Climate Stewards Seal of Approval

Calculation of Savings in CO_2e resulting from the use of Biosand Water Filters

Contents

1. Introduction & Background

The Climate Stewards Seal of Approval (SoA) is designed to provide a simple framework for assessing carbon savings from small-scale projects in the developing world.

This methodology uses examples from Climate Stewards' work with A Rocha Uganda to provide context for the discussion of the use of Biosand Water Filters for carbon offsetting.

Biosand Water Filter projects in other countries and localaties would, at a minimum, need to perform a baseline survey of the households to be involved in order to establish a project baseline after which monitoring surveys would verify year-on-year emissions reductions.

In much of East Africa, where there is no piped water, and/or water supplies are contaminated, it is common to boil water in order to kill pathogens and make it safer to drink. Water is usually boiled using firewood or charcoal, thus contributing to local air pollution and to global climate change. Filtering water offers the opportunity to increase its safety for drinking without emitting CO_2 into the atmosphere, and brings the added potential advantages of saving money and/or time spent buying or collecting firewood or charcoal, reducing the incidence of respiratory and eye diseases caused by smoke, and reducing the pressure on non-renewable biomass resources within the project boundary.

Our partner, A Rocha Uganda (ARU), has been delivering biosand water filters (BSFs) to poor households since 2008. In total they have constructed and supported the use of 819 filters in eight communities (six in the capital city, Kampala, and two in other locations across the country). The filters are all household-level biosand water filters, built to a design developed by CAWST[1] for use in developing countries. The filters are constructed from concrete and other locally-available materials. The families who receive them construct them with training and support from A Rocha Uganda.

This paper provides an explanation of the methodology used by Climate Stewards to evaluate the contribution of the A Rocha Uganda Biosand Water Filter Project ("the project") towards reducing CO_2e emissions. This methodology has been developed based on two published methodologies:

- the UNFCCC methodology given in AMS-II.G.: Energy efficiency measures in thermal applications of non-renewable biomass – Version 11.1,[2]
- and the Gold Standard "Technologies and Practices to Displace Decentralized Thermal Energy Consumption".[3]

We have assessed the methodologies above and adapted them to our aims of producing a simpler, easier to use project verification scheme.

2. Basis on which adopting BSFs can generate offsets

In the 2014 Uganda national census, 94% of households[4] reported using charcoal or firewood for cooking. At the same time, 28% of households[5] did not have access to an improved water source,

[1] https://www.cawst.org/
[2] https://cdm.unfccc.int/methodologies/DB/ZI2M2X5P7ZLRGFO37YBVDYOW62UHQP
[3] https://globalgoals.goldstandard.org/407-ee-ics-technologies-and-practices-to-displace-decentrilized-thermal-energy-tpddtec-consumption/
[4] http://www.ubos.org/2016/03/24/census-2014-final-results/
[5] Ibid.

and can therefore be assumed to rely on contaminated water sources such as rivers, streams and, in some instances, wells for all their water (generally shallow wells will be more susceptible to contamination than deep wells). In some cases, households will boil some of their water for drinking and food preparation.

Forest cover in Uganda is falling due to a number of factors, one of which is the rising demand for firewood and charcoal. This is caused by the lack of government investment in energy infrastructure, rising population and weak law enforcement allowing over-exploitation of forest products.[6]

In 2012, the National Forestry Authority estimated that 80,000 hectares of private and protected forests are being cleared annually in Uganda for the unsustainable production of charcoal and timber.[7]

The Uganda National Statistics report of 2015[8] states that charcoal and firewood consumption went up by an astonishingly high factor of 10 between 2005/6 and 2009/10.

A 2013 report by A Rocha Uganda[9] highlights that while charcoal was previously produced through selective removal of indigenous trees like *Combretum spp*, *Acacia spp*, *Albizia spp*, *Terminalia spp*, *Afzelia africana* and *Piliostigma thonningii*, in recent years the species range has expanded to include highly valuable fruit trees like mango, jack fruit and shea nut. There is a growing concern in Uganda about the deteriorating state of the country's forest cover, which has declined from about 45% in the early 1900s, to 21.3% by 1990, and 18.3 % in 2005.[10]

In its 2011 revised guidelines "Technologies and Practices to Displace Decentralized Thermal Energy Consumption"[11], the Gold Standard sets out the criteria for identifying whether or not fuelwood and charcoal consumed to boil water comes from a renewable source. This can be **either**

