Application of the Oeko-Institut/WWF-US/EDF methodology for assessing the quality of carbon credits

This document presents results from the application of version 3.0 of a methodology, developed by Oeko-Institut, World Wildlife Fund (WWF-US) and Environmental Defense Fund (EDF), for assessing the quality of carbon credits. The methodology is applied by Oeko-Institut with support by Carbon Limits, Greenhouse Gas Management Institute (GHGMI), INFRAS, Stockholm Environment Institute, and individual carbon market experts. This document evaluates one specific criterion or sub-criterion with respect to a specific carbon crediting program, project type, quantification methodology and/or host country, as specified in the below table. Please note that the CCQI website Site terms and Privacy Policy apply with respect to any use of the information provided in this document. Further information on the project and the methodology can be found here: www.carboncreditquality.org

Sub-criterion:	1.3.2 Robustness of the quantification methodologies applied to determine emission reductions or removals
Quantification methodology:	Clean Development Mechanism (CDM) AMS-II.G, Version 12.0, and CDM TOOL30, Version 3.0
Assessment based on carbon crediting program documents valid as of:	30 June 2021
Date of final assessment:	20 May 2022
Score:	1

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Assessment

Relevant scoring methodology provisions

The methodology assesses the robustness of the quantification methodologies applied by the carbon crediting program to determine emission reductions or removals. The assessment of the quantification methodologies considers the degree of conservativeness in the light of the uncertainty of the emission reductions or removals. The assessment is based on the likelihood that the emission reductions or removals are under-estimated, estimated accurately, or over-estimated, as follows (see further details in the methodology):

Assessment outcome	Score
It is very likely (i.e., a probability of more than 90%) that the emission reductions or removals are underestimated, taking into account the uncertainty in quantifying the emission reductions or removals	5
It is likely (i.e., a probability of more than 66%) that the emission reductions or removals are underestimated, taking into account the uncertainty in quantifying the emission reductions or removals OR The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) and uncertainty in the estimates of the emission reductions or removals is low (i.e., up to ±10%)	4
The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) but there is medium to high uncertainty (i.e., ±10-50%) in the estimates of the emission reductions or removals OR It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, but the degree of overestimation is likely to be low (i.e., up to ±10%)	3
The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) but there is very high uncertainty (i.e., larger than ±50%) in the estimates of the emission reductions or removals OR It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, and the degree of overestimation is likely to be medium (±10-30%)	2
It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, and the degree of overestimation is likely to be large (i.e., larger than ±30%)	1

Information sources considered

CDM quantification methodologies and documents:

1 CDM AMS-II.G, Version 12.0. Small-scale methodology for energy efficiency measures in thermal applications of non-renewable biomass

2 CDM TOOL30, Version 03.0. Methodological tool for the calculation of the fraction of non-renewable biomass.

3 CDM Concept Note CDM-MP85-A07. Analysis and options regarding caps used in AMS-I.E, AMS-II.G and TOOL30 Version 01.0

Further literature:

4 Gold Standard (2016) “Guidebook to Gold Standard and CDM Methodologies for Improved Cookstove Projects”, Version 1.0

5 Cames et al. (2016), Öko-Institut “How additional is the Clean Development Mechanism?”

6 Shishlov, Bellassen (2015) “Review of the experience with monitoring uncertainty requirements in the Clean Development Mechanism.”, Climate Policy, published online: 04 June 2015

7 Bailis et al. (2015) “The carbon footprint of traditional wood fuels.”, Nature Climate Change, published online: 19 January 2015

8 Bailis et al. (2020), Ci-Dev “Fraction of the non-renewable biomass in emission crediting in clean and efficient cooking projects.”, Word Bank Group, published online: September 2020.

9 IPCC 2006 Guidelines “Emission factors for the combustion of fuels for energy generation in the residential sector”

Original references for issues raised on f_{NRB} in the above documents:

10 Statistical Balances, International Energy Agency, 2012; http://www.iea.org/stats/index.asp

11 Rogner et al. in Climate Change 2007: Mitigation of Climate Change (eds Metz, B. et al.) 95–116 (IPCC, Cambridge Univ. Press, 2007).

12 de Miranda et al. (2013), de Miranda Carneiro, R.; Bailis, R. & de Oliveira Vilela, A. (2013). “Cogenerating electricity from charcoaling: A promising new advanced technology.”, Energy for Sustainable Development, 17 (2), pp. 171-176.

Original references for issues raised on accuracy and uncertainty in Source (2), pages 135-136:

13 Abeliotis & Pakula (2013) “Reducing health impacts of biomass burning for cooking.”

14 Lee et al. (2013), Lee, C. M.; Chandler, C.; Lazarus, M. & Johnson Francis X. (2013). “Assessing the Climate Impacts of Cookstove Projects: Issues in Emissions Accounting.” Available at https://www.sei-international.org/mediamanager/documents/Publications/Climate/sei-wp-2013-01-cookstoves-carbon-markets.pdf

15 Johnson et al. (2010), Johnson, M.; Edwards, R. & Masera, O. (2010). “Improved stove programs need robust methods to estimate carbon offsets.”

