Results for the Brickstar dMRV feasibility study

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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

1.1.1 Fire frequencies

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

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

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

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

$fr^*_{(M)ijk}$: project measures frequency for household j in subpopulation i on day k in the continuous monitoring (CM) phase.

1.1.2 Daily fuel use

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

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

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

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

1.1.3 Totals and averages

$fr_{(B)ij.}$: total frequency for the duration of the baseline scenario of the KT phase of baseline technology for household j in subpopulation i.

$\overline{fr}_{(B)ij}$: average daily baseline technology frequency for the duration of the baseline scenario of the KT phase for household j in subpopulation i.

$\overline{fr}_{(B)i}$: average daily baseline technology frequency for the baseline scenario of the KT phase for subpopulation i.

Totals and averages for other frequencies follow a similar notation.

$x_{(B)ij.}$: total fuel use (in kg) for the duration of the baseline scenario of the KT phase of baseline technology for household j in subpopulation i.

$\overline{x}_{(B)ij}$: average baseline technology fuel use per fire for household j in subpopulation i.

$\overline{x}_{(B)i}$: average baseline technology fuel use per fire in the baseline scenario of the KT phase for subpopulation i.

Totals and averages for other fuel use follow a similar notation.

1.2 Calculation of ER_y

1.2.0.1 Calculation

$$ER_y = BE_y - PE_y$$

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)

Table 1: Total emission reduction in year y across all project participants due to the project activity (tonnes)

place	year	fuel	BE	PE	ER
Lwandlamuni	2023	wood	374.8318 [t]	317.3845 [t]	57.44739 [t]

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.

Table 2: Calculation of PE

place	year	fuel	PEi	CPi	COEF	fNRB
Lwandlamuni	2023	wood	317.3845 [t]	678.1719 [t]	1560 [g/kg]	0.3

1.3.2 Calculation of $C_{(P)}$

1.3.2.1 Calculation

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

$$C_{(P)} = \sum_{i}^{n_{(KT)}} C_{(P)i}$$

Where

- $C_{(P)i}$ is the total fuel consumption in the project scenario for subpopulation i.
- $n_{(KT)}$ is the number of subpopulations in the kitchen test.

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

1.3.3.1 Calculation

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

$$C_{(P)i} = (\overline{d^*}_i \times N_i^*) \times (\overline{fr^*}_{(M)i} \times \overline{x}_{(M)i})$$

Where

- $\overline{d^*}_i$ is the average days of the sampled households in the continued monitoring phase of project operation in subpopulation i.
- N_i^* is the project population size in subpopulation i. At this stage it is set at $N = 1000$.

- $\overline{fr^*}_i$ is the average project measures frequency per day in subpopulation i in the continuous monitoring (CM) phase.
- $\overline{x}_{(M)i}$ is the average project measures fuel use (in kg) per fire for subpopulation i in the project scenario of the KT phase.

Table 3: Calculation of project emissions per place

place	year	fuel	date_start_monitoring_period	date_end_monitoring_period	project_days	mean_days	frMi	XMi	XBi	N	CPi
Lwandlamuni	2023	wood	2023-01-29	2023-05-31	2440	122	1.22	4.54	4.45	1000	678.1719 [t]

1.3.4 Calculation of $\overline{d^*}_i$

1.3.4.1 Calculation The average days of project operation is calculated as

$$\overline{d^*}_i = \frac{1}{n_i^*} \sum_{j}^{n_i^*} d_{ij}^*$$

Where

- d_{ij}^* is the total days of project operation in the CM phase 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.
- n_i^* is the total number of households that were observed in the CM phase.

In Table 3 $\overline{d^*}_i$ is 122 the average of the column *ndays_monitoring* in Table 4.