> (a) Survey results, national or local statistics, studies, maps or other sources of information such as remote sensing data show that carbon stocks are depleting in the project area;
> **or**, at least two of the following supporting indicators are shown to exist (or one of the following combined with (a) above):
> (b) Trend showing increase in time spent or distance travelled by users (or fuel wood suppliers) for gathering fuel wood or trend showing increase in transportation distances for the fuel wood transported into the project area;
> (c) Increasing trends in fuel wood price indicating scarcity;
> (d) Trends in the type of cooking fuel collected by users, suggesting scarcity of woody biomass; or
> (e) Inadequate access to energy for cooking, or scarcity of wood fuel resources, are

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[6] Status of forests in Uganda: African Journal of Ecology, December 2010 – https://www.researchgate.net/publication/227501298_Status_of_forests_in_Uganda

[7] http://www.undp.org/content/undp/en/home/ourwork/environmentandenergy/projects_and_initiatives/greening-the-charcoal-sector-in-uganda.html

[8] http://www.ubos.org/onlinefiles/uploads/ubos/statistical_abstracts/Statistical%20Abstract%202015.pdf

[9] Assessing the Contribution of Charcoal Production to Deforestation in Uganda: A Case study of Luwero District, A Rocha Uganda, April 2013.

[10] http://library.health.go.ug/publications/service-delivery-public-health/environment-and-sanitation/state-environment-report

[11] http://www.goldstandard.org/sites/default/files/documents/gs_tpddtec_meth_110411.pdf

significant components of poverty.

A 2012 UNDP report on sustainable charcoal production in Uganda[12] confirms that charcoal being sold in Kampala could have been produced anywhere in the country. Thus, the "project area" can be defined as the whole country. With strong evidence of continuing deforestation across the country, it is clear that the project meets criteria (a) above. The same UNDP report confirms that prices of charcoal rose by over 200% in the period 2010 to 2012, and anecdotal evidence from A Rocha Uganda (ARU) confirms that many or all of criteria (c) to (e) are also being met in many of the project scenarios, and so these are assumed in our calculations.

Thus it can be assumed for the purposes of this methodology that charcoal and firewood consumed for boiling water in Uganda is not coming from renewable sources and therefore contributes to deforestation and forest degradation.

4. Calculation method

4.1. Baseline scenario

In order to calculate emissions in the baseline scenario (and hence potential savings in the project scenario) it is necessary to know the quantity of fuel used per person per year for boiling water for drinking. From this, given that the carbon content of the fuel is known, the emissions can be calculated. A Rocha Uganda carried out a baseline survey in the proposed project area. The survey covered 62 households.

The baseline scenario is for heat delivery from stoves used to boil water. The only activity being displaced is the use of fuel to boil water for drinking. Other uses (food prep, cooking, etc.) are excluded.

4.2. Data required

To calculate the amount of fuel used per person per year for boiling water we need to know the following:

1. (**Q – litres**) Average water consumption per person per day in litres (expressed as lppd).
For the project scenario this is established by baseline survey of the requisite number of households. (see Appendix 1 for the full Ugandan baseline dataset). Our analysis of the Uganda baseline data shows that, on average water consumption is just 0.97 litres per person per day – this is way below the average recommended consumption of a minimum of 7.5 lppd based on WHO guidelines.[13]

2. (**N – dimensionless**) Person days of fuel use to be displaced.
Projects assume 365 days, i.e. each person uses their allowance each day of the year.

3. (**W – tonnes/litre**) Fuel used to boil one litre of water.
Gernally, this is established using a baseline water boiling test[14] (BWBT) whereby water is boiled for a known time (usually 10 minutes) with a known amount of fuel. After the test the fuel is allowed to

[12] http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/MDG%20Carbon%20Facility/CharcoalNAMAstudy_9Jan2013.pdf
[13] http://www.who.int/water_sanitation_health/emergencies/qa/emergencies_qa5/en/
[14] See "Technologies and Practices to Displace Decentralized Thermal Energy Consumption" 2011, Gold Standard, pg 39.

cool and the remains are weighed. The Partnership for Clean Indoor Air (PCIA)[15] publishes the results of its own tests and we have chosen to use this data as it comes from a reliable and widely recognised, publicly available source:

The table below shows the quantity of fuel used to boil one litre of water (from ambient temperature to "rolling boil"). These figures are based on data from

	Open fire (tonnes/l)	Improved stove (tonnes/l)[16]
Wood	0.000224	0.000161
Charcoal	0.000135	0.000139

4. (**C – fraction**) Portion of users of project safe water supply who were in the baseline using a non-boiling safe water supply. From our baseline survey, this figure is zero, that is, filters are only being proposed to households that do not have access to a safe water supply.

