Digitally native methodology to quantify greenhouse gas emission reductions from improved wood-fuelled cookstoves

Simulation of a 1000-household project

Nova Institute

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Contents

1 CO_2 emission reduction due to project activity (t/yr)

Definition

The total mass of CO_2 avoided per annum due to the project activity.

Rationale

CO_2 emissions are linked to climate change.

Source(s) of data

- stove tests (WBT)
- baseline and project field tests (KT)
- non-renewable biomass (NRB) assessment
- (ongoing) stove usage monitoring
- stove use logbooks
- usage survey

Credibility

Avoidance of specification error
Give preference to tests that represent the actual situation of the end-user.
Give preference to objective methods for ongoing sampling.
Use a randomly selected sample.

Avoidance of coverage or frame error
Keep a complete record of all participating households.

Avoidance of non-response error
Consider a moderate compensation to households for participating in tests that are invasive (like the KPT).

Avoidance of measurement error
Give preference to objective measurements.
Use triangulation.

Avoidance of processing errors
Report calculations transparently so that all processing steps, including intermediate steps, are visible.

Calculation

1.1 Notation

$fr_{(B)ijk}$: fire frequency for household j in subpopulation i on day k in the baseline scenario of the KT phase.

$fr_{(P)ijk}$: fire frequency for household j in subpopulation i on day k in the project scenario of the KT phase.

$fr_{(BS)ijk}$: Brick Star frequency for household j in subpopulation i on day k in the project scenario of the KT phase.

$fr^*_{(BS)ijk}$: fire frequency for Brick Star for household j in subpopulation i on day k in the post KT phase.

$x_{(B)ijk}$: daily fuel use (in kg) for household j in subpopulation i on day k in the baseline scenario of the KT phase.

$x_{(P)ijk}$: daily fuel use (in kg) for household j in subpopulation i on day k in the project scenario of the KT phase.

$x_{(BS)ijk}$: daily Brick Star fuel use (in kg) for household j in subpopulation i on day k in the project scenario of the KT phase.

$n_{(B)ij}$: total number of days that household j in subpopulation i was observed in the baseline scenario of the KT phase.

$n_{(P)ij}$: total number of days that household j in subpopulation i was observed in the project scenario of the KT phase.

n^*_{ij}: total number of days that household j in subpopulation i was observed in the post KT phase.

n_i: total number of subpopulations in the project.

1.2 Calculation of ER_y

1.2.0.1 Calculation

$$ER_y = BE_y - PE_y - LE_y$$

Where:

ER_y = The total mass of CO_2 avoided in year y across all project participants due to the project activity (tonnes)
BE_y = The total baseline CO_2 emissions for year y across all project participants (tonnes)
PE_y = The total project CO_2 emissions for year y across all project participants (tonnes) LE_y = The total leakage CO_2 emissions for year y across all project participants (tonnes)

1.2.0.2 Presentation and simulation results

1.3 Calculation of project CO_2 emissions

1.3.1 Calculation of PE_y

1.3.1.1 Calculation PE_y is calculated as:

$$PE_y = \sum_f C_{(P)y,f} \times EF_{(CO_2)f} \times f_{(NRB)y}$$

Where:

$C_{(P)y,f}$ = The total project consumption of fuel f for year y across all project participants (tonnes)
$EF_{(CO_2)f}$ = CO_2 emission factor for fuel f
$f_{(NRB)y}$ = The fraction of non-renewable biomass in the fuel-sourcing environment for year y

For simplicity in notation we will from this point forth use the notation $C_{(P)}$ for $C_{(P)y,f}$ with the understanding that $C_{(P)}$ is the total fuel consumption across all subpopulations and households for year y and fuel type f.

1.3.1.2 Presentation and simulation results

1.3.2 Calculation of $C_{(P)}$

1.3.2.1 Calculation $C_{(P)}$ is calculated as:

$$C_{(P)} = \sum_i^{n_i} C_{(P)i}$$

and $C_{(P)i}$ is the total fuel consumption in the project scenario for subpopulation i.

1.3.2.2 Presentation and simulation results

1.3.3 Calculation of $C_{(P)i}$

1.3.3.1 Calculation

$C_{(P)i}$ is calculated as

$$C_{(P)i} = (\overline{d}_{(P)i} \times N_{(P)i}) \times (\overline{fr^*}_{(BS)i} \times \overline{x}_{(BS)i})$$

- $\overline{d}_{(P)i}$ is the average days of project operatian in subpopulation i.
- $N_{(P)i}$ is the project population size in subpopulation i.
- $\overline{fr^*}_{(BS)i}$ is the average Brick Star frequency per day in subpopulation i in the post KT phase .
- $\overline{x}_{(BS)i}$ is the average Brick Star fuel use (in kg) for subpopulation i in the project scenario of the KT phase.

