Approved baseline and monitoring methodology AM0041

"Mitigation of Methane Emissions in the Wood Carbonization Activity for Charcoal Production"

I. SOURCE AND APPLICABILITY

Source

This methodology is based on the project activity "Mitigation of Methane Emissions in the Charcoal Production of Plantar, Brazil" whose baseline and monitoring methodology and project design document were prepared by RS Consultants, Statistics Department of IPEAD/UFMG - Institute of Economic, Administrative and Accounting Research of the Federal University of Minas Gerais, Plantar S/A and Carbon Finance Unit of the World Bank. For more information regarding the proposal and its consideration by the Executive Board please refer to case NM0110-rev: "Mitigation of Methane Emissions in the Wood Carbonization Activity for Charcoal Production" on http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html

This methodology also refers to the latest version of the *"Tool for the demonstration and assessment of additionality"*.[1]

Selected approach from paragraph 48 of the CDM modalities and procedures

"Existing actual or historical emissions, as applicable"

Applicability

The methodology is applicable under the following conditions:

- Emission reductions are achieved through the adoption of technologies and processes for improved kiln design and operations, thereby replacing the existing kilns by newer design, that avoid or diminish the production of methane emissions in the carbonization process.
- Local regulation does not require controlling methane emissions in charcoal production or is less stringent than the project controls or laws/regulations exist for mandating the project technology but the laws/regulations enforcement is not strong enough to ensure the widespread compliance. If such laws/regulations exist, the project activity is considered additional and shall receive credit only if it is demonstrated that there is widespread non-compliance with the regulation. The compliance rate shall be monitored on an annual basis. The evidence of non-compliance shall be based on data from the control group, set up as per this methodology, and/or data on legal action and enforcement mechanisms implemented under the prevailing regulation. The relevant laws and regulations are considered enforced if more than 50% of the charcoal production activities comply with the relevant laws and regulations. Other registered CDM projects are to be included in the analysis if the CDM has been used in more than 50% of the cases where the legislation or regulation has been enforced.

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[1] Please refer to: < http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html>

- Where it is possible to monitor and measure carbonization gravimetric yield (mass of charcoal over mass of wood) in the charcoal production process and apply the technical and statistical methods outlined under this methodology.
- 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.
- The moisture content of the wood and charcoal can be measured and monitored accurately as per the methods and procedures outlined in this methodology.
- The emissions reductions credited are limited to the existing rated capacity of carbonization units, where the project activity is implemented, using pre-project technology.
- 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.

Control group is defined as charcoal production companies, excluding the projects implemented under the CDM, in the region where the project is located. The region of the control group is defined as the geographic area around the project activity that has similar legal compliance requirements as for the project activity. The production capacity of the charcoal production companies included in the control group should represent at least 20% of the total production in the region and should include at least 10 charcoal production companies. In case the legal compliance requirements for all provinces in the country is similar, the production capacity of the charcoal production companies included in the control group should represent at least 20% of the total production in the country and should include at least 10 charcoal production companies.

II. BASELINE METHODOLOGY

Project boundary

The spatial extent of the project boundary is the area of the carbonization units that use the improved technologies and processes described in the project activity. A carbonization unit typically comprises a group of several charcoal kilns. The DOE shall verify the number of carbonization units included in the project activity at validation based on record of the project boundary and location of carbonization units in accordance with the monitoring plan.

Only methane (CH_4) emitted directly from charcoal production facilities, in particular the charcoal kilns, is monitored and its emissions calculated for the baseline and project scenarios, except for the provisions on leakage.

Table 1: Summary of gases and sources included in the project boundary, and justification / explanation where gases and sources are not included.

	Source	Gas	Included?	Justification / Explanation
Baseline	Carbonization Activity	CO_2	No	Sources and types of inputs are not changed in the project activity.
		CH_4	Yes	
		N_2O	No	Not applicable to the process

Project Activity	Carbonization Activity	CO_2	No	Sources and types of inputs are not changed in the project activity.
		CH_4	Yes	
		N_2O	No	Not applicable to the process

Procedure for the selection of the most plausible baseline scenario

The methodology applies the following steps to determine the baseline scenario:

Step 1. Identification of alternative scenarios to the proposed CDM project activity that is consistent with current laws and regulations.

Project participants are to identify all realistic and credible alternatives to the project activity that are consistent with current laws and regulations.

The following likely scenarios of charcoal production shall be assessed. Any other scenarios as applicable to the specific regional and project contexts could also be considered.

- Continuation of the existing carbonization practice. Continuation of existing carbonization practice may be taken in the baseline selection even if local laws/regulations exists which mandates the project technology provided that the law enforcement is not strong enough to ensure the widespread compliance. The evidence of non-compliance shall be estimated based on the procedure given in the second bullet under applicability conditions.
- Adoption of minor efficiency upgrades / refurbishments / improvements of carbonization kilns that are readily available.
- Investment in carbonization technologies and equipment that are based on sophisticated industrial processes, such as carbonization retorts.
- Development and adoption of technology or process innovations or improvements that limit methane emissions from kilns.
- Project activity implemented as a non-CDM project.

The alternatives to the project activity shall be in compliance with all applicable legal and regulatory requirements - taking into account EB decisions with respect to national and/or sectoral policies and regulations in determining a baseline scenario[2] - even if these laws and regulations have objectives other than GHG reductions, e.g. to mitigate local air pollution.

Step 2. Barrier analysis to eliminate alternatives to the project activity that face prohibitive barriers

Establish a complete list of barriers that would prevent alternative scenarios to occur in the absence of the CDM, using the guidance in Step 3 of the latest version of the "*Tool for the demonstration and assessment of additionality*".

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[2] Annex 3 of the 22nd EB meeting report: "Clarifications on the treatment of national and/or sectoral policies and regulations (paragraph 45(e)) of the CDM Modalities and Procedures) in determining a baseline scenario (version 2)"

Since the proposed project activity not being registered as a CDM project activity shall be one of the considered alternatives, any barrier that may prevent the project activity to occur shall be included in that list. Show which alternatives are prevented by at least one of the barriers previously identified and eliminate those alternatives from further consideration. All alternatives shall be compared to the same set of barriers.

If there is only one scenario alternative that is not prevented by any barrier, then this scenario alternative is identified as the baseline scenario.

Where more than one credible and plausible alternative remains, project participants shall, as a conservative assumption, use the alternative baseline scenario that results in the lowest baseline emissions as the most likely baseline scenario, or conduct an investment analysis (Step 3).

Step 3. Investments analysis (optional)

Conduct an investment analysis, consistent with the guidance in Step 2 of the latest version of the "*Tool for the demonstration and assessment of additionality*". The economically most attractive alternative is deemed as the most plausible baseline scenario.

NOTE: The methodology is only applicable if the baseline identified is the historical or the existing charcoal production practices.

Additionality

Additionality shall be demonstrated using the latest version of the *"Tool for the demonstration and assessment of additionality"* that is available on the UNFCCC web site with further guidance on its use as provided below.

Step 1: Identification of alternatives to the project activity consistent with current laws and regulations

The alternatives to be identified under this step should be the same alternative scenarios that are considered in determining the baseline scenario. The proposed project activity and the baseline scenario must be part of the list of alternatives.

All alternatives must comply with current laws and regulations unless these laws/regulations are not enforced and widespread non-compliance is observed.

If the project activity is mandated by laws or regulation, then the project activity is not additional. Show that, based on an examination of current practice in the country or region in which the law or regulation applies, those applicable legal or regulatory requirements are systematically not enforced and that non-compliance with those requirements is widespread in the country. A compliance threshold of 50% for the relevant laws and regulations is prescribed for the crediting period. Other registered CDM projects are to be included in the analysis if the CDM has been used in more than 50% of the cases where the legislation or regulation has been enforced. Documented evidence pertaining to the data and information on compliance and prevailing charcoal making technologies and production practices in the region or country shall be used to demonstrate enforcement/non-enforcement. If the information on the compliance of laws and regulation is not available, survey of charcoal production units in the region or country where the laws/regulations are applicable shall be conducted to obtain the information.

Step 2: Investment analysis

Investment analysis shall be used in situations where the charcoal production in the region[3] :
(i) is not dominated by traditional practices; and
(ii) charcoal pricing schemes enable generation of additional revenue from the implementation of the project activity (other than the potential CERs income).

In case the investment analysis is not chosen, the justification for the same shall be provided in the CDM-PDD.

