New Zealand Biochar
Research Centre

Proposed Voluntary Carbon Standard General Methodology

Quantifying the GHG Emission Reductions from the Production and Incorporation into Soil of Biochar in Agricultural and Forest Management Systems

Submission by the New Zealand Biochar Research Centre

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31 August 2009

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Disclaimer and Intellectual Property declaration

This submission was prepared by the New Zealand Biochar Research Centre (NZBRC) in response to the proposed *General Methodology for Quantifying the Greenhouse Gas Emission Reductions from the Production and Incorporation into Soil of Biochar in Agricultural and Forest Management Systems* (hereinafter the *Methodology*) for the scope of the global stakeholders' consultation in the two-stage Voluntary Carbon Standard approval process.

The comments provided on the Methodology are derived from the Author's own analysis and are based on a number of sources. These are publicly available in the literature and have been documented by the Authors to the best of their knowledge.

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For the Authors,
Attilio Pigneri
Attilio Pigneri
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Executive Summary

On behalf of the team at the New Zealand Biochar Research Centre we welcome the opportunity to submit our comments on the methodology for "Quantifying the GHG Emission Reductions from the Production and Incorporation into Soil of Biochar in Agricultural and Forest Management Systems" (hereinafter *the Methodology*) proposed by Carbon Gold for consideration under the Voluntary Carbon Standard.

It is our view that the proposed methodology, is not fit for approval in its current status as it presents a number of significant flaws in the following key areas:

- description of the scope and mitigation mechanism for the proposed project activity,
- level of scientific evidence supporting the assertions made with regard to the net, long-term GHG mitigation benefits of the proposed activity,
- the reporting obligations for project developers at the project design document (PDD) stage and subsequent monitoring and verification activities,
- assurance as to the sustainability principles to be adopted.

For these reasons our strong recommendation that the methodology be rejected and taken again into consideration only after it has been extensively redrawn to address the number of issues we raise in this document. These are grouped in the following four sections:

1 Scope of the proposed methodology,
2 Methodological issues,
3 Reporting obligations,
4 Sustainability principles.

An appendix follows where we describe in detail our proposed approach to the issue of leakage by means of an example for a specific leakage scenario.

We remain available for any further clarification required regarding our submission.

Attilio Pigneri, Ruy Anaya de la Rosa and Marta Camps
New Zealand Biochar Research Centre
31st August 2009

About this submission

The New Zealand Biochar Research Centre

The New Zealand Biochar Research Centre (NZBRC) was established in 2008 with a grant from the New Zealand Ministry for Agriculture and Forestry (MAF) following a successful proposal to host the Massey university Biochar Initiative, an integrated, multi-year RD&D program which aims to advance the understanding of biochar for mitigating global climate change and to enable its use in NZ, particularly by agricultural and forestry sectors.

The *Biochar Initiative* is organized into three closely linked streams of RD&D activities:

i soil science and biochar
ii pyrolysis plant engineering and biochar
iii biochar and greenhouse gas mitigation strategies

Information on the New Zealand Biochar Research Centre, regular updates and publications from the Massey University Biochar Initiative can be accessed through the NZBRC website <http://www.biochar.co.nz/>.

Authors' profiles

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Attilio is an adjunct senior lecturer at the Centre for Energy Research at Massey University.

Attilio has co-led the proposal for the establishment of the Massey University Biochar Initiative, where he now leads the third stream of RD&D activities (biochar and GHG mitigation strategies). Attilio serves on the Executive Committees of the NZBRC and the Australia and New Zealand Biochar Researchers' Network (ANZBiochar).

Attilio holds a MSc in Mechanical Engineering (Energy) from Politecnico di Milano in Italy and a PhD in Energy Systems and the Environment from Università del Salento in Italy.

