Kitchen Performance Test
Rock Bed Stove versus Open Fire
SNV Vietnam
For Sun24






Version 1.2, dated 19/06/2019

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June 2019

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1. Conclusions and Recommendations

SNV Vietnam was requested by Sun 24 to conduct independently and objectively a test to assess the fuel savings of an innovative cooking technology, by putting a rock bed under open fire. With a number of positive test results from across Sun 24's experiences in Africa and South Asia, this was a first introduction in South East Asia.

The test result of this Kitchen Performance Test demonstrated that fuel savings for cooking were achieved of **34%** by applying stones under the fire, compared to the normal situation of an open fire.

This confirms earlier laboratory test conducted by SNV in Hanoi in 2018. Fuel consumption showed a reduction of 30% compared to open fire when boiling 3 liters of water.

The qualitative feedback received by the cooks when the KPT was finalized, showed consistently positive reactions on the application of stones under the fire.

This accumulates to a body of evidence that tells that rock bed stoves do have a substantial impact on fuel efficient cooking.

SNV therefore strongly supports Sun24 to continue its advocating and disseminating work to get this highly potential and appropriate technology used in as many kitchens as possible.

The following recommendations are given, all of which SNV is interested to give its support to:

1. Triangulate data collection on fuel use with air sensors so that potential impact on health can be determined as well. SNV successfully trialled a few air quality sensors in kitchens for learning and found this to significantly strengthen our understanding of kitchen cooking systems.
2. Conduct a Controlled Cooking Test, a panel test cooking under controlled settings. This test eliminates influencing factors that play a role under the KPT whilst keeping close to realities.
3. Extend the tests in a methodological manner across different countries and in more different climatic settings to gain insights in the short term and long adoption and dissemination of the rock bed stoves.
4. Unravel the science behind this phenomenon through an academic review determining the physical dynamics and factors explaining the fuel savings.
5. Publish these highly exciting findings on websites, mass media and organise local workshops through the Vietnam Women Union and local NGOs to reach out to remote and poor areas.
6. Establish collaboration with stakeholders in related sectors such as, gender, nutrition, WASH, education, and climate adaptation and mitigation, and for applications in productive low developed industries.

2. Introduction

SNV Netherlands Development Organization is founding member of the Alliance for Clean Cooking and has over the last decade accelerated markets that sold over half a million cookstoves across a dozen developing countries, helping 2.5 million people and mitigating millions of tonnes of GHG. As part of its strategy, SNV aims to double this number by reaching 5 million people with improved and clean cooking solutions (improved biomass stoves, gasifiers, biogas, as well as modern fuels) by 2022. Throughout its projects, SNV follows stringent monitoring protocols and ensures the validation of performance through testing and survey analysis, so that it has the best possible information on dissemination numbers and on the impact for end users.

Sun24 is a non-faith based nonprofit that has distributed, or committed to distribute, over 170,000 solar lights in Africa. Besides, Sun24's mission is to improve the efficiency of cooking and one of the Sun24's designs to make the fires more efficient, reducing the use of firewood, reducing smoke and cooking faster is using the grate or small stones together with the traditional stove (3 stones/tripod stoves). The grate and rock stone cooking innovation are simple and cheap solutions that may proof suitable and effective to introduce in areas where the three stone fire is the norm. A qualitative user survey with 99 women in Sun24's previous test shows that with this small modification, the rock bed stove emits less smoke and higher thermal efficiency compared to the 3-stones stove without rocks. According to the information provided by Sun24's partners in Uganda, Kenya, Tanzania and India estimate that 1.5 million households have begun using rock beds since they began training in March 2019 which translated to one million tonnes of CO_{2e} per year. Sun24 will expand training to Ethiopia, Nigeria, Ghana and Malawi in the coming months. Sun24 projects that at least five million households will be using rock beds by the end of 2019, resulting in an annual mitigation of over three million tonnes of CO_{2e}.

To test and quantify the fuel saving and emission reduction, in end of 2018 and early 2019, SNV Vietnam (SNV) conducted the lab tests in Hanoi according to the Simplified Water Boiling (SWBT) to assess the difference in fuel use, Particulate Matter (PM) and Carbon monoxide (CO) emission between the Iron bar stove (which is similar to the 3 stones stove in term of efficiency) and the Iron bar with a grate and with small stones/bricks when boiling 3 liters of water. The lab test results showed that the fuel consumption could reduce 30% with the rock bed application. The reduction in emission of PM and CO were 35% and 45%.[1]

Stimulated by the lab results Sun24 commissioned SNV to conduct a KPT to assess the impact on fuel consumption in real settings.

[1] Advanced ceramic stove grates improved the impact even much further.

3. Objectives

With the aim to further add confidence through an experiences, independent verifier, Sun24 commissioned SNV to conducting the Kitchen Performance Test (KPT), which is a field test used to evaluate stove performance in real-world settings.

It is designed to assess actual impacts on household fuel consumption of Kg fuels and to receive qualitative feedback from the cooks. See details of the followed protocol on: https://www.cleancookingalliance.org/binary-data/DOCUMENT/file/000/000/83-1.pdf

The findings of this KPT report are meant of Sun 24 to strengthen their advocacy work and get SNV and its networks interested to support this movement.

4. Scope of Work

SNV carried out the Kitchen Performance Test (KPT) in Khanh Thuong commune, Ba Vi district, a mountainous district in Western part of Hanoi Province. Through an experienced team, SNV took great care all preparations, field activities, data recording, data analyzing and reporting was done in accordance to the protocol.

The work included recruiting and training surveyors for the field data collection; managing and supervising the survey implementation. SNV screened all data, filtered outliers and verified with surveyors when necessary.

Data validity is furthermore ensured through the use of a custom made app based survey-tool (designed by AKVO) that records time slots, GPS and photo evidence in questionnaires and observation forms.