Step 3: Barrier analysis

The typical barriers that are likely to impede the development, adoption and maintenance of innovative carbonization practices are illustrated below:

i) Investment barriers
  - The cost associated with the development and adoption of innovative technology and processes is too high (not considering the CDM incentive).
  - Return on investment for the improvements in carbonization efficiency and emission reductions in the charcoal industry is too low in comparison to the investment needs.
  - Short and long-term resource commitments to technological improvements are low to non-existent in a traditionally low profit industry such as charcoal production, further limiting the innovation.
  - High real or perceived risk involved in the development and adoption of new technology is a constraint for investments in technological or process innovations.

ii) Barriers due to prevailing practice.
  - The lack of regulation or best practice to reduce methane emissions from kilns limits the motivation of the project entity to make changes to the prevailing production process.
  - Lack of industry-wide emphasis on technological improvements limits the peer pressure to undertake the improvements.

iii) Technical/operational barriers.
  - The first-of-a-kind nature of the project highlights the technical and operational concerns, especially if the technology and process modifications have not been implemented elsewhere.
  - Information, implementation, and production risks associated with unfamiliar technologies contribute to risk aversion and inhibit its adoption.
  - Historically low-skilled human labor makes it difficult to introduce technological and process innovations and transfer of skills, especially where large trained labor may be needed to run large number of charcoal kilns using sophisticated processes.

iv) Other barriers, as applicable.
  - Lack of awareness with new technologies makes it a low priority for senior management.

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[3] As defined in the applicability section.

- Legal, regulatory, and other barriers may limit the implementation of the project scenario.

Step 4: Common practice analysis

The common practice analysis shall be undertaken using documented information on the prevailing charcoal making technologies in use in the region or in the country where the project is located. If such information is not readily available, a survey of charcoal production facilities shall be conducted to obtain information on production technologies and processes commonly applied. The common practice threshold shall be applied to the control group selected prior to the start of the project and at each renewal of the crediting period.

If more than 33%[4] of the control group uses an improved carbonization process that is similar to the project activity, then the project is not additional. If less than 33% of the control group uses an improved carbonization process that is similar to the project activity, then proceed to step 5. The designated operational entity shall verify the documented evidence for the purpose of common practice evaluation.

Step 5: Impact of CDM registration

The list provided in the additionality tool of the possible impact of the CDM registration on the project activity shall also include the awareness raising effect of the CDM and the associated incentive to invest in research, development and innovation.

Baseline emissions

The estimation of baseline emissions is done employing the three steps, described below:

Step 1: Adoption of the regression equation expressing statistical relationship between methane emissions and carbonization gravimetric yield:

The estimated relation between methane emissions and carbonization gravimetric yield (CGE) shall be based on experimental measurement and statistical analysis. The relation can be based on either:

(i) data collected as per the implementation of the carbonization research protocol, as described in Appendix 1, and following the statistical requirements presented in Appendix 2; or

(ii) Previously established statistical relationships and the applicable regression equations (e.g. based on the previous application of the same or the similar protocols to other project activities), provided such parameters are applicable to the circumstances of project participants and comply with the applicability conditions of this methodology and the statistical requirements in Appendix 2.

An independent third party shall implement the carbonization research and review the statistical procedures followed in the estimation process. The report on the choice of the approach and its justification, including report of implementation of Appendix 1 and Appendix 2 shall be presented and attached to the CDM-PDD. The report shall include all calculations, and the supporting documentation on the carbonization process improvements implemented. All documentation and references used for the

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[4] This threshold is referenced from Everett M. Rogers, 2003, Diffusion of Innovations, Fifth Edition, Simon & Schuster Inc. This value is subject to further guidance from the CDM-EB and sets no precedent.

determination of the regression equation must be presented to the Designated Operational Entity at the time of validation.

The following steps are used to establish a statistical relationship, which are further elaborated in Appendix 1:

1) Set up the experimental apparatus, including a real size carbonization kiln, an industrial scale, thermometers and gas collectors in order to enable mass balance analysis.
2) Run several charcoal manufacturing processes (carbonization processes) that reflect not only the actual practices undertaken by the project entity but also improved processes that demonstrate lower emissions, including the project activity technology, as per the terms defined in Appendix 1.
3) Document all input and output data, i.e., wood and charcoal weights on dry basis, and collect gas samples throughout the carbonization process. The gas samples shall be analyzed in certified laboratories for chromatographic analyses.
4) Conduct regression analysis and establish a linear or non-linear regression equation that best demonstrates the relationship between the methane emissions and the gravimetric yield, consistent with the statistical procedure presented in Appendix 2, the EB guidance on the use of regression in methodologies[5] and model selection procedure outlined below.
5) Record the technological changes required to improve the carbonization process.

Model selection for estimated relationship

The selection of the model (linear or non-linear) relating the methane emission and gravimetric yield shall be done as per the following criteria:

(i) Percent explained variance (R^2) ≥ 70%.

The percent explained variance or coefficient of determination (R^2) of the regression model shall be equal to or higher than 70% in order to establish the statistically significant relationship between methane emissions and carbonization gravimetric yield.

(ii) $CV(\beta_i) \leq 5\%$; $i = 1, 2, \ldots \kappa$

Where:

CV is the coefficient of variation
β_i are the coefficients of the regression model

The CV (β_i) is a stability measure of coefficients of the variables included in the model. In order to estimate CV (βi) in the criterion (ii) above, the methodology should use a *Jacknife procedure*[6] on the existing data sample.

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[5] Annex 7 of the 21st EB meeting report: "Recommendations on multiple regression analysis to estimate baseline emissions or project emissions "

[6] Jacknife is a statistical procedure used to test the robustness of regression coefficients. It facilitates the selection of the model based on the variability in regression coefficients. The procedure involves the iterative estimation of regression models by dropping one pair of values from the sample data points in order to identify the robust regression model that best explains the relationship between dependent and independent variables.

The regression equation shall be used to estimate the baseline emissions, as per the steps outlined below.

Mass of charcoal, methane emissions, time interval and location characteristics

The mass of methane emissions per mass of charcoal is a function of carbonization process and is not dependent on the time interval or the location of the production. The physical apparatus used in the carbonization process (e.g. carbonization kilns, gas bottles, scales, pipes and tubes etc.) is not affected by the time interval and location and the baseline and project scenario operate under similar time and location characteristics. Moreover, this methodology is based on the ex-post estimation of the baseline emissions, based on the baseline emissions factor applied to the same amount of charcoal produced under the project. Thus, it maintains the common time intervals for comparing the baseline and the project emissions and thereby avoids differences in the treatment of time under both scenarios.

Step 2: Calculation of the baseline emission factor.

The baseline emission factor shall be calculated as per the regression equation established in step 1. Examples of the generalized linear regression and non-linear regression equations (e.g. exponential, logarithmical) are presented in Appendix 2.

$$EF_{CH4,BL} = f\,(Y_{BL}) \qquad (1)$$

Where:

$EF_{CH4,BL}$ = Methane emission factor in the baseline scenario (tCH$_4$/tCharcoal)
Y_{BL} = Weighted average carbonization gravimetric yield in the baseline scenario (tCharcoal/tWood, dry basis), estimated as per procedure provided below

Baseline carbonization gravimetric yield

The carbonization gravimetric yield of the baseline represents the scenario that occurs prior to the implementation of the project activity and is fixed for the crediting period. The data to estimate Y_{BL} shall be collected as per the measurement protocols presented in the Appendix 3 of this methodology. The methods shall be applied by an independent third party and checked by the DOE at validation and renewal of the crediting period. In particular, the third party shall ensure that the operating conditions during the experiments corresponds to the normal operating practice of the existing kilns.

The value of Y_{BL} used in equation 1 above shall be estimated as follows:

(i) Calculate the coefficient of variation of gravimetric yield in the baseline

$$CV\,(Y_{BL,i}) = \sigma\,(Y_{BL,i}) / \mu(Y_{BL,i}) \qquad (2)$$

Where:

$CV\,(Y_{BL,i})$ = Coefficient of Variation in the baseline gravimetric yield of the sample.
$\sigma\,(Y_{BL,i})$ = Standard Deviation of the baseline gravimetric yield of the sample
$\mu(Y_{BL,i})$ = Average of the baseline gravimetric yield of the sample
$Y_{BL,i}$ = Baseline gravimetric yield of the sampled kiln i

(ii) Estimate the Y_{BL}

With the increase in the coefficient of variation, the width of 95% confidence interval around the mean carbonization yield is expected to increase, thus consideration of different quartiles of gravimetric yields of the sampled kilns under the baseline scenario leads to more conservative estimate of the baseline emissions. Based on estimated value of CV ($Y_{BL,i}$), use one the following approaches to determine the gravimetric yield of the baseline (Y_{BL}):

Approach 1 - If CV ($\mathbf{Y_{BL,i}}$)≤ 10% → take weighted average of $Y_{\mathbf{BL,i}}$ for all sample units

Approach 2 - If 10% < CV ($\mathbf{Y_{BL,i}}$)≤ 20% → take weighted average of $\mathbf{Y_{BL,i}} \geq Q_1$

Where,
Q_1 is first quartile of the distribution of $Y_{BL,i}$. The average is over all the values of $Y_{BL,i}$ that are greater than the first quartile value[7].