16 Berrueta et al (2008): Berrueta, V., Edwards, R. & Masera, O. (2008). Energy performance of wood-burning cookstoves in Michoacan, Mexico. Renewable Energy, 33(6), pp. 859–870.

References for issues raised on behavioral patterns:

17 Hanna et al (2016), Hanna, R., E. Duflo, and M. Greenstone, 2016 "Up in Smoke: The Influence of Household Behavior on the Long-Run Impact of Improved Cooking Stoves.", Am. Econ. J. Econ. Policy, 8, 80–114, https://doi.org/10.1257/pol.20140008.

18 Wathore et al. (2017), Wathore, R., K. Mortimer, and A. P. Grieshop, 2017 "In-Use Emissions and Estimated Impacts of Traditional, Natural- and Forced-Draft Cookstoves in Rural Malawi.", Environ. Sci. Technol., 51, 1929–1938, https://doi.org/10.1021/acs.est.6b05557.

19 Patange et al. (2015), Patange, O. S., and Coauthors, 2015 "Reductions in Indoor Black Carbon Concentrations from Improved Biomass Stoves in Rural India.", Environ. Sci. Technol., 49, 4749–4756, https://doi.org/10.1021/es506208x.

20 Aung et al. (2016), Aung, T. W., G. Jain, K. Sethuraman, J. Baumgartner, C. Reynolds, A. P. Grieshop, J. D. Marshall, and M. Brauer, 2016 "Health and Climate-Relevant Pollutant Concentrations from a Carbon-Finance Approved Cookstove Intervention in Rural India.", Environ. Sci. Technol., 50, 7228–7238, https://doi.org/10.1021/acs.est.5b06208.

21 Schilmann et al. (2019), Schilmann, A., and Coauthors, 2019 "A follow-up study after an improved cookstove intervention in 17 rural Mexico: Estimation of household energy use and chronic PM2.5 exposure.", Environ. Int., 18 131, 105013, https://doi.org/10.1016/j.envint.2019.105013

22 Shankar et al. (2014), Shankar, A., and Coauthors, 2014 "Maximizing the benefits of improved cookstoves: moving from acquisition to correct and consistent use.", Glob. Heal. Sci. Pract., 2, 268–274, https://doi.org/10.9745/GHSP-D-14-00060.

References for issues raised on the wood to charcoal conversion factor:

23 Revised IPCC Guidelines for National Greenhouse Gas Inventories Reference Manual (1996): Energy Chapter, page I.46, https://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ref3.pdf .

References for issues raised on default factor:

24 CDM Information Note (CDM-SSCWG42-A05). Rationale for default factors used in AMS-I.E and AMS II.G Version 1.0. Available at https://cdm.unfccc.int/Panels/ssc_wg/meetings/ssc_2013.html#42

Assessment outcome

The quantification method of methodology CDM AMS-II.G, Version 12.0, applied in combination with CDM TOOL30, Version 03.0, is assigned a score of 1. This assessment also applies to earlier versions of the methodology.

Justification of assessment

Project Type

This assessment refers to the following project type:

"Distribution of energy efficient fuel wood or charcoal cookstoves to households or institutions (e.g. schools), thereby replacing the use of less energy efficient fuel wood or charcoal cookstoves."

This is within the scope of the quantification methodology, which is applicable to the "introduction of efficient thermal energy generation units utilizing non-renewable biomass (e.g. complete replacement of existing biomass-fired cookstoves or ovens or dryers with more efficient appliances), or retrofitting of existing units reducing the use of non-renewable biomass for combustion" (Source 1).

Projects involving wood cookstoves are likely to occur in mainly rural areas, in households that cannot afford to buy any other type of solid fuel (e.g., charcoal, which is easier to handle) and thus rely on the collection of wood from the surrounding areas. In some cases, however, rural households might also use charcoal, but this is less common. This means that the baseline scenario would be cooking with wood or charcoal. Solar and biogas cookers replacing non-renewable biomass cooks stoves are covered instead by the methodology AMS-I.E, which concerns switching fuels.

Any other type of fuel displaced, apart from wood or charcoal, is therefore not part of this assessment or project type covered by AMS-II.G. In the case of urban households that use LPG, switching from this fuel to non-renewable biomass could increase emissions and this type of switch is unlikely to happen. The methodology is not applicable to this type of user. This highlights the importance of rigorous assessment of methodology applicability, which is required under the CDM.[1]

Also, another important consideration is the local context in which the project is implemented – and particularly the level of exposure to indoor air pollutants and the resulting burden on public health. While this is very high in some geographic locations, the methodology does not differentiate among countries. The countries that experience the highest levels of exposure to household air pollutants, and that are thus in the greatest need for projects that will alleviate the current burden on public health, such as efficient cookstove projects that effectively reduce the volume of indoor emissions from cooking, are identified by Bailis et al. (Source 7) to be:

- Africa: Chad, DR Congo, Cote d´Ivoire, Guinea, Guinea-Bissau, Liberia, Mozambique, Sierra Leone, Tanzania, Zambia, Zimbabwe, Cameroon, Central African Republic, Malawi, Mali, Niger, Timor-Leste, Kenya, Uganda, Ethiopia, Lesotho, Somalia, Togo, Burkina Faso, Burundi, Gambia, Eritrea, Rwanda, Sudan, Madagascar, and Benin.
- Asia: Pakistan, Bangladesh, Bhutan, Nepal, Indonesia, Laos, Myanmar, and Cambodia.
- Americas: Haiti.