1.3.3.2 Presentation and simulation results

1.3.4 Calculation of d_{ij}

1.3.4.1 Calculation

The average days of project operation is calculated as

$$\overline{d}_i = \frac{1}{n_i} \sum d_{ij}$$

and d_{ij} is the total days of project operation for household j in subpopulation i. The total days of operation for each household can be determined as the number of days since the project technology has been implemented for each household and will be available in the project register.

1.3.4.2 Presentation and simulation results

1.3.5 Calculation of $\overline{fr^*}_{(BS)i}$

1.3.5.1 Calculation

The average Brick Star frequency per day $\overline{fr^*}_{(BS)i}$ for subpopulation i is determined from a sample in the post KT phase and is calculated as

$$\overline{fr^*}_{(BS)i} = \frac{1}{n_i^*} \sum_i^{n_i^*} \frac{fr^*_{(BS)ij.}}{n_{ij}^*}$$

- $fr^*_{(BS)ij.}$ is the total frequency Brick Star fires for household j in subpopulation i for the post KT phase.
- n_{ij}^* is the total number of days that household j in subpopulation i was observed in the post KT phase.
- n_i^* is the number of households that were observed in the post KT phase.

1.3.5.2 Presentation and simulation results

1.3.6 Calculation of $\overline{x}_{(BS)i}$

1.3.6.1 Calculation

The average Brick Star fuel use (in kg) in the project scenario for subpopulation i is calculated as the average of the household average fuel use per Brick Star fire.

$$\overline{x}_{(BS)i} = \frac{1}{n_{(P)i}} \sum_j^{n_i} \frac{x_{(BS)ij.}}{fr_{(BS)ij.}}$$

1.3.6.2 Presentation and simulation results

1.3.7 Calculation of $x_{(BS)ij.}$

1.3.7.1 Calculation

The total Brick Star fuel use for household j in subpopulation i is the total fuel use in the project scenario minus the fuel use by non-Brick Star fires in the project scenario.

$$x_{(BS)ij.} = x_{(P)ij.} - (\overline{x}_{(B)i} \times (fr_{(P)ij.} - fr_{(BS)ij.}))$$

Presentation and simulation results

1.4 Calculation of baseline CO_2 emissions

1.4.1 Calculation of BE_y

1.4.1.1 Calculation

BE_y is calculated as:

$$BE_y = \sum_f C_{(B)y,f} \times EF_{(CO_2)f} \times f_{(NRB)y}$$

Where:

$C_{(B)y,f}$ = The total baseline consumption of fuel f for year y across all project participants (tonnes)
$EF_{(CO_2)f}$ = CO_2 emission factor for fuel f
$f_{(NRB)y}$ = The fraction of non-renewable biomass in the fuel-sourcing environment for year y (as calculated in section **??**)

For simplicity in notation we will from this point forth use the notation $C_{(B)}$ for $C_{(B)y,f}$ with the understanding that $C_{(B)}$ is the total fuel consumption across all subpopulations and households for year y and fuel type f.

1.4.1.2 Presentation and simulation results

1.4.2 Calculation of $C_{(B)}$

1.4.2.1 Calculation

$C_{(B)}$ is calculated as:

$$C_{(B)} = \sum_i^{n_i} eef_i \times C_{(P)i}$$

$C_{(P)i}$ is the total fuel consumption for subpopulations i (see calculation in previous paragraph).

eef_i is the energy efficiency factor for subpopulation i.

1.4.2.2 Presentation and simulation results

1.4.3 Calculation of eef_i

1.4.3.1 Calculation

eef_i is calculated as

$$eef_i = \frac{\overline{x}_{(B)i} \times \overline{rr}_i}{\overline{x}_{(BS)i}}$$

Where: $\overline{x}_{(B)i}$ the average fuel use (in kg) in the baseline scenario for subpopulation i.

$\overline{rr}_i$ the average replacement ratio at which non-Brick Star fires are replaced by Brick Star fires for subpopulation i.

$\overline{x}_{(BS)i}$ the average Brick Star fuel use (in kg) in the baseline scenario for subpopulation i.