Approach 3 - If 20% < CV ($\mathbf{Y_{BL,i}}$)≤ 30% → take weighted average of $\mathbf{Y_{BL,i}} \geq Q_2$

Where,
Q_2 is second quartile of the distribution of $Y_{BL,i}$. The average is for all the values of $Y_{BL,i}$ that are greater than the second quartile value.

Approach 4 - If 30% < CV ($\mathbf{Y_{BL,i}}$) ≤ 40% → take weighted average of $\mathbf{Y_{BL,i}} \geq Q_3$

Where,
Q_3 is third quartile of the distribution of $Y_{BL,i}$. The average is for all the values of $Y_{BL,i}$ that are greater than the third quartile value.

Approach 5 - If CV ($\mathbf{Y_{BL,i}}$) > 40% → reject the sample

Step 3: Calculation of total baseline emissions

Baseline emissions are calculated as follows:

$$\mathrm{BE}_{\mathrm{y}} = \mathrm{EF}_{\mathrm{CH4,BL}} * GWP_{\mathrm{CH4}} * P_{\mathrm{char,y}} \tag{3}$$

Where:
BEy = Baseline emissions during the year *y* (tCO_2/yr)
$\mathbf{EF_{CH4,BL}}$ = Methane emission factor in the baseline scenario (tCH_4/tCharcoal)
$\boldsymbol{GWP_{CH4}}$ = Global warming potential of methane (tCO_2e/tCH_4)
$\boldsymbol{P_{char,y}}$ = Production of charcoal during the year y (tCharcoal/yr)

All survey data, measurements and calculations collected as part of the baseline assessment shall be recorded in a spreadsheet database and shall be verified by the Designated Operational Entity.

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[7] Quartile designates any of the values in a series dividing the distribution of the individuals in the series into four groups of equal frequency.

Project Emissions

The project emissions shall be estimated as product of project methane emission factor and project charcoal production. The project methane emission factor shall be estimated using equation 1 with the project weighted average carbonization gravimetric yield (Y_P). With the calculation of Y_P as shown below.

All measurements and calculations must be recorded in a spreadsheet database and shall be validated and subsequently verified by the Designated Operational Entity

(i) estimate the coefficient of variation of gravimetric yield in the project case

$$CV\,(\mathbf{Y_{P,i}}) = \boldsymbol{\sigma}\,(\mathbf{Y_{P,i}}) / \mu(\mathbf{Y_{P,i}}) \qquad (4)$$

Where:

CV ($Y_{P,i}$) = Coefficient of Variation in the project gravimetric yield of the sample.
σ (Y_P) = Standard Deviation of the project gravimetric yield of the sample
μ($Y_{P,i}$) = Average of the project gravimetric yield of the sample
$Y_{P,i}$ Project gravimetric yield of the sampled kiln i

(ii) Estimate the Y_P

With the increase in the coefficient of variation, the width of 95% confidence interval around the mean carbonization yield is expected to increase, thus consideration of different quartiles of gravimetric yields of the sampled kilns under the project scenario leads to more conservative estimate of the project emissions. Based on estimated value of CV (Y_P), use one the following approaches to determine the gravimetric yield of the project (Y_P):

Approach 1 - If CV ($Y_{P,i}$) $\leq$ 10% → take weighted average of all sample units

Approach 2 - If 10% < CV ($Y_{P,i}$) $\leq$ 20% → take weighted average of $Y_{P,i} \leq Q_3$

Where,
Q_3 is third quartile of the distribution of $Y_{P,i}$. The average is over all the values of $Y_{P,i}$ that are less than the third quartile value.

Approach 3 - If 20% < CV ($Y_{P,i}$) $\leq$ 30% → take weighted average of $Y_{P,i} \leq Q_2$

Where,
Q_2 is second quartile of the distribution of $Y_{P,i}$. The average is over all the values of $Y_{P,i}$ that are less than the second quartile value.

Approach 4 - If 30% < CV ($Y_{P,i}$) $\leq$ 40% → take weighted average of $Y_{P,i} \leq Q_1$

Where,
Q_1 is first quartile of the distribution of $Y_{P,i}$. The average is over all the values of $Y_{P,i}$ that are less than the first quartile value.

Approach 5 - If CV ($Y_{P,i}$) > 40% → reject the sample

Calculation of total project emissions

Project emissions are calculated as follows:

$$\mathrm{PE}_{\mathrm{y}} = \mathrm{EF}_{\mathrm{CH4,P}} * GWP_{\mathrm{CH4}} * P_{\mathrm{char,y}} \qquad \textbf{(5)}$$

Where:

PE_y = Project emissions during the year *y* (tCO_2/yr)
$\mathbf{EF_{CH4,P}}$ = Methane emission factor of the project activity (tCH_4/tCharcoal)
$\boldsymbol{GWP_{CH4}}$ = Global warming potential of methane (tCO_2e/tCH_4)
$\boldsymbol{P_{charcoal,y}}$ = Production of charcoal during year y(ton)

Leakage

Leakage from the process improvements in the carbonization activity is not likely to be a major factor for the following reasons:

- The improvements in the carbonization process are expected to reduce the methane emissions and improve the conditions of the overall charcoal production to certain extent but do not determine the existence of the charcoal production business activity *per se* as the charcoal production occurs regardless of the process improvements undertaken in the project scenario. Therefore, no net changes in the anthropogenic GHG emissions attributable to the project activity are expected to occur outside of the project boundaries.

- If new kilns are constructed for the project activity, the emissions from disposal of the old kilns shall be accounted for as leakage and, as such, an algorithm shall be included in the CDM-PDD showing how this will be accounted.

In the event of leakage from the project activity, measures should be adopted to mitigate the leakage. The following measures can be used to account the leakage.

- 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. wood 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 under this or other relevant methodologies as per the EB guidance on double counting of emission reductions as outlined in the paragraph 38 of the EB26 Meeting Report.
- In cases where additional clarification on the treatment of leakage is required, project participants should request a revision of the methodology.

Emission reductions

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \qquad \textbf{(6)}$$

Where:
ER_y = Emission reductions during the year y (tCO_2/yr)
BE_y = Baseline emissions during the year y (tCO_2/yr)
PE_y = Project emissions during the year y (tCO_2/yr)
LE_y = Leakage emissions during the year y (tCO_2/yr)

Emission reductions shall be recorded in appropriate spreadsheets. As the carbonization gravimetric yield is the major determinant of the emissions, it must be strictly monitored and applied to the emission reductions calculations on an ex-post basis. The data and calculations should be verified by the Designated Operational Entity in order to confirm that the carbonization units are operating using the approved practices.

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

- Consistent with guidance by the Executive Board, project participants shall assess the continued validity of the baseline and update the baseline. In order to assess the continued validity of the baseline, project participants should apply the procedure to determine the most plausible baseline scenario, as outlined above. The crediting period may only be renewed if the application of the procedure shows that the baseline scenario determined in the registered the draft CDM-PDD still applies.

- It shall be demonstrated that the project activity is not a common practice using the procedure define in the Common Practice step of the Additionality assessment section. The Designated Operational Entity shall evaluate the common practice with the information provided regarding the technology and production process used in the project activity.

- The project entity shall be committed to update or replace the regression equation, if new and more conservative parameters become available during the subsequent crediting periods.

Data and parameters not monitored

Data / Parameter:	**Charcoal production capacity (CPC)**
Data unit:	Tons
Description:	Existing rated capacity of carbonization units.
Source of data:	Charcoal production department of the project entity.
Measurement procedures (if any):	Based on historic data of production for three years previous to the start of the project activity or documentation of rated capacity for the carbonization unit using pre-project technology.
Any comment:	

Data / Parameter:	**Y_{BL}**
Data unit:	tCharcoal/tWood, dry basis.
Description:	Weighted average carbonization gravimetric yield in the baseline scenario.
Source of data:	Charcoal production/ carbonization unit of the project entity.
Measurement procedures (if any):	Estimated as per procedure given in this methodology.
Any comment:	Baseline carbonization yield is used to calculate emissions in the baseline. The DOE shall check if the required conservativeness safeguards are incorporated in the calculation of baseline emissions.