In addition, SNV worked on air sensors of the Hanoi University that were trialed and adjusted, and the data added to the understanding of the KPT.

The enumerators compiled telling stories explaining the challenges in the field and the struggles that the people in this survey endure to secure their livelihoods

5. Methodology

The KPT survey method measures fuel consumption[2] before and after the introduction of the cooking innovation.

It includes the following 4 steps:

1. Identifying suitable households willing and able to cooperate

[2] The KPT equipment technical specification is described in Annex 4

2. Weighing of fuel used in the baseline scenario – BEFORE phase (using wood with their traditional stoves)
3. Introduction of the new cooking innovation: train the cook and let them use it themselves for 4 days
4. Weighing of fuel use in the intervention scenario – AFTER phase when the cook is using the rock bed stove under their traditional stoves.

During the test, households were instructed to cook normally as per their usual cooking behavior, as if no tests were happening; to feed the usual number of people and usual variation of food types.

The implementation of a 3 days KPT requires four visits to each household on consecutive days from Tuesday to Friday for each BEFORE and one sequence for the AFTER phase.

The main purpose of the KPT is to compare fuel usage between the BEFORE and AFTER phase of using cooking innovation. As all others is kept equal, the differences in fuel use can be attributed to the stove.

In order to ensure a consistent comparison, surveyors avoided periods that might disturb the usual fuel consumption patterns, like in weekends and festivals.

- Visit 1: Weighed all household fuels to be used (fuel wood) for the next 24 hour period. Placed all weighed fuels in the designated inventory areas.
- Visit 2 and 3: Weighed remaining fuel in the inventories. Add what would be needed for the next 24 hours to the inventory and re-weighed for the next day.
- Visit 4: Weighed remaining fuel in the inventories.

Under the BEFORE phase, the household continued using their traditional stove as usual. Below are some photos of baseline stoves:

Figure 1. Baseline stoves[3]

After the BEFORE phase, the households were introduced to use the rocks bed under their traditional stove with some examples configuration as below.

[3] Please find more photos in the Annex 3 of this report

Figure 2. Rock bed stoves[4]

Only fuel from designated stocks that were pre-weighed by the surveyors who were collecting the data. The surveyor monitored the wood fuel that the household used during the 24 hours intervals.

Readings of moisture content of wood was measured daily at three points on randomly selected sticks in the woodpile. A short questionnaire was administered daily to record information about stove and fuel usage, the number of prepared meals and the number of people cooked for. Cooks were asked to maintain their typical cooking patterns for the duration of the KPT.

According to the KPT methodology, the two (or a combination of) approaches can followed, a *paired-sample study* with same households applying step 2 to 4 or a *cross-sectional study*, involving different households for step 2; 3 and 4. Under this KPT, the paired-sample study was followed since this contains the least risk of unequal comparison, and faces less complicated organizational challenges.

According to the lab test, we expected to arrive at a fuel saving of 30%. The CoV (SD/mean) tolerance for KPT is 40%, therefore the minimum sample size should be 14 household according to the below table.

Table 1. Sample size for KPT survey

SAMPLE SIZE REQUIRED FOR THE PAIRED-SAMPLE TEST METHOD

	Pooled CV of measurements												
Detectable difference in means	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**
10%	8	31	71	126	196	283	385	502	636	785	950	1130	1326
20%	2	8	18	31	49	71	96	126	159	196	237	283	332
30%	1	3	8	14	22	31	43	56	71	87	106	126	147
40%	0	2	4	8	12	18	24	31	40	49	59	71	83
50%	0	1	3	5	8	11	15	20	25	31	38	45	53
60%	0	1	2	3	5	8	11	14	18	22	26	31	37
70%	0	1	1	3	4	6	8	10	13	16	19	23	27
80%	0	0	1	2	3	4	6	8	10	12	15	18	21
90%	0	0	1	2	2	3	5	6	8	10	12	14	16
100%	0	0	1	1	2	3	4	5	6	8	9	11	13

Based on our experience, and to account for the likely default during the test period, 30 households were selected for surveying. During the BEFORE phase, the surveyors had prepared the suitable rocks and in the last day of BEFORE phase, they provided training to the households and put the rocks bed in the kitchen of the selected participating households. The guidance for rocks bed configuration (Annex 1) was translated into Vietnamese language and this poster was stuck on the household's kitchen wall to remind about the cooks.

[4] Idem.

6. Timeline of Activities

The following provides an overview of the steps of the KPT survey process, taking place from May to June 2019, approximately 8 weeks from starting to completion of deliverables.