4.3. Calculating fuel consumption

The quantity of fuel (tonnes) consumed in a year per person can then be calculated from the following simple equation:[17]

$$B = (1 - C) \times Q \times N \times W$$

This is then multiplied by the average number of people in the household to get a figure per BSF per year. (The Uganda baseline survey shows an average household size of 7.4 people.)

So, for an average Ugandan household, consuming 0.97 lppd the fuel saved by switching from an unimproved wood stove to a BSF is:

$$(1 - 0) \times 0.97 \times 7.4 \times 0.000224 =$$

0.001607872 tonnes/day, or 587kg per year.

4.4. Calculating Emissions

From there it is a case of converting fuel used to CO_2e – based on the fact that the BSF will displace 100% biomass fuel use in the project scenario.

Equation used:

$$E = B \times ((f_{NRB} \times EF_{CO2}) + EF_{non\text{-}CO2}) \times NCV$$

Where:

- E emissions in tCO_2e.
- B fuel consumed in tonnes.
- f_{NRB} fraction of biomass that is non-renewable, based on CDM published list of country defaults.[18]

[15] http://www.pciaonline.org/testing/test-results-cook-stove-performance
[16] Not directly equivalent to a fuel efficient stove but similar.
[17] Equation derived from the "Technologies and Practices to Displace Decentralized Thermal Energy Consumption" 2011, Gold Standard, "*Project Scenario Fuel Consumption Calculation*" pg 36ff.
[18] https://cdm.unfccc.int/DNA/fNRB/index.html

- EF_{CO2} emissions factor for the CO_2 released when wood/charcoal is burnt. Under the Gold Standard methodology, the biomass fraction figure is applied only to this emissions factor. From the IPCC[19] data for wood fuel/charcoal – EF_{CO2} = 112 tCO_2/TJ.
- $EF_{non\text{-}CO2}$ emissions factor for non-CO_2 components of a fuel. The Gold Standard methodology incldes both Methane and Nitrous Oxide. The Emissions Factors for charcoal and wood are slightly different:
  - $EF_{CH4\text{-}WOOD}$ = 0.3 tCO_2/TJ × GWP[20] of 21 = 6.3 tCO_2e/TJ
  - $EF_{N2O\text{-}WOOD}$ = 0.004 tCO_2/TJ × GWP of 310 = 1.24 tCO_2e/TJ
  - $EF_{CH4\text{-}CHARCOAL}$ = 0.2 tCO_2/TJ × GWP[21] of 21 = 4.2 tCO_2e/TJ
  - $EF_{N2O\text{-}CHARCOAL}$ = 0.001 tCO_2/TJ × GWP of 310 = 0.31 tCO_2e/TJ
- NCV Net Calorific Value of fuel used, based on conservative IPCC data.[22]
  - NCV = 0.0156 TJ/tonne for wood fuel
  - NCV = 0.0295 TJ/tonne for charcoal

So, for the baseline data above. The displaced emissions for an unimproved wood stove, using the averages for water consumption and household size from the Ugandan baseline data would be:

$$\mathbf{0.59 \times ((0.82 \times 112) + 6.3 + 1.24) \times 0.0156}$$

$$\mathbf{= 0.91 \text{ tonnes of } CO_2e \text{ per year.}}$$[23]

Where:

- B = 0.59 tonnes of fuel used, from previous equation, page 4.
- f_{NRB} = 0.82.
- other values are as already detailed.

It is assumed that the filter can meet the requirements for water purification for the whole household. This seems realistic given that the CAWST BSF can filter up to 80 l/day, so a household of ten would have no problem meetings its requirements in any of the project scenarios analysed.

4.5. Charcoal Production

In addition to the emissions related to the burning of the stove fuel, for scenarios in which the BSF is replacing charcoal fired burners it is reasonable to account for the production of the charcoal itself – that is, include the emissions from charcoal production within the project boundary.

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[19] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (Table 2.5 – DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE RESIDENTIAL AND AGRICULTURE/FORESTRY/FISHING/FISHING
FARMS CATEGORIES).

[20] http://unfccc.int/ghg_data/items/3825.php

[21] http://unfccc.int/ghg_data/items/3825.php

[22] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf (Table 1.2 – DEFAULT NET CALORIFIC VALUES (NCVS)).

[23] When all of the data from the Ugandan baseline survey is taken into account, that is, for households using wood stoves or charcoal stoves, or a mixture of both, the average (mean) displaced emissions per BSF is 1.22 tonnes CO_2e per year. However, this is affected by the fact that the data is skewed with a long tail due to a small number of households that are either large or consume a lot of water. For the sake of accuracy in reporting then, the median figure of 0.87 tonnes should be considered to be the "true average". This figure also takes into account the emissions from charcoal production as detailed below.