The health benefits from indoor emission reductions resulting from the adoption of efficient cookstoves are therefore more significant in countries with the highest global burden of disease from exposure to household air pollutants (HAP), although the emission reductions of the project are based on the same parameters in any location.

Focus of assessment

The focus of this assessment is the emission reduction determination in Equations 1 and 2 of the CDM methodology and tool, in particular the specific elements that potentially introduce uncertainty. These elements are the amount of **wood saved**, the **emission factor based on fossil fuels**, and the f**raction of non-renewable biomass**, all of which are used in the calculation of the emission

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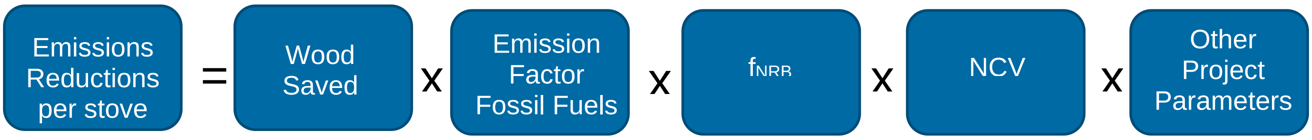
[1] For example, the Validation and Verification Standard for CDM project activities requires that, "The DOE shall validate that the selected methodologies…are applicable to the proposed CDM project activity… The DOE shall determine whether the selected methodologies…apply to the proposed CDM project activity and was correctly applied with respect to the following: (a) Project boundary; (b) Baseline identification; (c) Algorithms and/or formulae used to determine emission reductions; (d) Additionality; (e) Monitoring methodology."

reductions from improved stove projects. Figure 1 below shows the main elements of the quantification of emission reductions, most of which play a key role in the potential for the methodology to result in an under- or overestimation of emissions reductions.

Figure 1 Emission reductions as calculated in AMS-II.G, Version 12



Where:

- The **wood fuel savings** are quantified by one of the three approaches described in Equations 4-9 in pages 9-11 of the methodology (i.e., Water Boiling Test (WBT), Controlled Cooking Test (CCT) and Kitchen Performance Test (KPT)).
- The **emission factor (EF)** is based on displaced fossil fuels and may be calculated specifically for the project or a taken from the list of regional default values.
- The **fraction of non-renewable biomass (f_{NRB})**, based on CDM TOOL30, may be calculated using area-specific data or taken from the default value of 30%.
- The **net calorific value (NCV)** of the non-renewable wood substituted is taken from the IPCC default values for the combustion of wood in the residential sector (0.0156 TJ/t) or the measured NCV value for projects using briquettes as fuel, as stated in page 24 of the methodology.
- **Other project parameters**, included in Equation 2 on page 7 of the CDM AMS-II.G Version 12.0 methodology, are: number of devices, proportion of installed devices that are operational, and adjustment factor for the continuation of use of pre-project devices.

Elements potentially overestimating emission reductions

It is very likely for the following elements to have a systematic bias toward overestimation of project emission reductions under the AMS-II.G:

OE1. Fraction of non-renewable biomass (f_{NRB})

The fraction of non-renewable biomass (f_{NRB}) is the share of non-renewable wood in the total quantity of wood consumption for the country, region or project area, as described by in the CDM TOOL30.

This fraction has been estimated at different spatial levels. For example, at a global level, the f_{NRB} is estimated by the 4th assessment of the Intergovernmental Panel on Climate Change (IPCC) to be 10% (Sources 10 and 11), while Bailis et al. (Source 7) estimated country specific values between 27% and 34%, and Miranda et al. (Source 12) between 20% to 30%. By contrast, the median f_{NRB} used by 305 carbon market projects in 45 countries, as surveyed by Bailis et al. (Source 7) was 90%. Moreover, the f_{NRB} used by more than 85% of the 97 programs of activities (PoAs) in the CDM pipeline is above 80%. Out of these 97, only 3 reported f_{NRB} values below 60% (Source 3). In addition, the f_{NRB} used in the vast majority of 186 monitoring reports from 10 project activities and 39 PoAs reviewed by the CDM is above 80%, with the highest value being 100% in Bangladesh (Source 3). None of the f_{NRB} values were below 60% (Source 3). This is because the calculation approaches that are allowed in the methodology and tool can lead to much higher values than the more detailed spatial analysis approaches used in the literature to more accurately assess f_{NRB}.

When the CDM Tool 30 was introduced in 2017, it included a conservative default value of 30% as one of the options for project developers, which was much lower than the values being used in carbon market projects at the time. The value was based on the work of Bailis et al. (Source 7) and was therefore in the middle of the range of 27-34% from that peer-reviewed study.