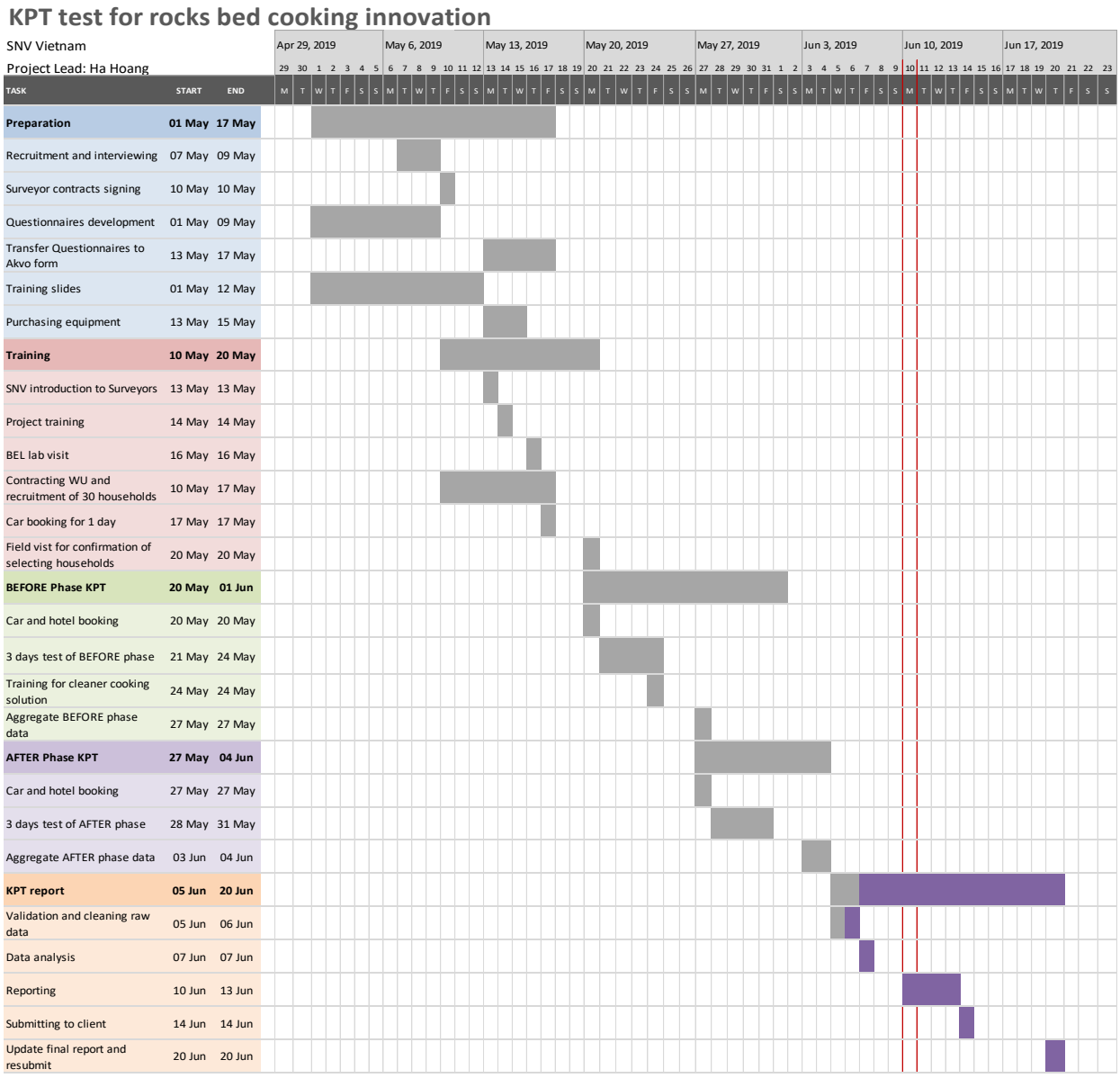


Figure 3. Project Gantt chart

7. Selection of households

Four villages in Khanh Thuong commune, Ba Vi district were selected (one surveyor per location) to arrive at a cross section of the area. The distribution of households for each village is below:

Table 2. Location of surveyed households

Location	No of HHs
Buoi village	7
Huong Canh village	8
Dong Song village	8
Go Dinh Muon village	7

The geographical distribution of KPT households could be found in the map below.