Ruy Anaya de la Rosa MSc

Ruy is one of the six PhD students funded within the Massey University Biochar initiative, his research focuses on the opportunities for GHG mitigation and sustainable development through a biochar strategy within the carbon markets. Prior to joining the NZBRC in June 2009

Ruy was Project Manager at the French NGO Good Planet/Action Carbone where he managed a diverse portfolio of pioneering biomass-based projects including biochar in India and green charcoal briquettes in Senegal.

Ruy holds a MSc degree in Sustainable Energy Technology from the TU/e, Netherlands.

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Marta Camps is an Associate Professor at the Institute of Natural Resources, Massey University where she holds the chair of Soil Science and Biochar and is a co-director of the New Zealand Biochar Research Centre.

Marta has a degree in agricultural engineering (University Politecnica de Catalunya) and a MSc and a PhD in Soil Science (University of California, at Davis).

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Abbreviations and acronyms

ALM	*Agricultural Land Management*
ANZBiochar	*Australia and New Zealand Biochar Researchers' Network*
ASTM	*American Society for Testing and Materials*
BCS	*biochar-C stored*
CC	*carbon content*
CDM	*Clean Development Mechanism*
EB	*Executive Board (CDM)*
FC	*fixed carbon content*
GWP	*global warming potential*
GWP_{100}	*global warming potential (integrated over 100 years)*
IBI	*International Biochar Initiative*
IFM	*Improved Forest Management*
LPG	*liquefied petroleum gas*
MAF	*New Zealand Ministry for Agriculture and Forestry*
MUBI	*Massey University Biochar Initiative*
NCV	*net calorific value*
NZBRC	*New Zealand Biochar Research Centre*
PDD	*project design document*
RD&D	*research, demonstration and development*
UNFCCC	*United Nations' Framework Convention on Climate Change*
VCS	*Voluntary Carbon Standard*
VM	*volatile matter*

Content

List of figures

List of tables

1 Scope of proposed methodology

1.1 Title

The title of the methodology is not in coherence with the scope described in the document.

We question the use of the "general methodology" for a methodology that instead focuses on the specific case of biochar production from crop and woody residues in Agricultural and Forest Management Systems.

1.2 Clarity of purpose

The proposed project activity is the storage of the carbon contained in the biochar into soils (biochar-C storage), the methodology does not describe how this fundamental step is going to be performed and remains limited to the biochar production step.

1.3 Size of the project activity

There appears to be a contradiction between the size of the project activities, and the proposed project. While the cap is fixed at 60 $kt_{CO2\text{-}e}$/y (e.g. the type III limit for the small-scale CDM category) the methodology does not contemplate the opportunity of bundling the operation of a large number of small pyrolysis units (e.g. at a scale that would allow direct management by rural farming communities in developing countries).

1.4 Temporal boundary

It is not clear why the temporal boundary is set at 10 years, nor is clear whether the accounting of GHG removals occurs every year during this period, or only at the beginning of the period.

2 Methodological issues

2.1 Fixed carbon content and long-term residence in soils

The methodology bases the GHG accounts on the fixed carbon content of the biochar materials. This is not appropriate as the fixed carbon, as derived from the relevant ASTM or other similar testing methods, only provides a measure of the thermal stability[1] of the amount of carbon contained in the material and does not bear any indication as to its long-term residence in soils, e.g. its stability to biological and other soil C turnover mechanisms. This will depend on a greater number of factors including the characteristics of the different chars and soils considered, land management practices and the prevalent pedo-climatic conditions.

The threshold set for “biologically inert” pyrolysis residues – the volatile-carbon/fixed-carbon ratio being equal to or lower than 50% (Carbon Gold 2009, §3.3, p.2) – is arbitrary and is not backed by any scientific evidence (nor any is referenced anywhere in the proposed methodology).

This is particularly problematic not only because it bears the implicit assumption that all chars and soils are equal (probably the major flaw in the methodology), but also because it is used in the proposed methodology to justify the accounting of GHG removals on the basis of the carbon content in the pyrolysis residues, independently of the evolution of the chars in soils (and of whether the chars are actually applied to the soils over the duration of the project[2]).