However, project developers were also given the option to determine country-specific, or even locality-specific, f_{NRB} values based on local studies. This explains why Bailis et al. (2020), in the Carbon Initiative for Development (Ci-Dev) review of the f_{NRB} in efficient cooking projects, noted that "since November 2017, when TOOL30 was approved, only eight registered programs of activities have adopted the tool, and just one has elected to use the conservative default value of 30%. The remaining programs of activities have all calculated their own f_{NRB} values, ranging from 82% to 97%, which are much higher than (the more detailed spatial modelling using) WISDOM-derived values" (Source 8). This also explains why out of the 186 monitoring reports mentioned above, only 1 PoA used an approved standardized baseline value, 51% determined the values for the f_{NRB} through default values adopted by the CDM Executive Board, and the remaining 48% calculated values based on international reports and statistics, such as publications from the Food and Agriculture Organization by the United Nations (FAO) and Intergovernmental Panel on Climate Change (IPCC) (Source 3).

While it is possible that cookstove projects registered under carbon crediting programs could be implemented in geographical areas with higher f_{NRB} values, it appears unlikely that the true (unknown) values for f_{NRB} are significantly higher in these projects than the values from the literature. Projects registered under carbon crediting programs have been implemented in many different regions, including deforestation hotspots but also areas where the literature suggests that the values f_{NRB} are much lower than the values used by registered projects.

In December 2020, the CDM Executive Board (CDM EB 108) considered the recommendation from the Methodologies Panel (MP) to cap the f_{NRB} at 60% and only allow for higher values under specific conditions. The Board did not decide on this recommendation but requested the MP to conduct additional analysis and explore alternative parameters to ensure this parameter is not overestimated (Source 3). This analysis has not yet been concluded.

Overestimation likelihood

Even with the revisions to the methodology and tool over the last few years, including the Concept Note with the considerations from CDM EB 108, project developers can still choose to calculate a project-specific f_{NRB} using Equations 1, 2, 3, and 4 on pages 4-6 of the CDM Tool 30 (Source 2), which involve input parameters of high uncertainty that may be estimated using less reliable options and data sources than the more detailed spatial modelling approaches used in literature (Source 8). One of these key parameters is the mean annual increment (MAI), which is used to estimate the annual supply of renewable biomass (RB), which is in turn used to calculate the amount of non-renewable biomass (NRB). The concepts of annual increment and sustainable yield, which are the key concepts underlying f_{NRB}, are taken from silviculture, where forest stands are well-bounded, planted with a single species, and not subject to other high-impact or simultaneous uses (Source 8). In contrast, the landscapes exploited for wood fuel are often forest mosaics with irregular stands of trees inter-mixed with crops and grazing lands, and they include many types of land cover other than forests, such as gardens, roadsides, live fences, agricultural lands, with undefined boundaries, which are also subject to multiple activities and periodic fires (Source 8). Therefore, there is large uncertainty in this parameter, and project developers are faced with the challenge of estimating MAI to determine the amount of RB. This has led to much higher values of f_{NRB} used in the projects that have applied the TOOL30 (Source 8), compared to values based on more detailed spatial modelling. Given that the peer-reviewed literature uses much more accurate and reliable approaches to estimate values for f_{NRB}, it is highly likely that the values used by project developers significantly over-estimate the f_{NRB}. Since NRB is determined by the quantity of renewable biomass (RB), subtracted from the total consumption (H) of wood, and the underestimation of the total consumption leads to an underestimation of the f_{NRB}, it is highly likely that the overestimation of the f_{NRB} lies in the underestimation of the RB.

On the other hand, another element of uncertainty that impacts the estimation of the f_{NRB}, but in the opposite direction, leading to an underestimation of the f_{NRB}, is not accounting for illegal or unreported logging and land clearing for crops. This is likely to lead to an underestimation of the biomass depletion rate in the area, an overestimation of the extent of the biomass supplying area, and an overestimation of the regenerative capacity of the land, or in other words, an underestimation of H, overestimation of the RB, and an overestimation of the MAI, respectively.

On the other hand, any changes in the use of land throughout the project lifetime, along with any variations derived from climate change, such as additional heat stress or freezing temperatures, water shortage, pests, and forest fires, will further impact the capacity of the land to re-generate wood supply, represented or characterized by the MAI value. The AMS-II.G and the related tools currently do not account for climate change, illegal logging, and land clearing, which leads to overestimation of the MAI, and of the RB, and, in turn, to underestimation of the f_{NRB}.

However, as previously discussed, the values for the f_{NRB} used in projects that have adopted TOOL30 are highly likely to be significantly overestimated, not underestimated, which suggests that ignoring these other elements that underestimate the f_{NRB} is likely to have a smaller overall impact than that of the elements that are likely to lead to an overestimation of the f_{NRB}.

To summarize, given the high uncertainty involved with the calculation of MAI and the RB, and given that the calculated f_{NRB} values for projects in practice are much higher than 30%, it is highly likely that project developers will choose to calculate their own f_{NRB} values instead of using the 30% default value. They therefore likely overestimate the f_{NRB}, which leads to overestimation of the emission reductions. The earlier citation from the CiDev report (Source 8) supports this, with almost no new projects choosing the conservative default value, pointing out that challenges remain and that more work is needed to ensure the environmental integrity of cookstove projects under the CDM. This finding is consistent with findings by relevant other studies (Source 5 and 7), including the CDM reviews cited earlier (Source 3).