Table 4: Sample of continuous monitoring data summarised by household

qr_code	place	year	fuel	date_start	date_end	ndays_monitoring	frMij
0036	Lwandlamuni	2023	wood	2023-01-29	2023-05-31	122	1.08
0086	Lwandlamuni	2023	wood	2023-01-29	2023-05-31	122	1.13
0182	Lwandlamuni	2023	wood	2023-01-29	2023-05-31	122	1.24
0219	Lwandlamuni	2023	wood	2023-01-29	2023-05-31	122	1.26
0249	Lwandlamuni	2023	wood	2023-01-29	2023-05-31	122	1.13
0255	Lwandlamuni	2023	wood	2023-01-29	2023-05-31	122	1.16

1.3.5 Calculation of $\overline{fr^*}_i$

1.3.5.1 Calculation The average project measures frequency per day in the CM phase $\overline{fr^*}_i$ for subpopulation i is determined from a sample in the continuous monitoring phase and is calculated as

$$\overline{fr^*}_i = \frac{1}{n_i^*} \sum_{j}^{n_i^*} \frac{fr_{ij.}^*}{n_{ij}^*}$$

Where

- $fr_{ij.}^*$ is the total project measures frequency for household j in subpopulation i for the CM phase.

- n_{ij}^* is the total number of days that household j in subpopulation i was observed in the CM phase.
- n_i^* is the number of households in subpopulation i that were observed in the CM phase.

In Table 3 $\overline{fr^*}_i$ is 1.22 which is the average of the column *frMij* in Table 4.

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

1.3.6.1 Calculation The average project measures fuel use (in kg) in the project scenario for subpopulation i is calculated as the average of the household average fuel use per project measures fire observed in the kitchen test.

$$\overline{x}_{(M)i} = \frac{1}{n_{(P)i}} \sum_{j}^{n_{(P)i}} \overline{x}_{(M)ij}$$

and $\overline{x}_{(M)ij}$ is calculated as

$$\overline{x}_{(M)ij} = \frac{1}{n_{(P)ij}} \sum_{k}^{n_{(P)ij}} \frac{x_{(M)ijk}}{fr_{(M)ijk}}$$

Where

- $x_{(M)ijk}$ is the project measures fuel use on day k for household j in subpopulation i for the project phase of the KT.
- $fr_{(M)ijk}$ is the project measures frequency on day k for household j in subpopulation i in the project phase of the KT.
- $n_{(P)ij}$ is the number of valid observations for household j in subpopulation i in the project phase of the KT.
- $n_{(P)i}$ is the number of households that were observed in the project phase of the KT.

Table 5: Sample of data from project kitchen test results summarised by household

fuel	assignment	place	year	household_qr_code	XBPij.	frBPij.	XBPij_m2	XMij.	frMij.	XMij_m2
wood	projectKT	Lwandlamuni	2023	fe85a0857cb4acf6d8c62806a5ad0f58	0.00	0	NaN	40.26	15	3.35
wood	projectKT	Lwandlamuni	2023	b90d7ffcebb632c069c9a0df3184130d	3.20	2	1.60	44.65	20	2.74
wood	projectKT	Lwandlamuni	2023	98be7d563ec1afde0471790aee42f49c	84.40	16	5.20	50.46	12	4.67
wood	projectKT	Lwandlamuni	2023	a7aba1933d7b6680ba9e33b733674b26	9.48	2	4.74	9.69	4	2.42
wood	projectKT	Lwandlamuni	2023	c294de3752b16a3f3dabd418fc98ee8f	11.00	2	5.50	15.62	3	5.21
wood	projectKT	Lwandlamuni	2023	04b4ea7c435e9648c57073bb440f9d18	66.92	8	7.15	60.10	17	4.06

In Table 5 $\frac{1}{n_{(P)ij}} \sum \frac{x_{(M)ijk}}{fr_{(M)ijk}}$ is given in column *XMij_m2*. In Table 3 $\overline{x}_{(M)i}$ is 4.54 which is the average of the column *XMij_m2* in Table 5.

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

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.

Table 6: Calculation of BE

place	year	fuel	BEi	CPi	COEF	fNRB
Lwandlamuni	2023	wood	374.8318 [t]	678.1719 [t]	1560 [g/kg]	0.3

1.4.2 Calculation of $C_{(B)}$

1.4.2.1 Calculation

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

$$C_{(B)} = \sum_i^{n_{(KT)}} \overline{eef}_i \times C_{(P)i}$$

Where

- $C_{(P)i}$ is the total fuel consumption for subpopulations i (see calculation in previous paragraph).
- $\overline{eef}_i$ is the average energy efficiency factor for subpopulation i.
- $n_{(KT)}$ is the number of subpopulations in the kitchen test.