2.1.1 Biochar-C storage and recalcitrant C fraction

Rather than considering the char as being inert, the long-term residence or stability of biochar-C, or any carbon addition to the soil carbon pools, should be instead evaluated in terms of the labile and recalcitrant fraction of the carbon in the char material (Lehmann *et al.* 2006; Hammes and Schmidt 2009; Lehmann *et al.* 2009), the first being the fraction that is decomposed or lost through the various soil C turnover mechanisms and the second being the amount remaining in the soil carbon pool.

Since the chars are not inert these two quantities are not constant, but will vary depending on the timeframe considered. In the context of biochar-C storage as a GHG mitigation activity, the time horizon of interest is set at 100 years. For any amount of carbon stored away

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[1] The carbon content is derived from comparing the carbon content of the material as is, and the carbon content after measuring the “loss-on-ignition” through a volatility test. Testing methods in use by the different disciplines (coal and bioenergy, soil science...) prescribe different temperatures and residence times for measuring the “loss-on-ignition”; as a result the volatile matter (VM) and fixed carbon content (FC) figures obtained may vary significantly.

[2] Interestingly, neither the accounting methods (see Carbon Gold 2009, §8.1, p. 7), nor the monitoring obligations proposed (see Carbon Gold, §16) give any consideration to the very central step in any biochar-C sequestration project.

from the atmosphere for at least this timeframe the GHG mitigation benefit of biochar-C sequestration can be computed as the Global Warming Potential integrated over 100 years (GWP_{100}) of the equivalent amount of atmospheric CO_2 (Pigneri and Anaya de la Rosa 2009).

With reference to the diagram in Figure 1 below, the quantity BCS(0) represents the initial amount of biochar-C applied to soils, whereas the quantity indicated as BCS(100) is the fraction of the initial amount of biochar-C stored that is recalcitrant over 100 years.

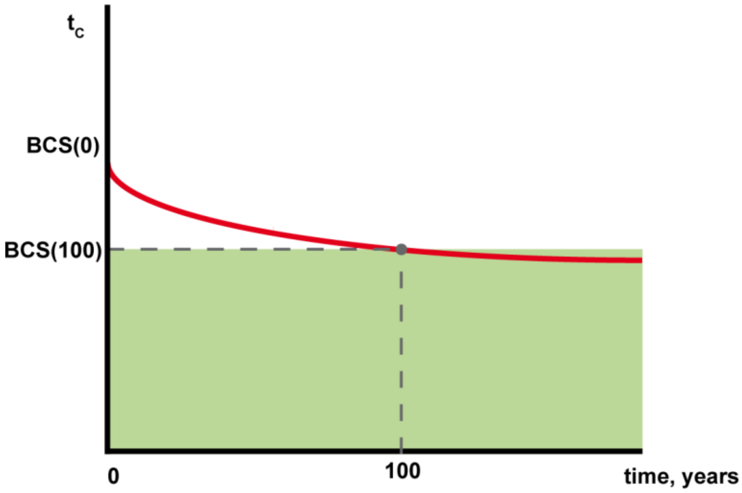

Figure 1. Biochar-C storage, recalcitrant C fraction over a 100-year time horizon[3]

2.2 Leakage

The way the issue of potential leakage is dealt with in the proposed methodology is not considered satisfactory. Leakage – e.g. '*the net change of anthropogenic emissions by sources of greenhouse gases (GHG) which occurs outside the project boundary, and which is measurable and attributable to the...project activity*' (CDM/EB 2009). – could occur, in the case of biomass residues being harvested for thermal conversion in pyrolysis kilns and subsequent addition to soils, as a result of one of the following:

- *fuel switching*, from biomass residues (fuel wood, straw...), wood processing byproducts (sawdust, shavings...) or biomass derivatives (charcoal) to fossil fuels (coal, natural gas..) or their derivatives (LPG, kerosene...);

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[3] reproduced from (Pigneri and Anaya de la Rosa 2009).