Data / Parameter:	**K**
Data unit:	Number of kilns.
Description:	Improved kilns that are operational at the start of the project.
Source of data:	Charcoal production department of the project entity.
Measurement procedures (if any):	Verification and registration of kilns operating under improved carbonization procedures.
Any comment:	

Data / Parameter:	**Percent explained variance**
Data unit:	%
Description:	The percent explained variance for model selection in the methodology.
Source of data:	Data from the experimental protocol demonstrating the relationship between methane emissions and carbonization gravimetric yield.
Measurement procedures (if any):	
Any comment:	Basis for the model to be selected to estimate the methane emissions in accordance with the regression relationship

Data / Parameter:	**CV (β_i)**
Data unit:	%
Description:	Coefficient of variation of the coefficients of the regression model.
Source of data:	Data from the experimental protocol demonstrating the relationship between methane emissions and carbonization gravimetric yield
Measurement procedures (if any):	In order to estimate it, the methodology should use a *Jacknife procedure* on the existing data sample.
Any comment:	

Data / Parameter:	**β_i**
Data unit:	
Description:	Coefficients of the regression model
Source of data:	Regression procedure for estimating the relationship between methane emission factor and carbon gravimetric yield as per Appendix 1.
Measurement procedures (if any):	As defined in Appendix 1.
Any comment:	

Data / Parameter:	**$EF_{CH4,BL}$**
Data unit:	tCH_4/tCharcoal
Description:	Methane emission factor in the baseline scenario.
Source of data:	Data from the experimental protocol demonstrating the relationship between methane emissions and carbonization gravimetric yield.
Measurement procedures (if any):	Calculation of methane emission factor of the baseline in accordance with the regression relationship.
Any comment:	

Data / parameter:	**CV ($Y_{BL,i}$)**
Data unit:	
Description:	Coefficient of Variation of the baseline gravimetric yield of the sample.
Source of data:	Calculated based on data on $Y_{BL,i}$ collected as outlined in Appendix 3.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	**σ ($Y_{BL,i}$)**
Data unit:	
Description:	Standard Deviation of the baseline gravimetric yield of the sample.
Source of data:	Calculated based on data on $Y_{BL,i}$ collected as outlined in Appendix 3.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	**$\mu(Y_{BL,i})$**
Data unit:	
Description:	average gravimetric yield of the sampled i kilns for the baseline
Source of data:	Calculated based on data on $Y_{BL,i}$ collected as outlined in Appendix 3.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	**$Y_{BL,i}$**
Data unit:	tCharcoal/tWood, dry basis
Description:	Baseline gravimetric yield of the sampled i kiln
Source of data:	Charcoal production department of the project entity.
Measurement procedures (if any):	Baseline gravimetric yield of sampled i kiln shall be calculated prior to the start of the project activity.
Any comment:	

Data / parameter:	**GWP_{CH4}**
Data unit:	tCO_2e/tCH_4
Description:	Global warming potential for CH_4
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

Monitoring procedures

The monitoring procedures and recording of the monitored data shall follow the operational sequence of the charcoal production process. As part of monitoring, the relevant changes to carbonization units 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 major variables that influence methane emissions should be carefully monitored and recorded. The implementation of the instructions on the measurement and calculation of carbonization gravimetric yield shall be ensured (Appendix 3). The compliance of instructions specified in the project's Monitoring Plan is taken into account at the time of validation. Considering that the monitoring data forms the basis for the estimation of methane emissions, the operational procedures shall be periodically verified by the supervisory personnel to ensure the integrity of the data monitored and collected. The amount of charcoal produced along with its end uses should be monitored and recorded, including the changes in the quantities of charcoal produced and operational procedures implemented.

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.

The only variable that is required to be monitored to determine the baseline emissions is the amount of charcoal produced. Charcoal output shall be monitored in accordance with the protocols for carbonization gravimetric yield and measurement of wood and charcoal weights and moisture contents (Appendix 3). Thus, this methodology encompasses the monitoring of the baseline emissions on an *ex-post* basis.

To calculate the project emissions, the gravimetric yield as per the procedure given in the baseline methodology (mass of charcoal/mass of wood) shall be estimated based on the data monitored and recorded monthly. In order to calculate the gravimetric yield,Y_p the data on wood weight, charcoal weight, on dry basis shall be collected following the measurement protocols presented in the Appendix 3 of the baseline methodology.

Data and parameters monitored

Data / Parameter:	$P_{charcoal,y}$
Data unit:	Tons
Description:	Production of charcoal during year y
Source of data:	Charcoal production / carbonization unit
Measurement procedures (if any):	All charcoal produced must be weighted.
Monitoring frequency:	Monthly
QA/QC procedures:	Scales in use must be accurately monitored and regulated. Check production and delivery records at the carbonization units.
Any comment:	Charcoal must be weighted at delivery

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

Data / Parameter:	**SDNP**
Data unit:	Carbonization unit
Description:	Initial date of the operational procedures to reduce methane emissions on carbonization process
Source of data:	Charcoal production department of the project entity.
Measurement procedures (if any):	Verification of operational records in the carbonization units.
Monitoring frequency:	As applicable
QA/QC procedures:	Production records must include the date of implementation of the new carbonization procedures.
Any comment:	Record the starting date of the adoption of new procedures at each carbonization unit

Data / Parameter:	**W**
Data unit:	Tons
Description:	The wood weight used in the carbonization process
Source of data:	Carbonization unit
Measurement procedures (if any):	Recording the weight of wood used in the carbonization process using measurement scales
Monitoring frequency:	Monthly
QA/QC procedures:	Scales used must be accurately monitored and calibrated. Records must be kept in line with production registries.
Any comment:	Wood must be weighted before its arrival at the carbonization units.

Data / Parameter:	$\mathbf{M_{Wood}}$
Data unit:	% water content
Description:	Wood moisture
Source of data:	Record on the wood used in carbonization
Measurement procedures (if any):	Laboratory sampling tests
Monitoring frequency:	Quarterly
QA/QC procedures:	Design work instructions based on proper and verifiable methods.
Any comment:	

Data / Parameter:	$\mathbf{M_{Charcoal}}$
Data unit:	% water content
Description:	Charcoal moisture
Source of data:	Carbonization unit
Measurement procedures (if any):	Laboratory sampling tests
Monitoring frequency:	Quarterly
QA/QC procedures:	Design work instructions based on proper and verifiable methods
Any comment:	

Data / Parameter:	$\mathbf{Y_P}$
Data unit:	tCharcoal/tWood, dry basis.
Description:	Weighted average carbonization gravimetric yield in the project scenario
Source of data:	Charcoal production/carbonization unit
Measurement procedures (if any):	Calculate (on dry-basis) and cross-check the charcoal weight with the wood weight used in the carbonization process.
Monitoring frequency:	Daily/Monthly
QA/QC procedures:	Follow operational guidelines in the applicable research and work instructions with a step by step guide for calculations.
Any comment:	Carbonization yield calculations will be stored in the “CY calculation spreadsheet”. The DOE shall check if the conservativeness on the safeguards are incorporated in the calculation of project emissions.

Data / parameter:	**σ ($Y_{P,i}$)**
Data unit:	
Description:	Standard Deviation of the project gravimetric yield of the sample
Source of data:	Charcoal production/carbonization unit.
Measurement procedures (if any):	Calculated based on data on $Y_{P,i}$ collected as outlined in Appendix 3.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	**μ($Y_{P,i}$)**
Data unit:	
Description:	Average of the project gravimetric yield of the sample
Source of data:	Charcoal production/carbonization unit.
Measurement procedures (if any):	Calculated based on data on $Y_{P,i}$ collected as outlined in Appendix 3.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	**$Y_{P,i}$**
Data unit:	tCharcoal/tWood, dry basis
Description:	Project gravimetric yield of the sampled i kiln
Source of data:	Charcoal production/carbonization unit.
Measurement procedures (if any):	Calculate (on dry-basis) the charcoal weight with the wood weight used in the carbonization process.
Monitoring frequency:	Daily/Monthly
QA/QC procedures:	Follow operational guidelines in the work instructions with a step by step guide for calculations.
Any comment:	

Data / Parameter:	**CV ($Y_{P,i}$)**
Data unit:	%
Description:	Coefficient of Variation in the baseline gravimetric yield of the sample.
Source of data:	Charcoal production/carbonization unit
Measurement procedures (if any):	Statistical procedures and protocol for the calculation of carbonization gravimetric yield
Monitoring frequency:	Monthly
QA/QC procedures:	Calculations must be performed using a verifiable spreadsheet database in accordance with applicable formulae.
Any comment:	

Data / Parameter:	**$RATE^{Compliance}_{y}$**
Data unit:	%
Description:	Compliance rate for relevant law and regulation
Source of data:	Official and public data on the charcoal production process from government sources, producer unions and associations.
Measurement procedures (if any):	The data on compliance of laws and regulation in the charcoal production sector or the methods used by the charcoal producers meet the legal criteria.
Monitoring frequency:	Annual
QA/QC procedures:	Compare the data collected on compliance with rate of threshold of 50% adopted on the compliance of laws and regulation under this methodology.
Any comment:	

Data / Parameter:	**$EF_{CH4,P}$**
Data unit:	tCH_4/tCharcoal
Description:	Methane emission factor in the project scenario.
Source of data:	Data from the experimental protocol demonstrating the relationship between methane emissions and carbonization gravimetric yield.
Measurement procedures (if any):	Calculation of methane emission factor of the project activity in accordance with the regression relationship.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

APPENDIX 1

EXPERIMENTAL PROTOCOL FOR MEASURING METHANE EMISSIONS IN THE CHARCOAL-MAKING PROCESS

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SUMMARY

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 ^{o}C and above (wood distillation). Within the previous a range of temperatures (from 25 to 180 ^{o}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.