Degree of Overestimation

As noted above, for projects applying TOOL30 since November 2017, f_{NRB} values range from 82 to 97 percent. Compared to the default value or the 27-34% range found by the Bailis et al (Source 7) study in tropical countries, this could lead to an over-estimation of in the order of **240%** to **360%** (i.e., 82%/34% to 97%/27%).

OE2. Wood to charcoal conversion factor

According to paragraph 35 on page 12 of AMS-II.G, “where charcoal is used as the fuel, the quantity of wood is determined by using the default wood to charcoal conversion factor of 6 kg of firewood, on a wet basis[2], per kg of charcoal on a dry basis. Alternatively, credible local conversion factors determined from a field study or literature may also be applied."

The review of 49 CDM registered project activities and PoAs for cook stoves showed that 38% involved charcoal, and that the values for the conversion factors used in these projects ranged from **6 to 12**. 74% of the values used the default value of 6 kg, while the remaining 26% used values based on literature, ranging from 7 to 12 kg (Source 3).

This wood to charcoal conversion factor is listed in paragraph 16 of page 5 of the TOOL30 (Source 2). As a source, the Revised 1996 IPCC Guidelines are cited. The Revised 1996 IPCC Guidelines indeed refer on page I.46 of the energy sector to a value of 6 kg of firewood per kg of charcoal in the absence of further information. They state, however, that the typical wood to charcoal conversion factors in many developing countries "would range from 2.5 to 3.5 and rarely beyond this" (Source 23). Given that the CDM is applied in developing countries, the methodology does not refer correctly to the 1996 Revised IPCC Guidelines. In the 2006 IPCC Guidelines (Source 9), the wood to charcoal conversion factor is no longer referenced. In addition, the methodology does not specify under what criteria, threshold, or indicator would a local conversion study be considered "credible".

If the range of 2.5 to 3.5 would be realistic today for developing countries, using the default factor of 6 kg would lead to an overestimation of emission reductions by a factor of two. Using local conversion factors determined from literature, as allowed by the methodology, has previously led to the use of an even larger values than 6, as observed in CDM PoAs in Mozambique, Togo, Kenya, Madagascar, and Rwanda (Source 3).

Recently, the CDM Executive Board considered a recommendation for a cap limiting this parameter to a maximum of 8 kg with exceptions to allow for higher values under specific conditions (CDM EB 108). The Board considered this recommendation and requested the MP to conduct additional analysis and explore alternative parameters to ensure this parameter, along with the f_{NRB} and the average woody biomass consumption, are not overestimated (Source 3). This analysis has not yet been concluded.

Overall, it can be concluded that there is considerable uncertainty whether the wood to charcoal conversion factors are appropriate. Comparing both the allowable default factors and the practice in many projects with the Revised 1996 IPCC Guidelines suggests that the factor may be overestimated by a factor of two or more, leading to an overestimation of overall emission reductions.

OE3 Average annual consumption of woody biomass per person

The average annual consumption of woody biomass per person may be determined under this methodology using a default value of 0.5 tons/capita/year, historical data or sample surveys, or national/regional values approved as standardized baselines (Source 3). The default value of 0.5 tons/capita/year was derived in 2013 by the Small-Scale Working Group of the CDM, based on an analysis of projects, the literature, and the minimum energy demand for cooking (Source 24). Both data from projects and the literature confirmed that this value is a typical value to be expected for these types of projects. Since the higher the rate of wood consumption, the higher the resulting biomass saved, and the more carbon credits generated by the project, the use of lower values is more conservative than the use of higher values.

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[2] The term 'wet basis' assumes that the wood is 'air-dried' as is specified in the IPCC default table (Source 23).

Only around 1% of the monitoring reports for CDM cookstove projects reviewed by the UNFCCC Secretariat for the Methodologies Panel used the default value of 0.5 tons/capita/year. The rest were calculated with the 2nd and 3rd options: 64% calculated the woody biomass consumption from primary data and 34% from secondary data based on literature (Source 3). The values from projects that calculated this parameter are, not surprisingly, well above the default value. The consumption per capita per year reported in CDM project design documents (PDD) averages 0.75 tons/capita/year for Asia and Sub-Saharan Africa, 0.83 tons/capita/year for the Middle East and North Africa, and 1.34 tons/capita/year for Latin America (Source 3), all of them well above the default value of 0.5 tons/capita/year.

In December 2020, the Methodologies Panel recommended a cap of 0.9 tons per person for the average annual consumption of woody biomass, with exceptions for higher values under certain conditions. This cap is based on data from the United Nations and Demographic and Health Surveys Program and considers an additional standard deviation of 0.38 above the average expected value of 0.52 (0.52+0.38) (Source 3). The Board also requested the Methodologies Panel to conduct additional analysis and explore alternative means to ensure this parameter is not overestimated (Source 3). This analysis has not yet been concluded.

Overall, it seems likely that the woody biomass consumption is over-estimated in many projects. Given that the average values reported in PDDs are 50-75% higher than the default value (which is meant to be a typical value not a conservative one), the level of overestimation could be significant for many projects.

OE4 Behavioral patterns

Stove stacking

Efficient cookstove projects are meant to displace pre-existing cookstoves. However, the pre-existing stoves may also be kept and used for different purposes, a phenomenon called “stove stacking”. In these cases, the efficient cookstoves have not fully replaced the previous consumption of biomass in traditional stoves. Thus, some of the fuel savings estimated, which assumed 100% of the cooking would take place with a single, new, device, provided by the project, will not take place in reality, leading to an overestimation of emission reductions.