- *increased biomass removals* within the region where the activity is implemented and resulting depletion of above-ground carbon stocks; and
- *land-use changes*.

The assertion that "...there is no land-use change involved, no people, crops or livestock will be displaced" (Carbon Gold 2009, §14.1, p.15) cannot be taken for granted simply because it is stated in a general methodology, as this would leave unchecked the necessary verification of this key assumption when specific projects are implemented.

For these reasons the issue of potential leakage should be covered in greater detail in a revised version of the proposed methodology.

On one side the methodology should specify the obligations for project developers to provide sufficient evidence[4] supporting the exclusion of fuel switching, increased biomass removals or land-use changes over the spatial and temporal horizons of the project. Alternatively, where the available evidence does not allow the exclusion of the occurrence of leakage, the methodology should prescribe, as a precautionary measure, the obligation for the GHG accounts in the project design document (PDD) *to include the maximum potential extent of leakage* and propose a simple mechanism for accounting this based on the current dominant use of the biomass residues (as assessed from the sources discussed in note[4] below).

When considering leakage to occur through fuel switching mechanisms this will depend on the following parameters:

- the type, characteristics (energy content, carbon content and emission factors), and current uses of the biomass residues or biomass derivatives considered for biochar-C sequestration;
- the type of pyrolysis processing technology and the operating conditions (temperature, heating rate and residence time);
- the characteristics (energy content and emission factors) of the replacement fuels;
- the energy efficiency of current (based on biomass residues or derivatives) and replacement (based on fossil fuels or their derivatives) end-use energy technologies.

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[4] This could be provided for example through an official biomass balance for the region interested by the project activity, where available, or through a biomass use survey for the region, developed by an independent third party, focused on the types of biomass residues specified in the project design document (PDD).

In the Appendix to this submission we sketch an example of such a methodology considering a scenario where charcoal derived from woody biomass harvested in the region is the dominant source of end-use energy for cooking services, and its use for biochar-C sequestration activities could result in switching alternative fossil fuels such as liquefied petroleum gases (LPG), through the use of LPG cookstoves.

In our example we have illustrated how the *maximum potential extent of leakage* could result in this case in an increase in GHG emissions outside the project boundary amounting to 0.277 $t_{CO2\text{-}e}$ per every $t_{CO2\text{-}e}$ sequestered through biochar addition in soils.

In our example we have also discussed how these results show a marked sensitivity to variations in the input values for the carbon content and the recalcitrant C fraction of biochar, reinforcing the importance of our earlier remarks with regard to the variations in the quality of biochars sourced from different biomass feedstocks and produced through different pyrolysis technologies and operating conditions.

Similar simplified mechanisms can be devised to account for the maximum potential extent of leakage in other contexts, such as for example cases where biomass residues such as rice husks are currently used for animal fodder or the byproducts of wood processing (bark, sawdust, shavings, etc.) are used on-site at the wood processing plant as a significant source of energy for heating or cogeneration purposes.

3 Reporting obligations

3.1 Biochar application schedule as part of the PDD

The methodology does not prescribe any reporting with regard to the actual application of the pyrolysed residues to char, yet this is the fundamental activity of any biochar-C sequestration scheme.

The methodology should be redesigned to account for the amount of biochar-C sequestered in soils in terms of the types of biochar applied, the surface of the agricultural/forestry land estates where the biochars will be applied and the respective application rates (in t/ha). These details should be provided for every year over the entire project duration and organized into a *biochar application schedule* to be submitted as part of the project design document (PDD).

The actual occurrence of the application of biochar, should be a key reporting obligation to the project developers and should be actively monitored for the entire duration of the project.

4 Sustainability issues

The sustainability principles stated in the methodology are vague, moreover the definition of feedstock categories such as "diseased trees" (Carbon Gold 2009, §3.2, p.2) is problematic as it leaves the ground open for different interpretations.