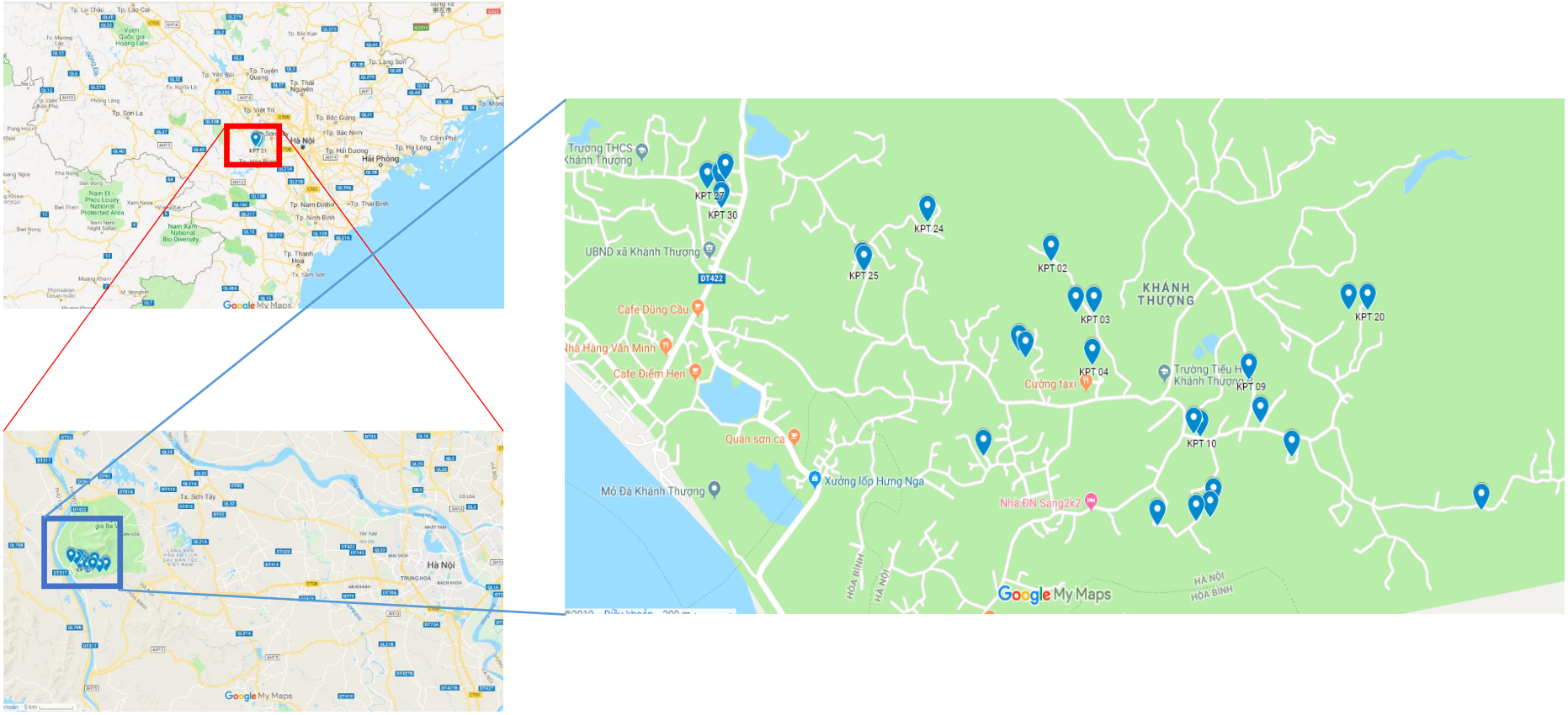


Figure 4. KPT household locations

8. KPT results

8.1. Standard Adult Persons

The amount people fed has relation to the amount of food and the fuel needed to prepare the meal. The more the people, the higher amount of food and fuel is used. It was thus important to know the number of people eating during the KPT and was therefore recorded. The gender and age of each person resulted in a so called standard adult (SA) persons following the conversion factors below:

Table 3. SA conversion factors[5]

Gender and age	Fraction of standard adult
Child: 0-14 years	0.5
Female: over 14 years	0.8
Male: 15-59 years	1.0
Male: over 59 years	0.8

During the BEFORE and AFTER phase, the total SA per day is presented below and shows substantial variations over the days which have been conversed in the KPT calculations.