Paragraph 34 on page 11 of AMS-II.G provides guidance for when two project devices are installed per household, in which case the total baseline wood consumption is divided between the two devices, and when possible, details on the thermal capacity, utilization hours, weighted average thermal output may be used to determine the savings of baseline consumption for each device.

However, this guidance, along with Equations 10 and 11 of the methodology, refers to two project devices being in use simultaneously over the crediting period, not one new and one old device, although the same criteria could be adapted to address stove stacking.

The methodology does include an adjustment factor to account for the continued use of a baseline stove, although it is less clear how this would be monitored and verified. Therefore, the degree to which this behavioural element would result in overestimation is unknown.

OE5 Cumulative adoption rate / Project implementation rate

The parameters concerning usage rate in Figure 1 do not include the adoption rate specifically. Whether or not the “proportion of installed devices that are operational” reported by project developers may ultimately consider the periodic adoption of project cookstoves, where applicable, would be under the discretion of project developers, since the cumulative adoption rate is not specifically addressed by the methodology.

Un-accounting for the fact that not all of the project cookstoves may become operational since the start of the project overestimates project emission reductions.

Elements potentially underestimating emission reductions:

It is very likely for the following elements to have a systematic bias toward underestimating project emission reductions under the methodology AMS-II.G.

UE1 Baseline emission factor based on fossil fuels

The emission factor (EF) used to estimate emission reductions in **Figure 1** is based on displaced fossil fuels and can either be calculated or be chosen from the default regional values listed on paragraph 25, page 8, of AMS-II.G, shown further below in **Table 2**.

Emission factors are based on the assumption that in the absence of the project, cooking would take place with the combustion of fossil fuels, as described in paragraph 23 of page 6 of the methodology, which is incongruent with the project type described on page 3 of the AMS-II.G, which addresses the reduction of non-renewable biomass combustion (and therefore excludes fossil fuel based baselines).

As noted in page 137 of Cames et al. (Source 5), this was the CDM Executive Board's solution to the fact that the only forestry-related project types allowed under the CDM were afforestation and reforestation – which does not include avoiding forest loss or degradation.

Underestimation likelihood

Using the emission factor for fossil fuels underestimates emissions reductions. As shown in **Table 1** below, the emission factor for the combustion of both wood and charcoal, which is 112 t CO_2/TJ according to the IPCC (Source 9) is the highest among the fuels commonly used in household applications, such as cooking, which makes any emission factor below 112 tCO_2/TJ lead to underestimation of emission reductions for projects using wood or charcoal as the baseline fuel. In this scenario, all of the values presented in **Table 2**, corresponding to the regional default values established by the methodology, are well below the default emission factor for CO_2 from the combustion of wood.

Therefore, for projects using wood or charcoal as a baseline fuel, estimating the emission factor as the average of a selected mix of fossil fuels in the proportion determined as most appropriate for the project location, or chosen from the regional default values listed in **Table 2**, this part of the methodology, requiring the use of emission factors from displaced fossil fuels in wood or charcoal fuel improved cookstove projects, will very likely lead to an underestimation of emission reductions.

Table 1 **IPCC default emission factors (EF) for common household fuels (6), in ascending order according to EFs for CO_2**

FUEL	DEFAULT CO2 EF (t/TJ)	DEFAULT CH4 EF (t/TJ)	DEFAULT N2O EF (t/TJ)
Liquefied petroleum gas (LPG)	63.1	0.005	0.0001
Kerosene	71.9	0.01	0.0006
Coal	94.6	0.3	0.0015
Wood	112	0.3	0.004
Charcoal	112	0.2	0.001

Degree of underestimation

The degree of underestimation will depend on the percentage determined for each of the displaced fossil fuels in the matrix, which will in turn determine the emission factor used to estimate the total fuel saved. For projects using both wood and charcoal as a baseline fuel, the higher the resulting emission factor, the lower the degree of underestimation.

Also, the higher the emission factor, the higher the resulting emissions reductions according to **Figure 1**, and thus the higher the profitability of the project, which is why project developers are assumed to be inclined towards the estimation alternative that results in the highest possible emission factor.

Table 2 shows the regional default emission factors presented by the methodology. The choice of regional default emission factors ranges from 57.8 to 85.7 tCO2e/TJ, while the individual fossil fuel emission factors that are used for the calculated EF range, as shown in **Table 1**, from 56.1 to 94 tCO_2e/TJ, the latter being the EF for CO_2 from the combustion of coal, which is not even commonly used for cooking in most countries. LPG and kerosene, which have Efs of 63.1 tCO_2e/TJ and 71.9 tCO_2e/TJ, respectively, are the fuels most likely to be used by similar consumers in the absence of wood. All these emission factors are well below the emission factor for CO_2 from the combustion of wood, which is 112 tCO2e/TJ.