Our suggestion is for the methodology to make explicit reference to sustainability guidelines developed by independent third parties, such as the one under development by the International Biochar Initiative and the Australia and New Zealand Biochar Researchers Network (Joseph and Krull 2009).

Appendix – Leakage example

Description

The leakage calculation example considers a region in a developing country where charcoal produced from woody biomass residues is used traditionally as the main source of energy for heating and cooking purposes.

The implementation of a project activity based on biochar-C sequestration could limit the available supply of woody biomass residues and induce fuel switching from charcoal to some sort of fossil fuel (we assume LPG for the scope of this example).

We focus here on determining the *maximum potential extent of leakage* that could occur as a result of the implementation of the project activity in the region: this is determined by assuming that the entire production of charcoal for biochar-C sequestration activities will need to be replaced by LPG. We base our leakage calculations on 1 $t_{CO2\text{-}e}$ stored through biochar C-sequestration as we are interested in determining how this quantity should be reduced to consider leakage.

Inputs

Table 1 below reports the inputs used for the leakage calculation example.

Table 1. Leakage example, inputs

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These are based on the following sources:

- net calorific values (NCV) for charcoal and LPG are those reported on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006)[5],
- efficiency of charcoal and LPG cookstoves are as reported in (Smith *et al.* 2000), and
- emission factors for both LPG and charcoal are derived from the relevant default IPCC emission factors[6] for CO_2, CH_4 and N_2O by applying the respective global warming potentials (GWPs) of 1, 21 and 310.

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[5] Vol.2 Energy, Table 1.2, pp.1.18-19.

- carbon content and recalcitrant C fraction for the biochar considered have been set by default at the values of 80% and 75%[7], respectively. The sensitivity of results to these two key input parameters is discussed below.

Calculations

Biochar requirements

The first step is determining the amount of charcoal or biochar that needs to be incorporated in soils in order to achieve 1 $t_{CO2\text{-}e}$ of mitigation.

We translate this value in carbon-equivalent terms multiplying it by the ratio of the molecular weights of carbon and carbon dioxide (12/44), and obtain 272.7 kg. This amount represents the amount of recalcitrant carbon in the charcoal.

By dividing this quantity by the fraction of recalcitrant carbon for the specific biochar considered (75% in our example) we obtain the total amount of carbon (including both the labile and recalcitrant fractions) in the charcoal as being 363.6 kg.

The amount of charcoal required is then calculated by dividing this amount by the carbon content of the specific charcoal considered (80% in our example) at 454.5 kg.

Charcoal and LPG equivalence

In order to compute the amount of LPG that will be required to displace the charcoal, we establish a term of comparison on the basis of the same level of energy services delivered (e.g. the useful heating energy available for cooking) by taking into account both the net calorific values and the efficiency of the cookstoves. We obtain the following values: 25.35 MJ/kg for LPG, and 5.16 MJ/kg for charcoal.

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[6] For stationary combustion in the residential and agriculture/forestry/fishing/fishing farms categories (IPCC 2006, vol.2 Energy, Table 2.5, pp.2.22-23).

[7] We have used for this parameter the information provided by Hammes (et *al.* 2008) which indicates “black carbon stocks decreased 25% over a century” in soils of the Russian steppe. We are aware that the decrease in charcoal observed by those researchers could also be attributed to other processes, in addition to decomposition. This value has only been used as an example, while the sensitivity analysis provide an evidence on how leakage decreases at increasing values of “recalcitrance”.

The ratio of these two terms defines the amount of charcoal required to provide the same amount useful energy when compared to LPG, e.g. the charcoal-to-LPG fuel-switching equivalent is calculated at 4.91 kg of charcoal for every kg of LPG.

Leakage

In order to account for the extent of leakage we need to assess the quantity of charcoal that could be replaced by LPG. As discussed above, in the absence of sufficient evidence the accounting methodology should consider by default the *maximum potential extent of leakage*, and accordingly set this parameter at 100%. In the Sensitivity analysis section below we discuss the sensitivity of the results to variations in this parameter.