Table 7: Calculation of baseline emissions per place

place	year	fuel	date_start_monitoring_period	date_end_monitoring_period	project_days	mean_days	XBi	N	CPi	mean_eef	CBi
Lwandlamuni	2023	wood	2023-01-29	2023-05-31	2440	122	4.45	1000	678.1719 [t]	1.18	800.9227 [t]

1.4.3 Calculation of $\overline{eef}_i$

1.4.3.1 Calculation

eef_i is calculated as

$$\overline{eef}_i = \frac{1}{n_{(P)i}} \sum_j^{n_{(P)i}} eef_{ij}$$

Where

- eef_{ij} is the energy efficiency factor for household j in subpopulation i.
- $n_{(P)i}$ is the number of households in the project phase of the KT.

The energy efficiency factor for household j in subpopulation i is calculated as

$$eef_{ij} = \frac{\overline{x}_{(B)ij} \times rr_{ij}}{\overline{x}_{(M)ij}}$$

Where

- rr_{ij} the replacement ratio at which baseline measures fires are replaced by project measures fires for household j in subpopulation i.
- $\overline{x}_{(B)ij}$ the average fuel use (in kg) per fire in the baseline scenario of the KT for household j in subpopulation i.
- $\overline{x}_{(M)ij}$ the average project measures fuel use (in kg) per fire in the project scenario of the KT for household j in subpopulation i.

NOTE: the eef_{ij} for household j in subpopulation i is not included in the calculation of $\overline{eef}_i$ if the total project measure frequency $fr_{(M)ij.}$ for household j in subpopulation i does not exceed a subminimum. This subminimum is set at 5. For a too small $fr_{(M)ij.}$ the replacement ratio rr_{ij} is unrealistically large and based on too little data, see Section 1.4.6

Table 8: Sample of the calculation of eef

place	year	household_qr_code	XBij_m3	XBPij_m2	XMij_m2	rr	eef
Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	4.03	5.24	3.91	0.91	1.02
Lwandlamuni	2023	8327a5a6d11e32ec6d23a0e13fbbb0e2	3.20	6.58	6.15	5.38	2.94
Lwandlamuni	2023	3403ad40c2c4a1eb44951d046a0463b2	3.45	5.64	8.22	-0.04	-0.02
Lwandlamuni	2023	3c367d67a239be8b700c4cdf8bfbfb71	3.66	10.95	7.92	2.21	1.29
Lwandlamuni	2023	15afde212d153f585773da146a511051	5.78	8.36	8.13	0.15	0.13
Lwandlamuni	2023	fb363e3c4781f9436c3e139fc75a4a52	1.80	14.66	1.56	0.90	1.15

In Table 8 eef_{ij} is given in column *eef* and is calculated from the product of $\overline{x}_{(B)ij}$ (in column *XBij_m2*) with rr_{ij} (in column *rr*) divided by $\overline{x}_{(M)ij}$ (in column *XMij_m2*).

1.4.4 Calculation of $\overline{x}_{(M)ij}$

The calculation of $\overline{x}_{(M)ij}$ was shown in Section 1.3.6.1.

1.4.5 Calculation of $\overline{x}_{(B)ij}$

1.4.5.1 Calculation The average fuel use (in kg) per fire in the baseline scenario for household j in subpopulation i is calculated as the average of the daily average fuel per fire.

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

Where

- $x_{(B)ijk}$ is the daily fuel use on day k for household j in subpopulation i for the baseline phase of the KT.
- $fr_{(B)ijk}$ is the frequency on day k for household j in subpopulation i in the baseline phase of the KT.
- $n_{(B)ij}$ is the number of valid observations for household j in subpopulation i in the baseline phase of the KT.