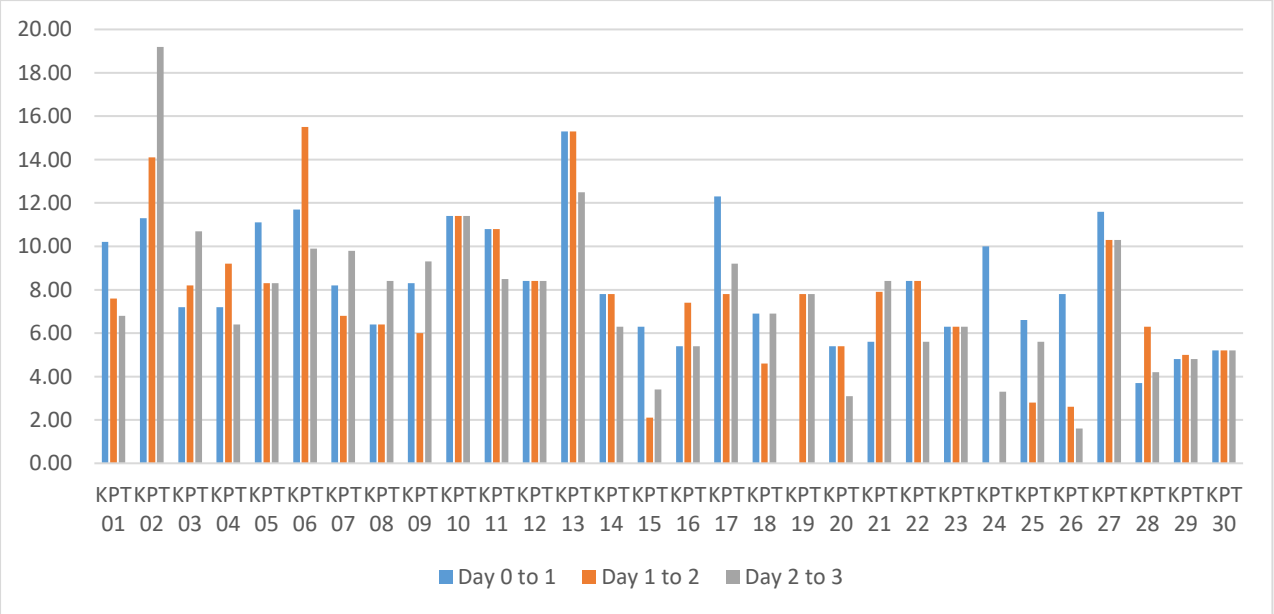


Figure 5. Total SA per day during BEFORE phase

[5] Kitchen Performance Test (KPT), version 4.0, March 2018

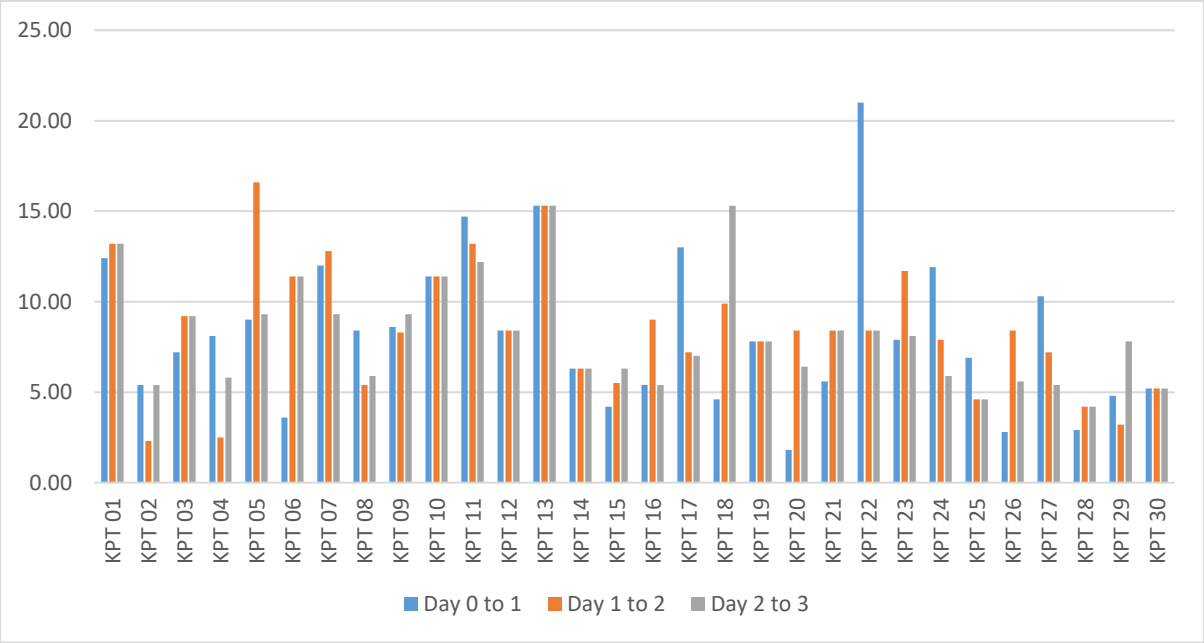


Figure 6. Total SA per day during AFTER phase

8.2. Moisture content in air and in the fuel wood

In the AFTER phase period, heavy rains poured down, therefore air humidity levels and the moisture content of wood in the AFTER phase was higher than the BEFORE phase. One air humidity sensor that placed in a kitchen confirmed this:

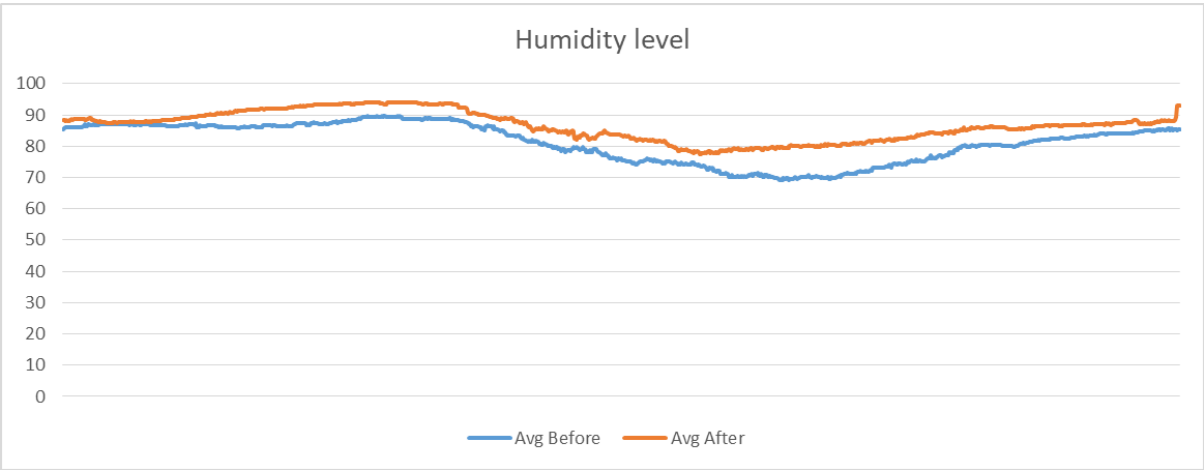


Figure 7. Air humidity level (%) measured by AIRSENSE

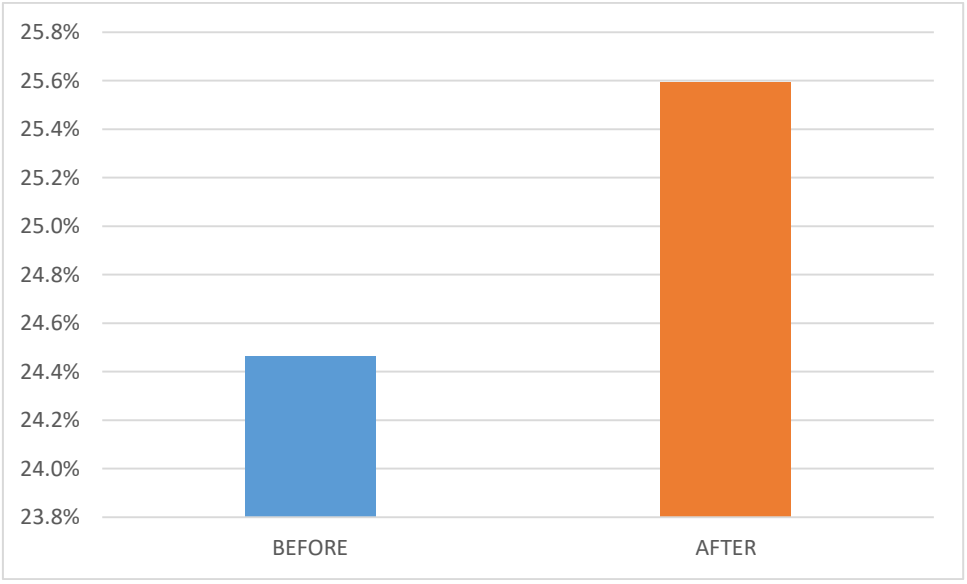


Figure 8. Average moisture content wood by daily measuring wood sticks

The moisture equipment measured fuel moisture of the wood, to deduct the moisture content (MC wet), we used the following calculation to arrive at the dry wood (MCwet)[6]:

$$MC_{wet} = \frac{MC_{dry}}{1 + MC_{dry}}$$

The dry-basis fuel was calculated as follow:

*Amount in dry-basis = Amount in wet-basis * (1-MC_{wet})*

The air moisture is not compensated in the KPT protocol even though can make and impact on the fuel consumption.

8.3. Dry Fuel consumption at household level

When considering the moisture content of fuel wood, the KPT result showed the reduction in fuel consumption of 23 households (with average reduction of 4.53 kg/household). In the remaining 7 households, the fuel consumption was slightly increased (with average increase of 1.61 kg/household).