We first multiply this value by the amount of charcoal required for biochar-C sequestration and divide the resulting quantity by the charcoal-to-LPG fuel-switching equivalent to obtain a total of 92.6 kg of LPG required.

The resulting GHG emissions from the combustion of LPG amount thus to 277 kg of CO_2 equivalent, calculated by multiplying the amount required to displace the charcoal by the net calorific value (NCV) and the default IPCC emission factor for LPG. These GHG emissions represent the maximum extent of potential leakage in this example.

Emissions associated with the combustion of charcoal in the baseline are not accounted for. This is consistent with the assumption of the same quantity of biomass used for biochar production[8] being sourced (within the project boundaries) as the residue of existing agricultural or forestry activities. Under this assumption, the biomass can be considered renewable and thus carbon neutral for the purpose of accounting net GHG emissions.

The resulting *maximum potential extent of leakage* for the present example expressed as a fraction of the tonnes of CO_2 equivalent mitigated through biochar-C sequestration, is thus 27.7%. This is the value that should be adopted by default to account for the risk of leakage in the example provided.

The calculations described to obtain this value are summarized in Table 2 below.

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[8] a net reduction in GHG emissions, within the project boundaries, could be observed as a result of the project activity implementing improved pyrolysis technologies (e.g. continuous feed pyrolysis reactors with syngas/energy recovery) with regard to the baseline charcoal production methods (e.g. traditional carbonization in earth mounds or pyrolysis kilns without syngas/energy recovery). This would be already accounted for within the methodology and does not affect the leakage calculations here described.

Table 2. Leakage example, summary of calculations

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Sensitivity analysis

It should be noted how the leakage calculations described are extremely dependent on the specific context of the biochar scheme in question, and particularly to the assumptions made with regard to the two fundamental characteristics of the biochar with regard to its suitability to biochar-C sequestration purposes: its carbon content and the fraction of recalcitrant C.

We illustrate the influence of these two parameters by means of a sensitivity analysis, varying them as follows:

- carbon content, between the values of 50% and 90%,
- recalcitrant C fraction, between the values of 70% and 95%

The scatter plot in Figure 2 below presents the results of this sensitivity analysis.

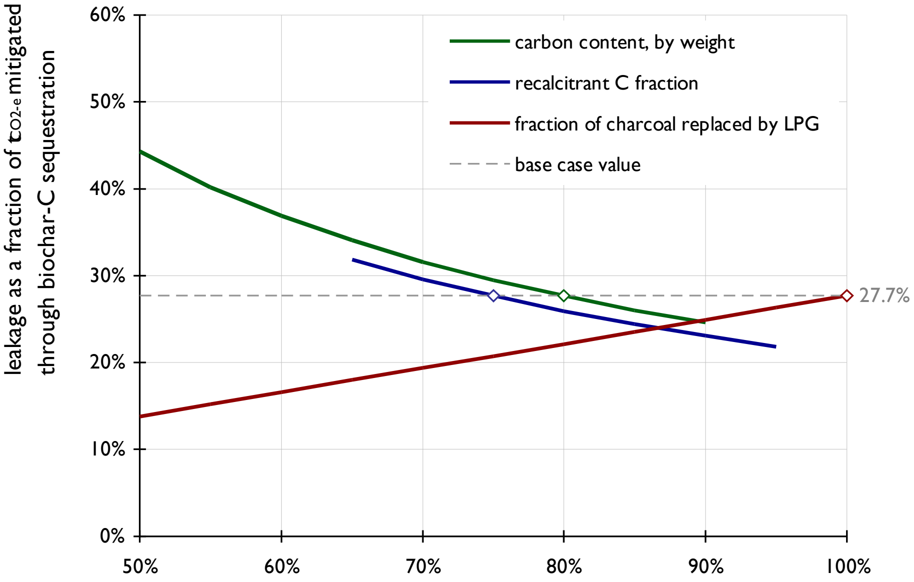

Figure 2. Leakage example, sensitivity analysis

At the lower end of the range, a carbon content of 50% determines an increase in the extent of leakage from the base case value of 27.7% to 44.3%[9]. Similarly, a recalcitrant C fraction of 70% determines an increase in the extent of leakage from the base case value of 27.7% to 29.6%.