1.4.3.2 Presentation and simulation results

1.4.4 Calculation of $\overline{x}_{(B)i}$

1.4.4.1 Calculation

The average fuel use (in kg) in the baseline scenario for subpopulation i is calculated as the average fuel use (in kg) for the j households in subpopulation i.

$$\overline{x}_{(B)i} = \frac{1}{n_{ij}} \sum_j \overline{x}_{(B)ij}$$

and $\overline{x}_{(B)ij}$ is the average fuel use (in kg) in the baseline scenario for household j subpopulation i.

$$\overline{x}_{(B)ij} = \frac{1}{n_{ijk}} \sum_k^{n_{ijk}} x_{(B)ijk}$$

1.4.4.2 Presentation and simulation results

1.4.5 Calculation of $\overline{rr}_i$

1.4.5.1 Calculation

The average replacement ratio is the average ratio for subpopulation i of the replaced non-Brick Star fires replaced by Brick Star fires and is calculated as

$$\overline{rr}_i = \frac{1}{n_{ij}} \sum_j rr_{ij}$$

and rr_{ij} is the replacement ratio for household j in subpopulation i.

1.4.5.2 Presentation and simulation results

1.4.6 Calculation rr_{ij}

1.4.6.1 Calculation

$$rr_{ij} = \frac{\overline{fr}_{(B)ij} - (\overline{fr}_{(P)ij} - \overline{fr}_{(BS)ij})}{\overline{fr}_{(BS)ij}}$$

$\overline{fr}_{(B)ij}$ is the average number of fires per day in the baseline scenario for household j in subpopulation i and is calculated as the total fires in the baseline scenario for household j in subpopulation i divided by the total days for household j in subpopulation i in the baseline scenario.

1.4.6.2 Presentation and simulation results

1.4.7 Calculation of $\overline{fr}_{(B)ij}$

1.4.7.1 Calculation

$$\overline{fr}_{(B)ij} = \frac{fr_{(B)ij.}}{n_{(B)ij}}$$

Similarly $\overline{fr}_{(P)}ij$ is the average number of fires per day in the project scenario for household j in subpopulation i

$$\overline{fr}_{(P)ij} = \frac{fr_{(P)ij.}}{n_{(P)ij}}$$

and $\overline{fr}_{(BS)ij}$ is the average number of Brick Star fires per day in the project scenario for household j in subpopulation i

$$\overline{fr}_{(BS)ij} = \frac{fr_{(BS)ij.}}{n_{(BS)ij}}$$

1.4.7.2 Presentation and simulation results

1.5 Calculation of leakage CO_2 emissions

1.5.1 Calculation of LE_y

1.5.1.1 Calculation Leakage will be due to continued use of baseline technology. LE_y is calculated as:

$$LE_y = \sum_f L_{(P)y,f} \times EF_{(CO_2)f} \times f_{(NRB)y}$$

Where:

$L_{(P)y,f}$ = The total baseline consumption of fuel f for year y across all project participants (tonnes)
$EF_{(CO_2)f}$ = CO_2 emission factor for fuel f
$f_{(NRB)y}$ = The fraction of non-renewable biomass in the fuel-sourcing environment for year y (as calculated in section **??**)

For simplicity in notation we will from this point forth use the notation $L_{(P)}$ for $L_{(P)y,f} $ with the understanding that L is the total fuel consumption across all subpopulations and households for year y and fuel type f.

1.5.2 Calculation or $L_{(P)}$

1.5.2.1 Calculation $L_{(P)}$ is calculated as:

$$L_{(P)} = \sum_i^{n_i} L_{(P)i}$$

and $L_{(P)i}$ is the total leakage in the project scenario for subpopulation i.

1.5.3 Calculation of $L_{(P)i}$

$L_{(P)i}$ is calculated as

$$L_{(P)i} = (\overline{d}_{(P)i} \times N_{(P)i}) \times (\overline{frr}_i \times \overline{fr^*}_{(BS)i} \times \overline{x}_{(B)i})$$

- $\overline{d}_{(P)i}$ is the average days of project operation in subpopulation i.
- $N_{(P)i}$ is the project population size in subpopulation i.
- $\overline{frr}_i$ is the average frequency ratio of non Brick Star fires to the Brick Star fires in subpopulation i in the project scenario of the KT phase.
- $\overline{fr^*}_{(BS)i}$ is the average Brick Star frequency per day in subpopulation i in the post KT phase .
- $\overline{x}_{(B)i}$ is the average fuel use (in kg) for subpopulation i in the baseline scenario of the KT phase.

1.5.4 Calculation of $\overline{frr}_i$

The average frequency ratio of non-Brick Star fires to the Brick Star fires in the project scenario for household j in subpopulation i is calculated as

$$\overline{frr}_i = \frac{1}{n_{(P)i}} \sum_j \frac{fr_{(P)ij.} - fr_{(BS)ij.}}{fr_{(BS)ij.}}$$