Charcoal is produced by burning (charring) wood in an oxygen deprived atmosphere (typically an earth mound kiln[24]). Various sources[25] suggest that it takes approximately 10kg of wood to produce 1kg of charcoal. Charcoal production produces both carbon dioxide emissions and significant methane emissions.

Pennise, *et al*[26] estimate that 0.77–1.63 kg of CO_2e is released for every kilogram of charcoal produced. Since we know the quantity of fuel burned by each stove that is to be replaced by a BSF we can estimate the emissions related to charcoal production that are also displaced. For this we use the most conservative figure given.

4.6 Project Lifetime

The CAWST filters that are being used in Uganda have an estimated useful life of up to 30 years, with evidence that concrete filters are still functioning efficiently after 10 years.[27] Our own lifetime analysis of the current ARU BSF project suggests a longer useful lifetime than any of the GS projects – we predict a "naïve" average of 14.3 years with a mean weighted by age of project at 15.3 years and a mean weighted by number of filters at 13.8 years. For the purposes of our own analysis we have decided to cap the lifetime at 12 years. This allows us to, over time, make realistic comparisons with other GS projects and also gives us a buffer against variability on filter lifetime in our calculations.[28]

5. Other factors affecting calculations

5.1. Construction

The CAWST BSF used in Uganda is made of concrete. Approx. 18kg of cement is used in the fabrication of the filter body. The cement's footprint is estimated at 180kg per tonne[29] – so 18kg has a footprint of 3.24kgCO_2 i.e. negligible.

5.2. Suppressed demand

The Gold Standard allows for the incorporation of "supressed demand" in the baseline scenario.[30, 31] According to Carbon Market Watch, "The concept of 'suppressed demand' tries to take into account the fact that their per-capita emissions would be much higher if the poor had better access to energy and goods".[32] The Climate & Development Knowledge Network suggests that, "Accounting for suppressed demand means the development of a common and transparent approach to setting

[24] Although the figure given by Pennise relates to charcoal production in Kenya the same type of kilns are used in Uganda.
[25] https://www.sei-international.org/blog-articles/3491, http://www.monitor.co.ug/OpEd/Commentary/689364-718680-2yxq0n/index.html, http://www.ccsenet.org/journal/index.php/eer/article/viewFile/24006/15252
[26] http://onlinelibrary.wiley.com/doi/10.1029/2000JD000041/pdf – "Emissions of greenhouse gases and other airborne pollutants from charcoal making in Kenya and Brazil".
[27] http://biosandfilters.info/technical/fact-sheet-biosand-filter
[28] See Appendix 5 for a lifetime analysis.
[29] https://en.wikipedia.org/wiki/Environmental_impact_of_concrete
[30] Technologies and Practices to Displace Decentralized Thermal Energy Consumption 11/04/2011 http://www.goldstandard.org/sites/default/files/documents/gs_tpddtec_meth_110411.pdf
[31] https://ssir.org/articles/entry/thirty_million_dollars_a_little_bit_of_carbon_and_a_lot_of_hot_air
[32] http://carbonmarketwatch.org/category/additionality-and-baselines/suppressed-demand/

baseline scenarios to reflect future increases in emissions in countries, and not merely historical emissions".[33]

In essence, this means that households report that before receiving a BSF, raw water was consumed, but that it would have been boiled in the absence of both the project activity and prevailing energy poverty barriers. By including supressed demand, much greater energy savings can be reported. The question is, are these real savings?

The use of suppressed demand in Gold Standard projects is justified as an accounting methodology, stating: "Rather than wait until emissions have increased along with development, providing emission credits for suppressed demand delivers the finance for a country to use low-carbon technologies from the outset. Carbon market revenues allow the 'leapfrogging' of high-carbon, business as usual technologies to cleaner ones that are based on renewables and/or increased efficiency."

The Climate Stewards Seal of Approval methodology does **not** include the use of estimated suppressed demand, as we consider that this is an artificial construct, based on a number of unprovable assumptions, which reduces transparency and can lead to confusion. The CS methodology only reports actual calculated carbon savings. This means that if a water filter is supplied to a household which did not boil their water beforehand, there will be no carbon saving. Ideally, BSFs would only be supplied to households that had shown in the baseline survey that the boiled water was used for drinking – but this takes no account of other social and health reasons for a family wishing to use a BSF. Overall, not using estimated suppressed demand in our calculations means that our figures for carbon savings are very conservative when compared with other standards.

5.3. Risk buffer

Knowing where to add in a risk buffer such that the calculations of real displaced emissions are not compromised, as we believe happens with suppressed demand, means thinking about where the most likely changes in the scenario are to be encountered.

