appendix 2. Regression analyses that do not comply with Appendix 2 shall not be valid under this methodology.

Special attention shall be devoted to the minimum amount of carbonization procedures undertaken within the actual practices of the project entity, i.e. higher emissions (1/3 of the tests) and the implementation of efficiency improvements, i.e. lower emissions (2/3 of the tests), as per Section 3.3 of this protocol.

This provision ensures that the lower emissions resulting from the efficiency improvements (improved gravimetric yields) are incorporated in the establishment of the equation and thus, in the assessement of methane emission, even though, by definition, the actual emissions of a given organization refers to less efficient carbonization processes in comparison with the ones enabled by the project activity.

Therefore, the establishment of the regression equation leads to a highly conservative estimation of methane emission reductions.

7. FINAL REPORT

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.

Appendix 2: Statistical analysis of regression models of methane emissions and carbonization yield

This appendix is to provide adequate statistical parameters for the assessment of regression models used to study the relationship between the emissions of methane and carbonization gravimetric yield, in accordance with the technical parameters outlined in the experimental protocol presented in Appendix 1. As such, it provides statistically valid references for the evaluation of the quality of the estimated regression models, verifying the "goodness-of-fit" of its adjustment to the empirical data, as well as the validity of the assumptions of the regression model for a given project activity.

1. INTRODUCTION AND ESTIMATE OF MODEL PARAMETERS

In order to assess the quality of the relationship between carbonization gravimetric yield and methane emissions, and to ensure that methane emissions are conservatively estimated, the regression tests herein outlined shall be strictly followed. Regression equations that have been established in accordance with the experimental protocol (Appendix 1) and that comply with the proposed tests are deemed to be adequately conservative for the estimation of methane emissions.

Considering the main technical references and guidance presented in Appendix 1, linear or non-linear best fit regression may be used to estimate the parameters that characterize the law relating the variables "Methane emissions" and "Charcoal Yield". The latter shall be considered the independent variable (predictor) and the former as the dependent variable (result). The statistical tests presented below are applicable to both sorts of regression models.

The method adopted to estimate the adjusted line intercept and the regression coefficient, namely β_0 e β_1, shall be the Least Squares Procedure (LSP) which consists of finding the estimates $\hat{\beta}_0$ e $\hat{\beta}_1$ that minimize the sum of the squares of the squares of the differences between the estimate ($\hat{Y}$) and the value actually observed (*Y*) for the dependent variable.

It is possible to demonstrate that these least squares estimates are obtained from expressions (1) and (2).

$$\hat{\beta}_1 = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sum_{i=1}^{n}(X_i - \overline{X})^2} = \frac{S_{XY}}{S_{XX}} \qquad \textbf{(1)}$$

$$\hat{\beta}_0 = \overline{Y} - \beta_1 \overline{X} \qquad \textbf{(2)}$$

The following models provide examples of likely regressions resulting from the experimental protocol presented in Appendix 1:

Simple linear regression:	$Y = \beta_0 + \beta_1 X + \varepsilon$	*(1.1)*
Exponential Regression:	$Y = \beta_0 + (\beta_1)^X + \varepsilon$	*(1.2)*
Logarithmical Regression:	$LogY = \beta_0 + \beta_1 X + \varepsilon$	*(1.3)*
Squared Regression:	$Y = \beta_0 + \beta_1 X_1 + \beta_2 (X_2)^2 + \varepsilon$	*(1.4)*

With:
Y – dependent variable (methane emissions);
X – independent variable (carbonization gravimetric yield);
β_1 - slope (regression coefficient);
β_0 - adjusted line intercept;
ε - Random error that is the part of Y that is not explained by X.

2. *TESTING THE ASSUMPTIONS OF THE REGRESSION MODEL*

Associated with the linear or non-linear regression model are a set of assumptions which are considered as valid in principle, but which should be checked later.

These assumptions refer to random error involved in the construction of the model and can be presented in the following manner:

(1) The errors are random independent variables and are identically distributed (not correlated);

(2) The mean of the random errors is zero and the variance is constant and unknown (homoscedasticity);

(3) The errors follow Normal distribution.

In those cases where the assumptions 2 and 3 (homoscedasticity and normal distribution) do not hold, the transformation in y shall be used as a corrective measure. As such, this methodology recommends the use of the power transformation y^λ, where λ is a parameter to be determined (for example, if λ=0,5 $\sqrt{y}$ shall be used as the response variable).

In synthesis, provided that the eventual non-normal distributions be adjusted in accordance with the proposed transformation test, the basic assumptions associated with the regression model can be defined as: *errors are iid* $N(0, \sigma^2)$.