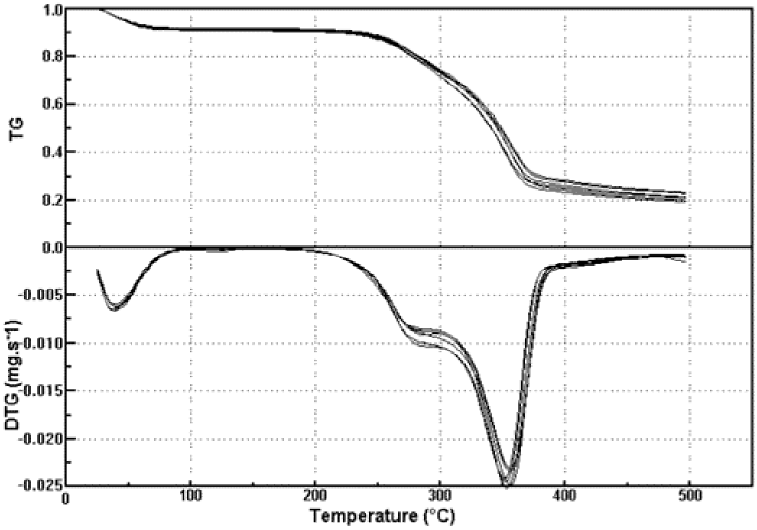

Figure 1- Eucalyptus Wood Pyrolysis (Pinheiro, P.C.C. et al, 2001).

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.

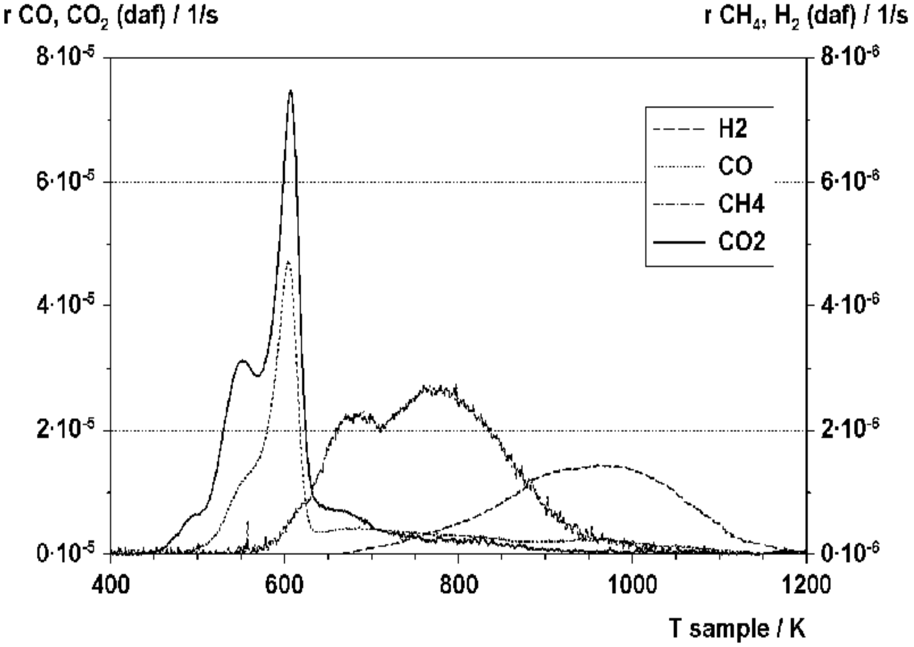

Figure 2- Aspen Pyrolysis Gases (Klose, W. et al, 2000).

~~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:

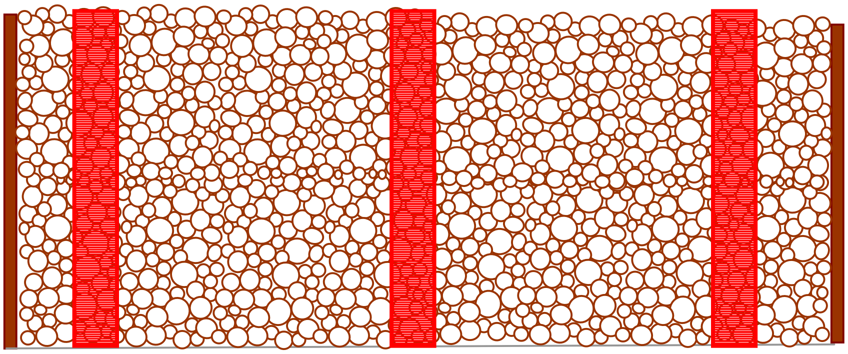

Figure 3: Example of sampling collection in a stack.

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:

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

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.
– Close and seal the kiln's door. ..
3.3 - Ignite the kiln.

~~3~~.4 - 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.

<u>Note</u>: 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.

3.5 - 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.

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

3.7 - Stop the gas sampling procedure.

3.8 - Wait for natural cooling.

3.9 - Open the kiln.

3.10 - Take off the charcoal.

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

3.12 - Take off the brands.

3.13 - 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[8] 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:

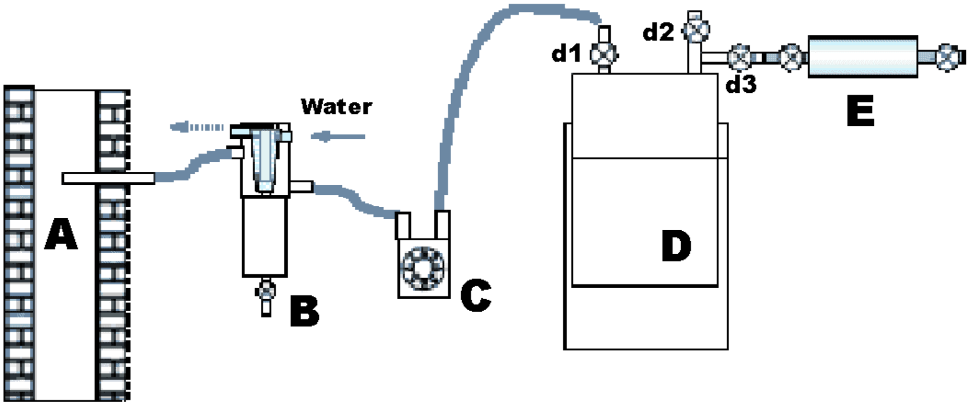

Figure 4 offers a schematic view of the assembly for collecting gas samples. An intake with a stainless steel tip (A) is installed in the central point of the chimney's transversal section. The suctioned gas passes through the condenser and oil filter (B), through the pump (C), and is released by the gasometer (D).

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

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.

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) $\mathbf{M_{cond}}$
  - 4.3.2.3 - Measure carefully the volume and temperature of the gasometer $\mathbf{(V_{gasometer}, T_{gasometer})}$
  - 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.

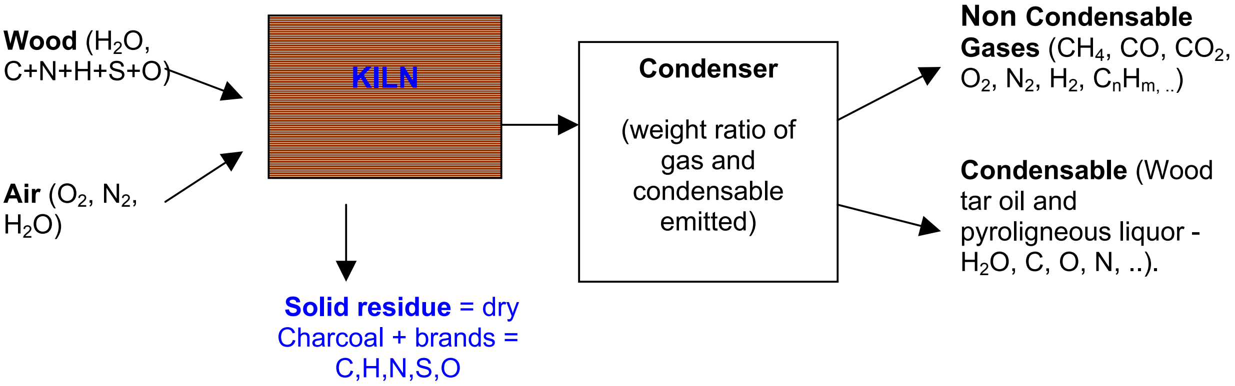
Note 2: Researchers may connect a gas chromatography apparatus directly to valve d2 to make the chromatography analysis.