The most likely areas for change are i) BSF usage by household; and ii) water consumption.

If a BSF is not properly maintained then throughput suffers and it will take a long time for water to flow through the filter. The need for prompt access to water means that a badly maintained filter which is producing only a trickle is likely to be abandoned or ignored. This can be addressed by adequate initial training, and monitoring with access to repair materials and helpers[34] who can sort out sub-functioning filters.

Based on analysis of the lifetime of the ARU filters – a comparison of installed and in use filters – it would be appropriate to build in a projected "attrition rate" for filters. The analysis suggests that currently the ARU filters are experiencing an annual attrition rate of between 4.4% and 4.9%. from the data gathered (household freeform responses to a question about issues with their filter) this appears to be almost exclusively due to a lack of capacity for follow-up as the filters that are no longer in use are without exception either repairable if resources were to be available, or could be brought back into use with extra training of household members. Issues that have led to households

[33] http://cdkn.org/2012/04/suppressed-demand-in-climate-change-negotiations/?loclang=en_gb
[34] These helpers will be known as "Filter Buddies" in the communities.

abandoning their filter include: sand wastage, broken lids and diffusers, reduced flow due to dirty sand. These are all issues which can be addressed given appropriate resources and training. Of the 100 filters surveyed only one was damaged beyond repair – options for repair weren't included in the survey so this filter is considered to be lost.

Based on the fact that the project scenario includes the appointment of local helpers, along with a budget line item for repairs/renewals we are confident that we can keep the annual attrition rate below 1%. It will be possible to adjust this over time as we gather more data about the lifetime of BSFs in the project scenario.

After practical usage of the filters themselves, water consumption in the baseline scenario has the biggest effect on projected annual displaced emissions. In the baseline scenario, the more water used, the more fuel burned, the higher the emissions – thus the higher the displaced emissions in the project scenario. The Ugandan baseline data shows that a typical household uses less than one litre of water per person per day. We would expect this figure to increase with time due to the ease of use of the biosand filter giving access to easily available clean potable water, but this does not have any effect on the displaced emissions as calculated in the baseline scenario; given the nature of the technology, additional water consumption is free of emissions.

6. Monitoring and evaluation

Because A Rocha Uganda has been supplying filters for nine years, it was possible to carry out research into what percentage of filters remain in use for different periods. This survey has been carried out by A Rocha Uganda using a representative sample of participants in previous projects, and funded by Climate Stewards.

A monitoring survey was carried out by A Rocha Uganda in late 2017. The monitoring survey was carried out across a number of sites and the original project design didn't take any account of carbon emissions displacement during the selection of the original participants (i.e. that households had been boiling water prior to receiving a BSF). This means that 20 households ended up being "weeded out" of the results as they didn't boil water and thus no emissions were being displaced. This left a set of 80 households of which three claimed not to have consumed any water – leaving a data set of 77 households for emissions displacement calculations.

Although the project areas are different, the communities being served are similar, with average household size in the baseline scenario being 7.4 and 8.2 in the monitoring survey. The median displaced emissions per filter per year is in the baseline scenario was 0.89 tonnes and 0.90 tonnes from the monitoring survey. Based on this result we are confident that our ex-ante calculation from the baseline survey data is accurate and conservative.

There are challenges involved in ensuring that BSFs are well maintained and used correctly in order to ensure that carbon savings are maximised. These can include failure to use the BSF consistently, lack of hygienic storage for clean water, failure to replace the active bio-film layer, and owners moving away and abandoning their filter. Some of the pitfalls in collecting data to measure carbon savings are summarised in a 2015 research paper by Summers et al.[35] One of the chief pitfalls is "courtesy bias" where respondents reply according to what they think the interviewer wants to hear rather than giving a true picture of the situation. Because A Rocha Uganda is well-established in the

[35] http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0122894

communities where it works, employs national staff, and has almost ten years' experience of constructing BSFs, we are confident that courtesy bias can be all-but eliminated for the project participants. We have also encouraged ARU to follow CAWST guidelines for interviewing BSF users in monitoring surveys.[36]

7. Conclusions

We have decided to report real savings only, and not to include supressed demand in our calculations. For other variables, such as household size and water used per day, we have taken conservative figures based on real-world data from the project area, thus effectively increasing the risk buffer embodied in the calculations. We are therefore confident that these figures represent conservative estimates of carbon savings from the BSFs that will be installed by A Rocha Uganda and can be used as the basis for Climate Stewards offset calculations.

[36] See "Monitoring Biosand Filter Projects", CAWST, October 2011, available from https://resources.cawst.org/manual/13813976/monitoring-biosand-filter-projects-manual