Overall among 30 households, a household reduce 3.1 kg fuel per day equivalent to reduction of 28.5% of fuel consumption.
The fuel consumption of each household during BEFORE and AFTER phase could be illustrated in the below figure:

[6] KPT version 3.0

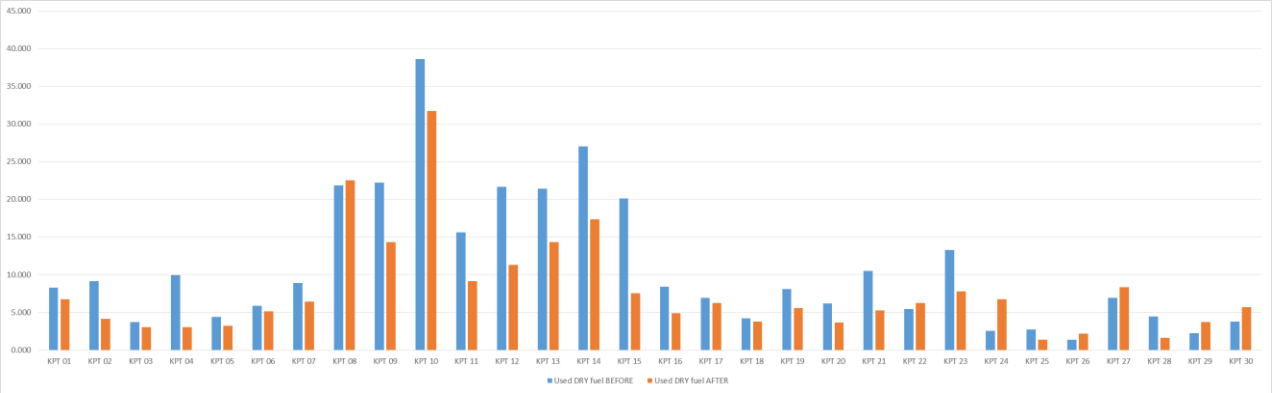


Figure 9. Average household fuel use during BEFORE and AFTER phases on dry-basis

The follow up interviews with the households who against expectations increased the fuel consumption were called and the potential reasons were summarized in the Annex 5.

Among the households which show odd results by increased fuel consumption, there is a special case with HH KPT26, during the BEFORE phase, they use the 4 bricks stove:

Figure 10. KPT 26 BEFORE stove

However, due to the very narrow and small space within the stove, the rocks bed was difficult to set up for the AFTER phase test, the household and surveyor

agreed to change the stove to iron bar then the rocks bed innovation could be applied.

Figure 11. KPT 26 AFTER stove

With same logic to the rocks bed stove, the bricks likely helped to improve the thermal efficiency.

8.4. Fuel consumption at SA level

As per the KPT protocol, the fuel consumption per standard adult person (SA) was analyzed in standard spreadsheets. Abnormal situations from specific households were excluded as outliers. For example, during KPT test, there were cases that in the BEFORE phase, the household did not cook any meal during the day. Then when analyzing at household level, the result will not be comparable across the BEFORE and AFTER phases.

For each day, the total dry fuel consumption and SA were calculated from the wet-basis fuel, moisture content and the number of people with their age and gender. After that, the dry fuel consumption for each day was calculated accordingly, following the below formulae:

Dry fuel consumption/SA
= Total dry fuel consumption per day / Total SA per day

After removing outliers following the guidance from Goldstandard methodology "Technologies and Practices to Displace Decentralized Thermal Energy Consumption" (TPDDTEC), mean values and standard deviations were calculated as in below section.

SA fuel consumption analysis for BEFORE phase

HH code	HH day code	DRY Fuel consumption	Total SA	DRY fuel consumption/SA	Outlier?
KPT 01	KPT 01.D1	13.66	10.20	1.34	FALSE*
KPT 01	KPT 01.D2	6.43	7.60	0.85	FALSE
KPT 01	KPT 01.D3	4.75	6.80	0.70	FALSE
KPT 02	KPT 02.D1	8.07	11.30	0.71	FALSE
KPT 02	KPT 02.D2	9.19	14.10	0.65	FALSE
KPT 02	KPT 02.D3	10.09	19.20	0.53	FALSE
KPT 03	KPT 03.D1	4.68	7.20	0.65	FALSE
KPT 03	KPT 03.D2	2.31	8.20	0.28	FALSE
KPT 03	KPT 03.D3	4.08	10.70	0.38	FALSE
KPT 04	KPT 04.D1	10.06	7.20	1.40	FALSE
KPT 04	KPT 04.D2	13.54	9.20	1.47	FALSE
KPT 04	KPT 04.D3	6.25	6.40	0.98	FALSE
KPT 05	KPT 05.D1	3.58	11.10	0.32	FALSE
KPT 05	KPT 05.D2	4.24	8.30	0.51	FALSE
KPT 05	KPT 05.D3	5.39	8.30	0.65	FALSE
KPT 06	KPT 06.D1	8.36	11.70	0.71	FALSE
KPT 06	KPT 06.D2	5.44	15.50	0.35	FALSE
KPT 06	KPT 06.D3	3.75	9.90	0.38	FALSE
KPT 07	KPT 07.D1	9.17	8.20	1.12	FALSE
KPT 07	KPT 07.D2	9.21	6.80	1.35	FALSE
KPT 07	KPT 07.D3	8.20	9.80	0.84	FALSE