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 de 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[9] 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 = $\mathbf{M_{drywoo}}$) 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]

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

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) =

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

5.2.2.2 - Gasometer mass of dry non-condensable gases

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

5.2.2.3 - Mean 6 hours Methane mass fraction gas content:

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

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

5.3.9 - Specific Methane emission

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

~~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 assessment 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

PARAMETERS FOR STATISTICAL ANALYSIS OF REGRESSION MODELS OF METHANE EMISSIONS ON CARBONIZATION YIELD

Sampling Planning for Estimating Carbonization Gravimetric Yield

Summary

1. Objectives
2. Regression Analysis Methodology Assessment
    2.1. Introduction and estimate of model
    2.2. Testing the assumptions of the regression
    2.3. Verification of the existence of extreme points
    2.4. Inference about the model
    2.5. Adjustment
    2.6. Autocorrelation
    2.7. Assessment of the coefficients of correlation and
    2.8. Prediction
3. Sampling Measurement
    3.1. Simple random
    3.2. Stratified random
        3.2.1. Applicable sampling designs for the estimation of the average carbonization gravimetric
        3.2.2. Sample designs to obtain estimators with the project entity’s
            3.2.2.1. Stratified sample by carbonization
            3.2.2.2. Stratified sample by charcoal production
    3.3. Sampling designs to obtain estimators with representativeness by
        3.3.1. Stratified sample by carbonization
        3.3.2. Simple random sampling
    3.4. Sampling design to obtain estimators with representativeness by carbonization
4. Bibliography

1. OBJECTIVES

This document has two main objectives. The first 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.

The second objective of this document is to determine the sampling methodology to estimate mean carbonization gravimetric yields, as to provide basis for the estimation of the baseline emissions factor applicable to a given project activity, with a maximum error of 5% in relation to its true value, considering a confidence interval of 95%.

2. REGRESSION ANALYSIS METHODOLOGY ASSESSMENT

2.1. 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)*.

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

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

The following models provide <u>examples</u> 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*.

In addition to the tests and guidance presented below, project participants shall provide a descriptive analysis of the values of the observations obtained in the carbonization tests and chromatography phase (i.e gravimetric yield and methane emissions). The mean, median, standard deviation, minimum and maximum values, first and third quartile limits shall be presented. In order to adequately demonstrate the existence of a strong negative relationship between the two variables, that is, as the carbonization yield grows, methane emissions tend to fall, the coefficients of correlation and determination shall be assessed, in light of the carbonization phenomenon. Specific guidance on the later coefficients are presented in item 2.6

2.2. 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[10] 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.

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.

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

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.

2.3. 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.

2.4. 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.

2.5. ADJUSTMENT TESTS

The adjustment test is a way to verify whether the form of the model that was adjusted to the data is correct or not, that is, to evaluate the quality of the adjustment of the regression model.

Given that the assumptions of normality, independence and constant variance of the errors are valid[11], and that there are repeated observations of *Y* for at least one level of *X*, in synthesis, the adjustment test is used to evaluate whether the relationship between the dependent variable and the independent variable is quite close to a straight line in the region studied. By the same token, the hypotheses of interest for this test are:

$$\begin{cases} H_0 \Rightarrow \text{The model is well-fitted to the data} \\ H_1 \Rightarrow \text{The model is not well-fitted to the data} \end{cases}$$

2.6. AUTOCORRELATION TESTS

One of the basic assumptions of a linear or non-linear regression model refers to the fact that the error associated to any observation does not influence the error associated to any other observation, that is, the errors are not correlated. When this assumption is violated, the results of some adjustments can be questioned. For instance, the auto-correlation of errors

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[11] For the cases of non-normal distributions, the power transformation y^{λ} shall be applied, as per Section 2.2.

can undermine the quality of minimum squares estimates for the coefficients of regression equation, the appropriateness of confidence intervals and hypothesis tests based on the distributions *t* and *F*.

In order to verify the absence of auto-correlation errors, a graphical analysis of the evolution of errors through time shall be performed. By means of graph analysis, one can verify that the errors are distributed randomly around zero, not evidencing, thus, a mechanism that generates auto-correlation.

Additionally, the Durbin-Watson test shall be used to confirm the absence of auto-correlation. This test considers that the errors are generated by the first order auto-regressive model, which, in turn, assumes that the error of a period influences the error of the next period according to the following mechanism: $\mu_t = \rho.\mu_{t-1} + \varepsilon_t$, where $-1 \leq \rho \leq 1$. The hypotheses considered in the Durbin-Watson test to detect the presence of auto-correlation are:

$$\begin{cases} H_0: & \rho = 0 \ \text{(Non - correlated errors)} \\ H_1: & \rho \neq 0 \ \text{(Correlated errors)} \end{cases}$$

To test the described hypothesis, the linear regression model shall be firstly adjusted, as per the minimum squares method, and the adjustment residuals shall be calculated. Then, the Durbin-Watson test (D) shall be applied as follows:

$$D = \frac{\sum_{t=2}^{n} \left(e_t - e_{t-1}\right)^2}{\sum_{t=1}^{n} e_t^2} \tag{3}$$

where, e_t is the residual *t* associated to the adjusted model, and D varies from 0 to 4.

The decision rule for this test is:

- If $0 < D < D_{\alpha,I}$, rejects H_0, there is positive auto-correlation between errors;
- If $D_{\alpha,I} \leq D \leq D_{\alpha,S}$, the test is not conclusive;
- If $D_{\alpha,S} < D < 4\text{-}D_{\alpha,S}$, do not reject H_0, errors are not correlated;
- If $4\text{-}D_{\alpha,S} \leq D \leq 4\text{-}D_{\alpha,I}$, the test is not conclusive;
- If $D_{\alpha,I} < D < 4$, rejects H_0, there is negative auto-correlation between errors.

The critical values $D_{\alpha,I}$ and $D_{\alpha,S}$ for several sample sizes (*n*), for several numbers of regressive variables (*k*) in the regression model, and for two levels of significance (α=0,01 and α=0,05) are presented in the critical values' table for Durbin-Watson statistics.

To better visualize the decisions to be made, there is:

f(D)

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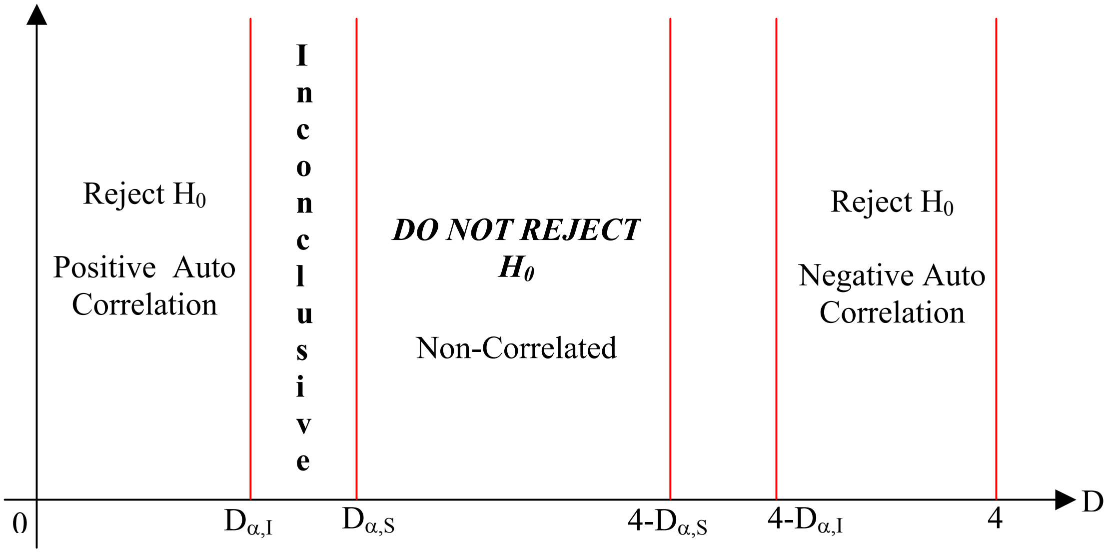


2.7. ASSESSMENT OF THE COEFFICIENTS OF CORRELATION AND DETERMINATION

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 explanation or 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 *(4)*, and the closer it is to the higher interval, the more the adjusted model explains the data.

$$R^2 = \frac{\sum_{i=1}^{n} (\hat{Y}_i - \overline{Y})^2}{\sum_{i=1}^{n} (Y_i - \overline{Y})^2} \tag{4}$$

Given the specific features of every industrial manufacturing process, it is, by no means, possible to establish, *ex-ante*, an absolute number as a conservative *R* or R^2 threshold. Essentially, it shall be ensured that the evaluation of the appropriateness of a statistical relationship takes into account the nature and the characteristics of the process at stake. For example, as elaborated in the research protocol in Appendix 1 and considering the historical low control over the carbonization process, the relationship between methane emissions and carbonization yield with an R^2 of about 0.7 is taken as a substantially conservative value.