Although the least squares estimates can be obtained irregardless of the distribution of the variable involved, the validity of these three assumptions[6] is essential for the derivation of the properties of the estimators and for the construction of confidence intervals and hypothesis tests, which are used to test the meaning of the parameters in question β_0 and β_1.

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[6] Non-normal distribution does not undermine the validity of the model, provided that the power transformation y^λ be applied, as explained above.

The residual $\hat{e}_i = Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_i$ is the quantity that the regression equation cannot explain and is due to the effect of external or omitted variables and to the natural variability between sampling units.

As such, residual analysis is a fundamental stage of the study and analysis of any regression model. Moreover, it is also useful to reveal the presence of extreme observations known as "outliers" and which impact on the estimated parameters.

The most common form to do residual analysis is through the construction of some graphs, as recommended by this methodology below:

(1) Graph of residuals versus the order of the observations: used to verify whether the errors are not correlated;

(2) Graph of the residuals versus adjusted values: used to verify whether the errors have constant variance;

(3) Graph of normal probability: used together with a test of normality, to verify whether the errors follow a Normal distribution.

By constructing the first two graphs mentioned, it is expected that the residuals are randomly distributed around zero that is that they are located approximately in a horizontal range centered around $e_i=0$.

From the normal probability graph it is expected that the residuals are located close to the plotted line and that the probability of significance (p-value) associated with the test of normalcy is greater than 0.05. Substantial distances from a straight line indicate that the distribution is not normal and, in this case, the p-value of the test will be lower than the 0.05 significance level.

After carrying out the residual analysis and validating all the assumptions for the adjustment of the model, the adjusted regression line can be considered adequate.

3. VERIFICATION OF THE EXISTENCE OF EXTREME POINTS (OUTLIERS)

The occurrence of "aberrant" points as compared to the configuration plotted by the majority of the points that represent the observed results can strongly affect the estimated parameters for the regression line. For this reason, adequate statistics such as Cook's Distance and DFFITS shall be used to verify whether or not points of this nature exist in the model.

4. INFERENCE ABOUT THE MODEL PARAMETERS

After estimating the regression model parameters, significance tests of these parameters shall be done in order to verify whether the sample used contains sufficient evidence to affirm that the relationship between the variables effectively exists in the population as a whole.

5. ASSESSMENT OF THE COEFFICIENTS OF CORRELATION AND DETERMINATION

It is extremely important to notify and quantify the correlation existing between methane emissions and carbonization gravimetric yield, as well as to identify the manner in which one variable relates to the other. The coefficient of correlation *R* determines the strength of the relationship between two given variables. The coefficient's sign indicates the direction of such a relationship, i.e. negative signs indicate that the variables change in opposite directions (X increases, as Y decreases, or vice-versa) and positive signs indicate that the variables change in the same direction (X increases, as Y also increases), For linear regressions the Pearson coefficient shall be presented, whereas for non-linear regressions project developers shall use statistically valid coefficients, which comply with the regression model at stake (e.g. logarithmical, exponential, etc.).

The coefficient of determination, R^2 is the percentage of the variance of *Y* that is explained by the regression line. This measurement can be interpreted as the proportion of variance present in the observations of the dependent variable *Y*. which is explained by the independent variable *X* in the regression model adjusted to the data.

This measurement is contained in the interval $0 \leq R^2 \leq 1$ and is defined in *(3)*, and the closer it is to the higher interval, the more the adjusted model explains the data.

$$R^2 = \frac{\sum_{i=1}^{n}(\hat{Y}_i - \overline{Y})^2}{\sum_{i=1}^{n}(Y_i - \overline{Y})^2} \qquad \textbf{(3)}$$

The relationship between methane emissions and carbonization yield shall produce an R^2 of at least 0.7.

Appendix 3: Mitigation of methane emissions in the wood carbonization activity for charcoal production

PROTOCOL FOR CARBONIZATION GRAVIMETRIC YIELD CALCULATION

Section A: Determination of Wood Moisture

Section B: Determination of Charcoal Moisture

Section C: Determination of Carbonization Gravimetric Yield on dry basis

A. Operational Procedures to Determine Wood Moisture

1 – Purpose

This procedure establishes the conditions for verification of wood moisture at the plot level.

2 – Responsibility

The Supervisor/ Foreman are responsible for the operations.

3 – Description of the Activities

3.1 – Definitions

For this procedure, the following definition shall apply:

Plot: Unit of silvicultural area.

3.2 – Equipment

Scale;

Oven;

Chainsaw;

Measuring Tape

3.3 – Individual Protection Equipment (IPE)

Chainsaw operator: uniform, gloves, boots (steel toe), earpiece, helmet, visor or glasses.