Table 2 **Default regional emission factors (EF), in ascending order, used under the CDM AMS-II.G Version 12 methodology in paragraph 25, page 8**

REGION	DEFAULT EF (t CO_2e/TJ)
Europe and Central Asia	57.8
Middle East and North Africa	63.9
South Asia	64.4
Latin America and the Caribbean	68.6
Sub-Saharan Africa	73.2
East Asia and the Pacific	85.7

Therefore, the degree of underestimation depends on the final value of emission factor, and may range from 17% to 49%, with the highest values corresponding to projects using the lowest Efs (i.e., 57.8 tCO2e/TJ for Europe and Central Asia).

However, because project developers will choose the quantification alternative resulting in the highest emission reductions, and using host country values to determine a matrix of displaced fuels may lead, in some cases, to an EF higher than the regional default values, the underestimation of emissions reductions will likely tend to be somewhat lower than based on the regional default values.

Elements with uncertain impact

The following elements introduce uncertainty. However, assessing whether they lead to systematic under or overestimation of project emission reductions, requires a more detailed analysis.

U1 Fuel saved

The **wood fuel savings** are quantified by one of the following three methodologies, as described in Equations 4-9 in pages 9-11 of the methodology, all of which involve uncertainty:

- Thermal Energy Output (TEO) of the stove, combined with different efficiencies for project and baseline cooking devices.
- Kitchen Performance Test (KPT), which is a field-based method that better represents cooking behavior but yields high uncertainty in the measurements, since sources of error are difficult to control (Source 4).
- Water Boiling Test (WBT) which is a laboratory-based method that is standardized and replicable, with the additional advantages of simplicity and reduced costs, but with a lower accuracy level due to under-representation of cooking habits (Source 10) as well as reliance on default values for baseline cookstove biomass consumption (Source 4).
- Controlled Cooking Test (CCT) which is laboratory-based method that demonstrates what is possible under ideal conditions, but not necessarily what occurs under daily use (Source 4).

As for the WBT, the accuracy of this method has been called into question by Abeliotis & Pakula (2013), who found that stove performance does not necessarily translate to cooking actual meals in households (Source 13), and by Berrueta et al. (2008), who evaluated the performance of a stove designed primarily for tortilla-making by using all three tests and found that the WBT “gave little indication of the overall performance of the stove in rural communities” (Source 16). Furthermore, Cames et al. (2016) indicate that evidence suggests the Water Boiling Test (WBT) is not an appropriate tool and should be removed from the CDM methodology (Source 5).

Whether the different approaches other than KPT consistently over- or under-estimate biomass savings and emission reductions is not clear.

U2 Ex-ante estimate of f_{NRB}

Paragraph 27 on page 9 of the methodology AMS-II.G provides two options for the timing of the calculation of the f_{NRB}: ex-ante, before the emission reductions take place and determined only once during the crediting period, and ex-post, after the emission reductions take place, at an annual basis (Source 1). Estimating the f_{NRB} once for the entire crediting period, without re-evaluating circumstances that may arise unexpectedly year by year, is an approach that may lead to an over- or underestimation of emission reductions. However, the magnitude and direction of impact requires further analysis.

U3 Efficiency losses

The methodology AMS-II.G addresses the loss of efficiency through one of the following four alternatives, all of which apply for projects estimating fuel savings through the thermal energy output and water boiling tests only: a) assuming a constant linear decrease, b) assuming no decrease at all, justified through national standards or appropriate certifying agent, c) measuring the decrease for the first batch only, or d) measuring a representative sample for each batch annually. When project participants use the first batch approach (option c), the methodology specifies that project developers shall describe the measures taken to ensure all batches receive the same level of quality control in the maintenance and replacements during the crediting period as the first batch, and that the actions must be described in the monitoring reports. However, this statement does not mandate the need for maintenance or replacements themselves, but rather the need for comparability in the assessment criteria between the first batch and the following ones. For the rest of the options (a, b, and d), no further mention is made regarding maintenance and repair. Whether or not these issues are considered is under the discretion of project developers, although any degradation of efficiency will be picked up by option d) directly.

On the other hand, for projects estimating fuel savings through the other two methods allowed under the methodology, the kitchen performance test (KPT) and the controlled cooking test (CCT), the loss of efficiency due to aging is expected to be reflected through changes in the specific fuel consumption, captured by the project performance tests themselves. The KPT and the CCT shall be conducted in representative households, and for the CCT, the representative devices chosen must have been subject to the regular process of replacement/maintenance since the beginning. Furthermore, Parameter table 14 of the methodology specifies that the measurement procedures for the efficiency of the project cookstoves should be able to demonstrate that comparable repair and maintenance practices are undertaken on all project stoves.

The evaluation of the improved biomass cookstoves under real-world conditions has shown that they often have lower efficiency than expected, and in many cases, limited long-run health and environmental impacts, as the households use these stoves irregularly and inappropriately, fail to maintain them, and their usage declines over time (Source 17 to 20). In addition, other authors have previously noted the need to address mid- and long-term needs of maintenance, repair, or replacement to support their sustained use under various improved cookstove programs (Source 21 and 22).

Therefore, although the methodology AMS-II.G addresses a drop of efficiency during the project lifetime due to aging as a mandatory requirement on paragraph 37 (i.e. need for repairs and maintenance), there could be cases where the actual decline in efficiency is different from the assumed linear increase or the assumption of no decline, even when the latter is proposed by the manufacturer. The degree to which the unaccounted loss of efficiency can impact the emission reduction calculations is unknown, however, and would require further research to be defined.