2.8. PREDICTION INTERVALS

An interval with *λ%* of confidence for the mean value of *Y* for a particular value for X_0 of X is given by the formula below. In order to ensure conservativeness, project participants shall estimate prediction intervals derived from the regression data, complying with a 95% confidence level interval:

$$IC = \left[\hat{Y}_o \ \mp \ t_0 \ s \ \sqrt{\frac{1}{n} + \frac{\left(X_0 - \overline{X}\right)^2}{\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum X_i\right)^2}{n}}} \right] \qquad (5)$$

with $t_0 = t_{\alpha/2,\ n-2}$ and $s = \sqrt{QMR}$.

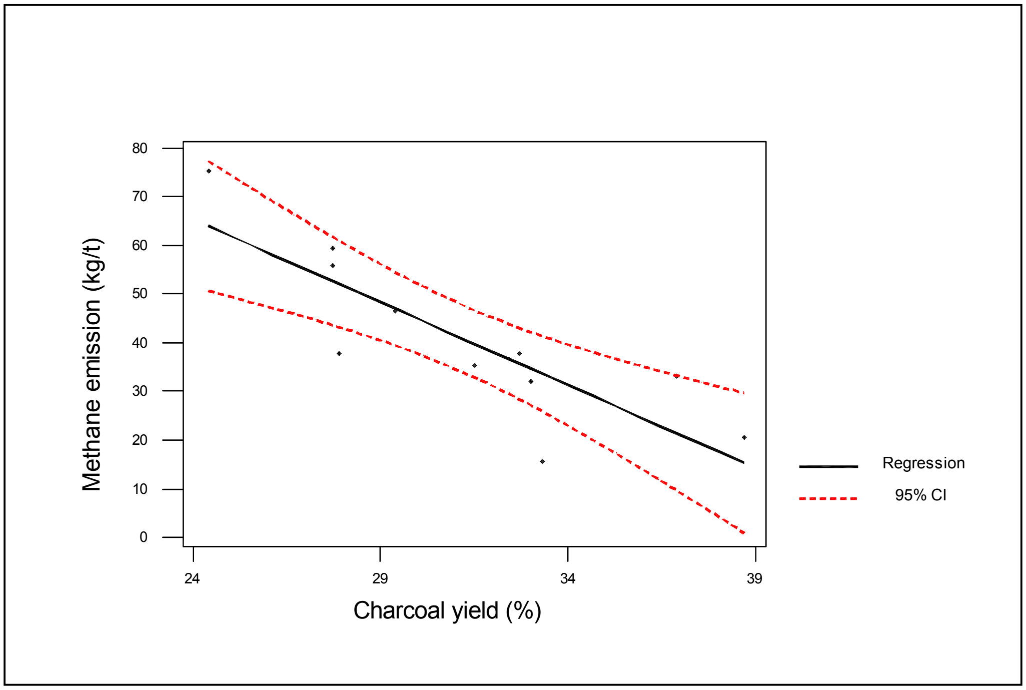
Table 1 – **Examples of Prediction intervals for Methane Emissions**

Charcoal Yield (%)	Point estimate for the mean value of Methane Emissions- $\hat{Y}_i$ (kg/t)	Confidence interval for the mean value of Methane Emissions for each level of Charcoal Yield
36.9	21.43	(9.62; 33.24)
38.7	15.31	(0.92; 29.69)
33.3	33.67	(25.94; 41.41)
27.9	52.04	(43.20; 60.89)
27.7	52.72	(43.66; 61.79)
32.7	35.72	(28.38; 43.05)
33.0	34.7	(27.17; 42.22)
31.5	39.8	(32.90; 46.70)
24.4	63.95	(50.58; 77.31)
29.4	46.94	(39.42; 54.46)
27.7	52.72	(43.66; 61.79)

Figure 1 shows an example of graph of observations under analysis, together with an adjusted regression line and the confidence intervals for the mean of the dependent variable.

z3

Figure 1: **Graphic example of estimated confidence intervals**



3. SAMPLING MEASUREMENT

Project participants shall use either one of the sampling methods for the assessment of baseline and/or project related emissions, as applicable. The simple random sampling methodology should only be used in those cases where no sorts of stratification exist .

3.1. SIMPLE RANDOM SAMPLING

Simple random sampling (SRS) is the simplest method to select a sample. In addition to serving as a plan by itself, its procedure is repeatedly used in multiple stage procedures. On the other hand, the SRS plan introduces mathematical and statistical advantages, principally the independence between the units drawn, which greatly facilitates the determination of the properties of the estimators of the target population quantities.

The measurement of a sample according to this method is given by:

$$n = \frac{N s^2}{(N-1)\frac{B^2}{t_{\alpha/2}^2} + s^2} \qquad (6)$$

where:

n – sample size;

N – population size;

s^2 – estimate of population variance of the variable to be estimated;

B – confidence interval (margin of error tolerated);

$t_{\alpha/2}$ – value of the *t* distribution associated with the desired confidence interval.

3.2. STRATIFIED RANDOM SAMPLING

Stratified random sampling consists of dividing a population into groups (strata), according to one or more known characteristics in the population being studied, and then taking samples in convenient proportions from each one of these strata. Stratification is mainly used to solve some problems such as improving the precision of estimates.

Briefly, the principal reasons for using Stratified Random Sampling instead of Simple Random Sampling are the following:

1) Stratification can produce lower estimating error than would be produced from a simple random sampling of the same size. principally when the measurements within the strata are homogenous;

2) The cost per observation in the survey can be reduced through stratification of the population elements into convenient groups;

3) Estimates of population subgroups may be necessary. These subgroups should however, be clearly identifiable strata.

The estimate of the sample size in this case is given by:

$$n = \frac{\sum_{i=1}^{c} \frac{N_i^2}{W_i} s_i^2}{\sum_{i=1}^{c} N_i s_i^2 + N^2 D} \qquad (7)$$

where:

N_i - population of each stratum;

N - total population;

c - total of strata;

s_i^2 - estimate of variance for each stratum i;

$W_i = \frac{N_i S_i}{\sum_{i=1}^{c} N_i S_i}$ - weight of each stratum in the population, using Neyman allocation;

$D = B^2 / t^2_{\alpha/2}$ with B being the acceptable limit for estimation error (precision) and $t_{\alpha/2}$ the point of the *t* distribution that defines the estimator confidence interval.

For the carbonization units for which data can not be collected, a weighted mean of the existing variances shall be used.

3.2.1. APPLICABLE SAMPLING DESIGNS FOR THE ESTIMATION OF THE AVERAGE CARBONIZATION GRAVIMETRIC YIELD.

In order to determine the average gravimetric yield to be used in the estimation of the baseline emissions factor, stratification and sub-stratification may vary in each project activity, depending on the disposal and management of the carbonization units. In order to provide adequate guidance to project developers, this methodology presents below five possible sampling designs for the gathering of data to estimate the three variables involved in the assessment of the gravimetric yield, given the amount of kilns, i.e. dry wood weight, dry charcoal weight and the calculation of the carbonization yield *per se*.

It is worth emphasizing that, for each case, calculations of samples for the three variables described in Table 2 shall be considered with their respective error margins, observing a maximum error of 5% of the mean value.

Table 2: ***Maximum*** *Error margins used in sampling measurement*

Variable	Error margin used to determine samples
Dry wood weight (kg)	5% of the mean
Charcoal weight (kg)	5% of the mean
Carbonization yield (%)	5% of the mean

3.2.2. SAMPLE DESIGNS TO OBTAIN ESTIMATORS WITH THE PROJECT ENTITY'S REPRESENTATIVENESS

3.2.2.1. STRATIFIED SAMPLE BY CARBONIZATION UNIT

In this case, each of the project entity's carbonization units shall be taken as a population stratum. This procedure is justified by the assumption that there exists heterogeneity between the different carbonization units with respect to the carbonization process and an internal homogeneity concerning the same process. We emphasize that the means obtained for each carbonization unit will serve only to compose the project entity's global mean, which is given by:

$$\overline{y}_p = \sum_{i=1}^{15} \left(\frac{N_i}{N} \right) \overline{y}_i \qquad (10)$$

where:

$\overline{y}_p$ - variable mean (weight of wood. charcoal or yield) for the project entity;

$\overline{y}_i$ - variable mean (weight of wood. charcoal or yield) for the carbonization unit i; $i = 1. .... 15$;

N_i - number of charcoal kilns of the carbonization unit i; $i = 1. .... 15$;

N - total number of charcoal kilns at the project entity.