HH code	HH day code	DRY Fuel consumption	Total SA	DRY fuel consumption/SA	Outlier?
KPT 08	KPT 08.D1	16.82	6.40	2.63	FALSE
KPT 08	KPT 08.D2	23.78	6.40	3.72	FALSE
KPT 08	KPT 08.D3	24.87	8.40	2.96	FALSE
KPT 09	KPT 09.D1	23.03	8.30	2.77	FALSE
KPT 09	KPT 09.D3	18.57	9.30	2.00	FALSE
KPT 10	KPT 10.D1	38.53	11.40	3.38	FALSE
KPT 10	KPT 10.D2	39.72	11.40	3.48	FALSE
KPT 10	KPT 10.D3	37.72	11.40	3.31	FALSE
KPT 11	KPT 11.D1	13.99	10.80	1.30	FALSE
KPT 11	KPT 11.D2	16.90	10.80	1.56	FALSE
KPT 11	KPT 11.D3	16.02	8.50	1.89	FALSE
KPT 12	KPT 12.D1	17.98	8.40	2.14	FALSE
KPT 12	KPT 12.D2	23.55	8.40	2.80	FALSE
KPT 12	KPT 12.D3	23.47	8.40	2.79	FALSE
KPT 13	KPT 13.D1	15.82	15.30	1.03	FALSE
KPT 13	KPT 13.D2	23.85	15.30	1.56	FALSE
KPT 13	KPT 13.D3	24.53	12.50	1.96	FALSE
KPT 14	KPT 14.D1	19.55	7.80	2.51	FALSE
KPT 15	KPT 15.D1	20.22	6.30	3.21	FALSE
KPT 16	KPT 16.D1	8.96	5.40	1.66	FALSE
KPT 16	KPT 16.D2	8.40	7.40	1.14	FALSE
KPT 16	KPT 16.D3	7.80	5.40	1.44	FALSE
KPT 17	KPT 17.D1	8.30	12.30	0.68	FALSE
KPT 17	KPT 17.D2	7.78	7.80	1.00	FALSE
KPT 17	KPT 17.D3	4.64	9.20	0.50	FALSE
KPT 18	KPT 18.D1	5.58	6.90	0.81	FALSE
KPT 18	KPT 18.D2	3.89	4.60	0.85	FALSE
KPT 18	KPT 18.D3	3.21	6.90	0.47	FALSE
KPT 19	KPT 19.D2	8.26	7.80	1.06	FALSE
KPT 19	KPT 19.D3	8.15	7.80	1.05	FALSE
KPT 20	KPT 20.D1	4.87	5.40	0.90	FALSE
KPT 20	KPT 20.D2	7.74	5.40	1.43	FALSE
KPT 20	KPT 20.D3	5.90	3.10	1.90	FALSE
KPT 21	KPT 21.D1	14.70	5.60	2.63	FALSE
KPT 21	KPT 21.D2	9.25	7.90	1.17	FALSE
KPT 21	KPT 21.D3	7.55	8.40	0.90	FALSE
KPT 22	KPT 22.D1	5.48	8.40	0.65	FALSE
KPT 22	KPT 22.D2	6.00	8.40	0.71	FALSE
KPT 22	KPT 22.D3	4.75	5.60	0.85	FALSE
KPT 23	KPT 23.D1	14.84	6.30	2.36	FALSE
KPT 23	KPT 23.D2	15.32	6.30	2.43	FALSE

HH code	HH day code	DRY Fuel consumption	Total SA	DRY fuel consumption/SA	Outlier?
KPT 23	KPT 23.D3	9.66	6.30	1.53	FALSE
KPT 24	KPT 24.D1	6.01	10.00	0.60	FALSE
KPT 24	KPT 24.D3	1.36	3.30	0.41	FALSE
KPT 25	KPT 25.D1	5.87	6.60	0.89	FALSE
KPT 25	KPT 25.D2	0.91	2.80	0.33	FALSE
KPT 25	KPT 25.D3	1.37	5.60	0.24	FALSE
KPT 26	KPT 26.D1	2.26	7.80	0.29	FALSE
KPT 26	KPT 26.D2	0.17	2.60	0.07	FALSE
KPT 26	KPT 26.D3	1.66	1.60	1.04	FALSE
KPT 27	KPT 27.D1	5.66	11.60	0.49	FALSE
KPT 27	KPT 27.D2	8.37	10.30	0.81	FALSE
KPT 27	KPT 27.D3	6.66	10.30	0.65	FALSE
KPT 28	KPT 28.D1	3.48	3.70	0.94	FALSE
KPT 28	KPT 28.D2	6.36	6.30	1.01	FALSE
KPT 28	KPT 28.D3	3.47	4.20	0.83	FALSE
KPT 29	KPT 29.D1	2.45	4.80	0.51	FALSE
KPT 29	KPT 29.D2	1.48	5.00	0.30	FALSE
KPT 29	KPT 29.D3	2.80	4.80	0.58	FALSE
KPT 30	KPT 30.D1	2.96	5.20	0.57	FALSE
KPT 30	KPT 30.D2	3.29	5.20	0.63	FALSE
KPT 30	KPT 30.D3	5.02	5.20	0.97	FALSE
KPT 09	KPT 09.D2	25.01	6.00	4.17	TRUE*
KPT 14	KPT 14.D2	29.88	7.80	3.83	TRUE
KPT 14	KPT 14.D3	31.70	6.30	5.03	TRUE
KPT 15	KPT 15.D2	15.35	2.10	7.31	TRUE
KPT 15	KPT 15.D3	24.87	3.40	7.31	TRUE
KPT 19	KPT 19.D1	7.80	0.00		TRUE
KPT 24	KPT 24.D2	0.32	0.00		TRUE

* FALSE=not an outlier record, TRUE=outlier record

After removing the outlier records, the mean and SD value were calculated and resulted as below:

Unit: Kg/SA

Average dry wood Equivalent	**1.49**
Standard deviation	**1.37**
Number of valid test	**83**