U4 Other elements introducing uncertainty

Other elements addressed by the AMS-II.G that introduce uncertainty are:

- Stove lifetime (years)
- Rated thermal capacity of stoves (BTUs)
- Specific fuel consumption rates (tons of fuel/hour or tons of fuel/unit output)
- Average number of persons per household (number of persons)
- Usage rate parameters:
  - Stove utilization time (hours/year)
  - Number of devices

- proportion of installed devices that are operational
- Adjustment factor for the continuation of use of pre-project devices

While these variables do introduce uncertainty, the direction and magnitude of the uncertainty is not known.

Summary and conclusion

Table 3 summarizes the results of the assessment and, where possible, presents the potential impact on the quantification of emission reductions for each of the previously discussed elements.

Table 3 Relevant elements of assessment and qualitative ratings

Element	Fraction of projects affected by this element[3]	Average degree of under- or overestimation where element	Variability among projects where element materializes [4]
Elements potentially overestimating emission reductions			
OE1 Fraction of non-renewable biomass (f_{NRB})	High	High (on the order of 300%)	Low. In practice, since the adoption of TOOL30, f_{NRB} values for projects have ranged from 82-97%, while only one project has used the 30% default parameter. Previously, the median surveyed for 305 projects for 45 countries was 90%.
OE2 Charcoal conversion factor	High	High	Unknown
OE3 Average annual consumption of woody biomass	High	High	High. Average values are 50-75% of default value, so actual project-specific range would be even higher.

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[3] This parameter refers to the likely fraction of individual projects (applying the same methodology) that are affected by this element, considering the potential portfolio of projects. “Low” indicates that the element is estimated to be relevant for less than one third of the projects, “Medium” for one to two thirds of the projects, “High” for more than two third of the projects, and “All” for all of the projects. “Unknown” indicates that no information on the likely fraction of projects affected is available.

[4] This refers to the variability with respect to the element among those projects for which the element materializes. “Low” means that the variability of the relevant element among the projects is at most ±10% based on a 95% confidence interval. For example, an emission factor may be estimated to vary between values from 18 and 22 among projects, with 20 being the mean value. “Medium” refers to a variability of at most ±30%, and “High” of more than ±30%.

OE4 Behavioural patterns: stove stacking, decline in efficiency	Unknown	Unknown	Unknown
OE5 Adoption rate	Unknown	Unknown	Unknown
Elements potentially underestimating emission reductions			
UE1 Emission factor (EF) based on fossil fuels, wood fuel projects	High	Medium-High (with an approximate range of 17% to 49%).	Low. The actual woody biomass emission factor is likely to vary not very much.
Elements with unknown impact			
U1 Biomass fuel savings	Unknown	Unknown	Unknown
U2 Ex-ante estimate of f_{NRB}	Unknown	Unknown	Unknown
U3. Efficiency losses	Unknown	Unknown	Unknown
U4 Other elements introducing uncertainty	Unknown	Unknown	Unknown

Overall, the very likely overestimation of f_{NRB} has the largest impact on emission reduction quantification for cookstove projects. The magnitude of over-estimation exceeds by far the known magnitude of underestimation (i.e., due to the choice of baseline emission factors based on fossil fuels rather than wood or charcoal). Other factors also contribute to uncertainty, either with an unknown direction or with a tendency to overestimate emission reductions.

In conclusion, it is very likely that the overall emission reductions are significantly overestimated, considering the uncertainty in quantifying the emissions reductions, and the degree of overestimation is very likely to be significantly greater than 30%.

Supporting the conclusion of this assessment regarding the significant overestimation of emission reductions, are the conclusions by Bailis et al. (Source 7), indicating that project developers are very likely overstating the emission reduction potential of improved stoves, and by Cames et al. (Source 5) indicating that cookstove projects under the CDM are likely to be over estimating emission reductions considerably, due to a number of unrealistic assumptions and default values. Cames et al (Source 5) further recommend that cookstove methodologies be revised considerably, including more appropriate values for the fraction of non-renewable biomass, for efficient wood cookstove projects to remain eligible (Source 5).

Furthermore, Lee et al. (Source 14) also conclude that there is uncertainty in the approaches to estimating wood saved, the emission factor based on fossil fuels, and the fraction of non-renewable biomass, which are the same three parameters of focus of this assessment. A study by Johnson et al. (Source 15) assessed the relative contributions of these three variables to the overall uncertainty in carbon offset estimation for an improved cookstove project in Mexico, and also found that all three parameters of main focus of this assessment contributed significantly to uncertainty. The fraction of non-renewable biomass (f_{NRB}) contributed to 47% of the uncertainty, followed by fuel consumption which contributed to 28% of the uncertainty, while the emission factors of the projected fossil fuel accounted for remaining 25% of the uncertainty.

Therefore, according to the relevant scoring methodology provisions described in page 2 of this document, which assess the robustness of the quantification methodologies applied by the carbon crediting program to determine emission reductions or removals, the overall assigned score for the AMS-II.G Version 12.0 methodology is 1.