Through the application of stratified sampling with Neyman allocation, the quantity of kilns to be sampled shall be presented, in conformity with the respective variables that will be estimated (*Table 3 provides a data presentation example*).

Table 3: Sample of kilns according to variable to be estimated (EXAMPLE ONLY)

Stratum (Carbonization Unit)	**Total Number of Kilns**	**Sample of Kilns by variable**		
		Wood	**Charcoal**	**Yield**
Campo Alegre 1	68	3	5	3
Campo Alegre 2	63	2	4	2
Jaboticaba	48	2	4	2
Lagoa do Capim	84	3	6	4
Meleiro 1	50	1	3	2
Meleiro 2	74	2	6	3
Central	72	3	5	3
Ical	45	1	3	2
Pau Preto	100	5	10	6
Tia Dósia	100	4	7	5
Pindaíba	40	2	3	2
Venda Nova	92	4	6	4
Santa Marta	105	5	6	4
Congonhas	144	6	11	7
TOTAL	**1.085**	**43**	**79**	**49**

3.2.2.2. STRATIFIED SAMPLE BY CHARCOAL PRODUCTION FARM

Supposing that the carbonization units of each charcoal production farm, belonging to one project entity, are homogenous with respect to carbonization processes, we can take each farm as a population stratum. This means that we assume heterogeneity between the project entity's farms and internal homogeneity at both farms. We emphasize that the means obtained for each farm will serve only to compose the project entity's global mean, which will be given by the expression:

$$\bar{y}_p = \sum_{i=1}^{2} \left(\frac{N_i}{N} \right) \bar{y}_i \qquad (11)$$

where:

$\bar{y}_p$ - variable mean (weight of wood, charcoal or yield) for the project entity;

$\bar{y}_i$ - variable mean (weight of wood, charcoal or yield) for the farm i; $i = 1.\ 2$;

N_i - number of charcoal kilns at the farm i; $i = 1.\ 2$;

N - total number of charcoal kilns at the project entity.

The results obtained through the sample calculations shall be registered and presented. *Table 4 provides a data presentation example.*

Table 4: *Sample of kilns according to variable to be estimated* **(EXAMPLE ONLY)**

Stratum (Farm)	Total Number of Kilns	Sample of Kilns per variable		
		Wood	Charcoal	Yield
Farm MG02	504	15	39	20
Farm MG15	581	27	51	30
TOTAL	**1.085**	**42**	**90**	**50**

3.3. SAMPLING DESIGNS TO OBTAIN ESTIMATORS WITH REPRESENTATIVENESS BY FARM

3.3.1. STRATIFIED SAMPLE BY CARBONIZATION UNIT

With the aim of obtaining representative results for each farm, this sampling design assumes that each farm is considered to be a population and the carbonization units are the respective strata. Again, it must be pointed out that the mean obtained for each carbonization unit shall serve only to compose the mean of each farm. The mean for each farm is given by:

$$\overline{y}_{F_j} = \sum_{i=1}^{c_j} \left(\frac{N_{ij}}{N_{F_j}} \right) \overline{y}_{ij} \qquad (12)$$

where:

$\overline{y}_{F_j}$ - variable mean (weight of wood. charcoal or yield) by farm *j*; *j* = 1. 2;

$\overline{y}_{ij}$ - variable mean (weight of wood, charcoal. or yield) for carbonization unit *i* of farm *j*. *i* = 1. ....c_j e *j* = 1. 2;

N_{ij} - number of charcoal kilns of carbonization unit *i* of farm *j*. *i* = 1. ....c_j e *j* = 1. 2;

N_{F_j} - Total number of charcoal kilns of farm *j*.

C_j - Number of carbonization units of farm *j*.

The formula for the project entity's global mean is given by:

$$\bar{y}_p = \frac{N_{F_1}}{N}\bar{y}_{F_1} + \frac{N_{F_2}}{N}\bar{y}_{F_2} \tag{13}$$

where:

$\bar{y}_p$ - mean (weight of wood. charcoal or yield) for the project entity;

$\bar{y}_{F_1}$ - mean (weight of wood. charcoal or yield) for farm 1;

$\bar{y}_{F_2}$ - mean (eight of wood. charcoal or yield) for farm 2;

N_{F_1} - number of charcoal kilns at farm 1;

N_{F_1} - number of charcoal kilns at farm 2;

N - total number of charcoal kilns at the project entity.

Tables 5 and 6 present examples of sampling measurements results, according to each farm. We emphasize that the determination of the error margins shall be calculated using the same maximum percentages previously described, and taking into account the mean of each individual farm.

Table 5: *Sample of kilns according to variable to be estimated for Farm MG02 (EXAMPLE ONLY)*

Strata (Carbonization Unit)	**Total Number of Kilns**	**Sample of Kilns by variable**		
		Wood	**Charcoal**	**Yield**
Campo Alegre 1	68	4	8	6
Campo Alegre 2	63	3	6	3
Jaboticaba	48	3	6	4
Lagoa do Capim	84	5	10	7
Meleiro 1	50	2	4	4
Meleiro 2	74	3	10	6
Central	72	4	9	6
Ical	45	2	5	4
TOTAL	**504**	**26**	**58**	**40**

Table 6: *Sample of kilns according to variable to be estimated for Farm MG15 (EXAMPLE ONLY)*

Stratum (Carbonization Unit)	**Total Number of Kilns**	**Sample of Kilns by variable**		
		Wood	**Charcoal**	**Yield**
Pau Preto	100	10	18	12
Tia Dósia	100	8	13	9
Pindaíba	40	3	5	3
Venda Nova	92	8	12	8
Santa Marta	105	9	12	7
Congonhas	144	11	19	12
TOTAL	**581**	**49**	**79**	**51**

3.3.2. *SIMPLE RANDOM SAMPLING*

In this case, we have a sampling design that considers each farm to be a population of homogenous kilns. The estimators with representativeness for each farm will be obtained by simple arithmetic average of the data collected at each farm. The mean for the project entity will be obtained by applying formula13. Example of results of sampling calculations are presented in *Table 7*.

Table 7: *Sample of kilns according to model to be estimated (***EXAMPLE ONLY)**

Farm	**Total Number of Kilns**	**Sample of Kilns by variable**		
		Wood	**Charcoal**	**Yield**
MG02 Farm	504	25	65	36
MG15 Farm	581	57	84	58
TOTAL	**1.085**	**82**	**149**	**94**

3.4. *SAMPLING DESIGN TO OBTAIN ESTIMATORS WITH REPRESENTATIVENESS BY CARBONIZATION UNIT*

In this model, the results obtained will have representativeness by carbonization unit. Each carbonization unit shall be treated as a population and the sampling calculation shall be done individually for each of them. It is true that this sampling design generates a greater number of kilns to be sampled, but on the other hand, the results obtained will have representativeness by carbonization unit.

The mean obtained for each carbonization unit (wood, charcoal and yield) shall be estimated with the error margins shown in *Table 8*.

Table 8: ***Maximum*** *Error margins allowed in the sampling measurement*

Variable	Maximum error margin to determine sample size
Dry wood weight (kg)	5% of the mean
Charcoal weight (kg)	5% of the mean
Carbonization yield (%)	5% of the mean

The mean for each farm will be given by formula 12. The project entity's global mean can be obtained using formula 10.

Examples of results of the measurement for this sampling design are presented in *Table 14*.

Table 9: *Sample of kilns by variable to be estimated*

Carbonization Unit	Total Number of Kilns	Sample of Kilns by variable		
		Wood	Charcoal	Yield
Campo Alegre 1	68	10	9	8
Campo Alegre 2	63	8	6	3
Jaboticaba	48	9	9	7
Lagoa do Capim	84	10	9	8
Meleiro 1	50	6	5	5
Meleiro 2	74	6	10	7
Central	72	10	9	8
Ical	45	4	9	9
Pau Preto	100	15	15	14
Tia Dósia	100	10	9	8
Pindaíba	40	9	8	7
Venda Nova	92	12	8	8
Santa Marta	105	13	7	5
Congonhas	144	11	10	8
TOTAL	**1.085**	**133**	**123**	**105**

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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 – Definition
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.

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