3.4 – Accomplishment Period

3.4.1 – Minimum 60 days after harvesting.

3.5 – Operational Procedure

3.5.1 – Get samples of diameters that represent diameter distribution of the plot;

3.5.2 – Choose 70 pieces of wood in proportionately to the diameter classes;

3.5.3 – Cut a 2 to 5cm thick disk from the middle of 1/3 of the length of each piece of wood;

3.5.4 – Weigh freshly cut wood disks. The disks should have no fissures, cracks or knots.

3.5.5 – Identification of the disk with its weight and number.

3.6 – Sample Drying

3.6.1 – Set the oven at 103º (with variation around 2ºC);

3.6.2 – Put the wood disks in the oven;

3.6.3 – Dry until they reach constant weight, after three constant weighing processes;

3.6.4 – Weigh the disks and take note of the weight;

3.6.5 – Calculate the moisture percentage, using the following formula:

$$\%U = \frac{\text{humid weight} - \text{dry weight}}{\text{Dry weight}} \times 100$$

B. Operational Procedures for the Determination of Charcoal Moisture

1 – Purpose:

This procedure establishes the conditions to check charcoal moisture in carbonization units.

2 – RESPONSIBILITY:

Charcoal Supervisor, Carbonization Unit Foreman, and Research Department Assistant.

3 – DESCRIPTION OF THE ACTIVITIES:

3.1 - DEFINITIONS

Bulk charcoal – charcoal discharged in the units' patios.

3.2 - EQUIPMENTS:

- Scale
- Oven
- 200 liters barrel
- Spade
- Sample divisor device
- Sieve (sieve kit)
- $2m^2$ plastic canvas
- Socket

3.3 – Personal Protection Equipment (PPE)

Personal Protection Equipment	**Sample Preparer**	**Research Assistant**
Uniform	X	X
Gloves		X
Boots with steel toe	X	
Respirator		X
Helmet	X	
Visor or glasses	X	
Jacket		X

3.4 - Execution Period

3.4.1 – Minimum 48 hours after the charcoal is discharged on the patio.

3.5 – Operational Procedure

3.5.1 – Get samples from different points of charcoal piles equivalent to 2kg;

3.5.2 - Use same procedure until it reaches 200 liters;

3.5.3 – Transfer the 200 liters sample to the sample divisor device table;

3.5.4 – Remove the diagonal portion for sending as sample for moisture determination;

3.5.5 – Reduce the size of sample particles and grind them manually;

3.5.6 – Mix the ground portion;

3.5.7 – Remove 2kg from the ground portion;

3.5.8 – Put in waterproof plastic bags, seal with tape and label them;

3.5.9 – Send to Research and Development Department.

3.6 – Sample's Preparation

3.6.1 – Sift in ½ and 3/8 sieve kit;

3.6.2 – Remove sample from the part retained above 3/8 until it reaches 200gr;

3.6.3 – Weigh on the scale with graduation lines of 0,01gr.

3.7 – SAMPLE'S DRYING

3.7.1 –Adapt the oven at 100ºC (variation of around 5ºC);

3.7.2 – Put the sample in the oven;

3.7.3 – Dry samples until they reach constant weight after 3 constant weightings;

3.7.4 – Weight the sample and write the weight;

3.7.5 – Calculate the moisture percentage using the following formula:

$$\%H= \frac{\text{humid weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

3.7.6 – Keep part of the sample for 01 week for counter proof.

C. Operational Procedures for the Determination of Gravimetric Yield of Carbonization Units

1 – Purpose

Establish the Methodology to verify the carbonization yield.

2 – Responsibility

Forestry Coordinator, Research and Development Team, Charcoal Foreman, Unit Foreman, Carbonizers.

3 – Description of activities

3.1 - Wood:

Weigh and measure all wood received at the Carbonization Unit

3.2 - Verification of the Wood Consumed by Carbonization:

Measure the stocks of wood in the carbonization unit (box + kilns), on the last day of each month;

Calculate the volume of wood use

Wood use = (initial stock + transport) – final stock

Convert the daily entry of wood in the carbonization unit from volume (m3) to weight (tons) on dry basis.

3.3 - Verification of the Produced Charcoal Mass

The charcoal volume and weight are verified upon delivery in the mill and packing unit;

At the end of each month, the charcoal stocks are calculated and converted from volume to weight on dry basis;

The charcoal production is estimated using the following formula:

Production = final stock + reception at the mill or packing unit – initial stock

3.4 - Gravimetric yield

Weight of charcoal produced divided by wood used for charcoal production on dry basis.

$$\text{Gravimetric yield (\%)} = \frac{\text{charcoal weight}}{\text{wood weight}} \times 100$$

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History of the document

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