At the maximum values of 90% and 95% for carbon content and 95% for recalcitrant C fraction the resulting extent of leakage is 24.6% and 21.8%, respectively.

In our sensitivity analysis we also explore the influence of the fraction of charcoal that needs to be replaced by LPG (e.g. the extent of fuel-switching induced outside of the project boundaries by the implementation of the project activities); leakage has a linear dependence from this parameter: the extent of leakage under a 50% induced fuel-switching scenario is 13.85% or half the extent of leakage in the base case scenario considered.

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[9] It should be noted how our simplified analysis does not consider how the lower heating value varies for charcoals with different carbon contents.

References

[1] Carbon Gold 2009. *General Methodology for Quantifying the Greenhouse Gas Emission Reductions from the Production and Incorporation into Soil of Biochar in Agricultural and Forest Management Systems*. Submitted by Carbon Gold to the Voluntary Carbon Standard, July 2009. <http://www.v-c-s.org/>

[2] CDM/EB 2009. *Glossary of CDM terms. Version 05*. CDM-Glos-05, published by the Executive Board of the Clean Development Mechanism, United Nations Framework Convention on Climate Change, 19 August 2009. <http://cdm.unfccc.int/>

[3] Hammes, K., M.S. Torn, A.G. Lapenas and M.W.I. Schmidt 2008. Centennial black carbon turnover observed in a Russian steppe soil. *Biogeosciences*, 5:1339-1350. <http://www.biogeosciences.net/>

[4] Hammes, K. and M.W.I. Schmidt 2009. Changes of Biochar in Soil. *In:* Biochar for Environmental Management: science and technology. Lehmann, J. and S. Joseph (Eds.). London: Earthscan, Chapter 10:169-182. <http://www.earthscan.co.uk/>

[5] IPCC 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Prepared by the National Greenhouse Gas Inventories Programme. Eggleston, H.S., L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Kanagawa, Japan: Institute for Global Environmental Strategies. <http://www.ipcc-nggip.iges.or.jp/>

[6] Joseph, S. and E. Krull (Eds.) 2009. *Guidelines for a Safe Biochar Industry*. Draft for discussion, August 2009. Available through the website of the International Biochar Initiative <http://www.biochar-international.org/>

[7] Lehmann, J., J. Gaunt, and M. Rondon 2006. Biochar sequestration in terrestrial ecosystems - a review. *Mitigation and Adaptation Strategies for Global Change*, 11:403-427. <http://www.springerlink.com/>

[8] Lehmann, J., C. Czimczik, D. Laird and S. Sohi 2009. Stability of Biochar in Soil. *In:* Biochar for Environmental Management: science and technology. Lehmann, J. and S. Joseph (Eds.). London: Earthscan., Chapter 11:183-206. <http://www.earthscan.co.uk/>

[9] Pigneri, A. and R. Anaya de la Rosa 2009. Opportunities and challenges for biochar/bioenergy systems in the compliance and voluntary carbon markets. Presented at the 1st Asia-Pacific Biochar Conference, Gold Coast, Australia, 17-20 May 2009. <http://www.anzbiochar.org/>

[10] Smith, K.R., R. Uma, V.V.N. Kishore, K. Lata, V. Joshi, J Zhang, R.A. Rasmussen and M.A.K. Khalil 2000. *Greenhouse Gases from Small-scale Combustion Devices in Developing Countries, Phase IIa: Household Stoves in India.* Technical report EPA-600/R-00-052, prepared for the U.S. Environmental Protection Agency, Office of Research and Development, June 2000. <http://www.epa.gov/>