Table 9: Sample of data from baseline kitchen test

fuel	assignment	place	year	household_qr_code	diffB	frBijk	XBijk_m2	XBij_m2
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	NA	NA	NA [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	8.82	3	2.940000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	11.80	4	2.950000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	2.16	1	2.160000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	15.12	2	7.560000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	11.34	3	3.780000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	3.00	1	3.000000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	4.90	3	1.633333 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	3.96	1	3.960000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	14.18	2	7.090000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	8.48	2	4.240000 [kg]	4.39
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	9.02	1	9.020000 [kg]	4.39

Table 10: Sample of data from baseline kitchen test results summarised by household

fuel	assignment	place	year	household_qr_code	XBij.	frBij.	XBij_m2
wood	baselineKT	Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	92.78	23	4.39
wood	baselineKT	Lwandlamuni	2023	8327a5a6d11e32ec6d23a0e13fbbb0e2	105.66	33	3.37
wood	baselineKT	Lwandlamuni	2023	3403ad40c2c4a1eb44951d046a0463b2	75.94	22	4.64
wood	baselineKT	Lwandlamuni	2023	3c367d67a239be8b700c4cdf8bfbfb71	153.54	42	4.63
wood	baselineKT	Lwandlamuni	2023	15afde212d153f585773da146a511051	103.95	18	7.15
wood	baselineKT	Lwandlamuni	2023	fb363e3c4781f9436c3e139fc75a4a52	41.51	23	1.98

Table 9 gives the observations for a single household. Column *XBijk_m2* gives $\frac{x_{(B)ijk}}{fr_{(B)ijk}}$, the daily average fuel use per fire.

In Table 10 $\overline{x}_{(B)ij} = \frac{1}{n_{(B)ij}} \sum \frac{x_{(B)ijk}}{fr_{(B)ijk}}$ is given in column *XBij_m2*. In Table 3 $\overline{x}_{(B)i}$ is 4.45 which is the average of the column *XBij_m2* in Table 10.

1.4.6 Calculation rr_{ij}

1.4.6.1 Calculation The replacement ratio for household j in subpopulation i is calculated as

$$rr_{ij} = \frac{fr_{(B)ij.} \times \frac{ndays\_PKT}{ndays\_BKT} - fr_{(BP)ij.}}{fr_{(M)ij.}}$$

Where

- $fr_{(B)ij.} \times \frac{ndays\_PKT}{ndays\_BKT}$ is the scaled total number of fires per day in the baseline phase for household j in subpopulation i to take into account the difference in total days in the baseline phase of the kitchen test and the project phase of the kitchen test.
- $fr_{(BP)ij.}$ is the total number of baseline fires per day for household j in subpopulation i in the project phase of the kitchen test.
- $fr_{(M)ij.}$ is the total number of project measures fires per day for household j in subpopulation i in the project phase of the kitchen test.

Table 11: Calculation of replacement ratio per household

place	year	household_qr_code	frBij.	ndays_BKT	frMij.	frPij.	ndays_PKT	rr
Lwandlamuni	2023	6a8af21c1da0835997802ce38148acea	23	20	8	18	15	0.91
Lwandlamuni	2023	8327a5a6d11e32ec6d23a0e13fbbb0e2	33	20	2	16	15	5.38
Lwandlamuni	2023	3403ad40c2c4a1eb44951d046a0463b2	22	20	13	30	15	-0.04
Lwandlamuni	2023	3c367d67a239be8b700c4cdf8bfbfb71	42	20	12	17	15	2.21
Lwandlamuni	2023	15afde212d153f585773da146a511051	18	20	10	22	15	0.15
Lwandlamuni	2023	fb363e3c4781f9436c3e139fc75a4a52	23	20	18	19	15	0.90

Table 11 shows the calculated replacement ratio for a sample of the households.

1.5 Calculation of leakage CO_2 emissions

1.5.1 Calculation of LE_y

Leakage will be due to continued use of baseline technology. However, for this project the baseline emissions is calculated as the product of the energy efficiency factor and the project emissions only. Neither the calculation of the baseline emissions, nor the calculation of the project emissions, take into account the emissions from baseline technology. The subtraction of leakage emissions in the emission reduction is therefore not valid for this project.