SA fuel consumption analysis for AFTER phase

HH code	HH day code	DRY Fuel consumption	Total SA	DRY fuel consumption/SA	Outlier?
KPT 01	KPT 01.D1	6.72	12.40	0.54	FALSE*
KPT 01	KPT 01.D2	5.64	13.20	0.43	FALSE
KPT 01	KPT 01.D3	7.84	13.20	0.59	FALSE
KPT 02	KPT 02.D1	7.03	5.40	1.30	FALSE
KPT 02	KPT 02.D2	1.84	2.30	0.80	FALSE
KPT 02	KPT 02.D3	3.51	5.40	0.65	FALSE
KPT 03	KPT 03.D1	2.60	7.20	0.36	FALSE
KPT 03	KPT 03.D2	2.54	9.20	0.28	FALSE
KPT 03	KPT 03.D3	4.00	9.20	0.44	FALSE
KPT 04	KPT 04.D1	2.87	8.10	0.35	FALSE
KPT 04	KPT 04.D2	2.65	2.50	1.06	FALSE
KPT 04	KPT 04.D3	3.53	5.80	0.61	FALSE
KPT 05	KPT 05.D1	1.61	9.00	0.18	FALSE
KPT 05	KPT 05.D2	5.71	16.60	0.34	FALSE
KPT 05	KPT 05.D3	2.38	9.30	0.26	FALSE
KPT 06	KPT 06.D1	3.42	3.60	0.95	FALSE
KPT 06	KPT 06.D2	6.88	11.40	0.60	FALSE
KPT 06	KPT 06.D3	5.04	11.40	0.44	FALSE
KPT 07	KPT 07.D1	6.96	12.00	0.58	FALSE
KPT 07	KPT 07.D2	6.86	12.80	0.54	FALSE
KPT 07	KPT 07.D3	5.42	9.30	0.58	FALSE
KPT 09	KPT 09.D1	19.25	8.60	2.24	FALSE
KPT 09	KPT 09.D3	9.96	9.30	1.07	FALSE
KPT 10	KPT 10.D3	24.09	11.40	2.11	FALSE
KPT 11	KPT 11.D1	8.12	14.70	0.55	FALSE
KPT 11	KPT 11.D2	7.51	13.20	0.57	FALSE
KPT 11	KPT 11.D3	11.70	12.20	0.96	FALSE
KPT 12	KPT 12.D1	11.97	8.40	1.43	FALSE
KPT 12	KPT 12.D2	10.70	8.40	1.27	FALSE
KPT 12	KPT 12.D3	11.20	8.40	1.33	FALSE
KPT 13	KPT 13.D1	14.02	15.30	0.92	FALSE
KPT 13	KPT 13.D2	12.73	15.30	0.83	FALSE
KPT 13	KPT 13.D3	16.19	15.30	1.06	FALSE
KPT 15	KPT 15.D1	2.47	4.20	0.59	FALSE
KPT 16	KPT 16.D1	4.05	5.40	0.75	FALSE
KPT 16	KPT 16.D2	7.02	9.00	0.78	FALSE
KPT 16	KPT 16.D3	3.59	5.40	0.66	FALSE
KPT 17	KPT 17.D1	9.97	13.00	0.77	FALSE
KPT 17	KPT 17.D2	4.08	7.20	0.57	FALSE
KPT 17	KPT 17.D3	4.64	7.00	0.66	FALSE
KPT 18	KPT 18.D1	2.38	4.60	0.52	FALSE

HH code	HH day code	DRY Fuel consumption	Total SA	DRY fuel consumption/SA	Outlier?
KPT 18	KPT 18.D2	4.41	9.90	0.45	FALSE
KPT 18	KPT 18.D3	4.46	15.30	0.29	FALSE
KPT 19	KPT 19.D2	8.12	7.80	1.04	FALSE
KPT 19	KPT 19.D3	1.60	7.80	0.21	FALSE
KPT 20	KPT 20.D1	0.87	1.80	0.48	FALSE
KPT 20	KPT 20.D2	1.61	8.40	0.19	FALSE
KPT 20	KPT 20.D3	8.43	6.40	1.32	FALSE
KPT 21	KPT 21.D1	7.05	5.60	1.26	FALSE
KPT 21	KPT 21.D2	3.66	8.40	0.44	FALSE
KPT 21	KPT 21.D3	5.07	8.40	0.60	FALSE
KPT 22	KPT 22.D1	6.38	21.00	0.30	FALSE
KPT 22	KPT 22.D2	5.44	8.40	0.65	FALSE
KPT 22	KPT 22.D3	6.97	8.40	0.83	FALSE
KPT 23	KPT 23.D1	10.54	7.90	1.33	FALSE
KPT 23	KPT 23.D2	7.17	11.70	0.61	FALSE
KPT 23	KPT 23.D3	5.54	8.10	0.68	FALSE
KPT 24	KPT 24.D1	8.73	11.90	0.73	FALSE
KPT 24	KPT 24.D3	7.97	5.90	1.35	FALSE
KPT 25	KPT 25.D1	1.61	6.90	0.23	FALSE
KPT 25	KPT 25.D2	1.70	4.60	0.37	FALSE
KPT 25	KPT 25.D3	0.82	4.60	0.18	FALSE
KPT 26	KPT 26.D1	3.41	2.80	1.22	FALSE
KPT 26	KPT 26.D2	2.22	8.40	0.26	FALSE
KPT 26	KPT 26.D3	0.86	5.60	0.15	FALSE
KPT 27	KPT 27.D1	9.45	10.30	0.92	FALSE
KPT 27	KPT 27.D2	7.89	7.20	1.10	FALSE
KPT 27	KPT 27.D3	7.70	5.40	1.43	FALSE
KPT 28	KPT 28.D1	1.16	2.90	0.40	FALSE
KPT 28	KPT 28.D2	2.24	4.20	0.53	FALSE
KPT 28	KPT 28.D3	1.46	4.20	0.35	FALSE
KPT 29	KPT 29.D1	3.12	4.80	0.65	FALSE
KPT 29	KPT 29.D2	3.53	3.20	1.10	FALSE
KPT 29	KPT 29.D3	4.41	7.80	0.57	FALSE
KPT 30	KPT 30.D1	5.57	5.20	1.07	FALSE
KPT 30	KPT 30.D2	7.25	5.20	1.39	FALSE
KPT 30	KPT 30.D3	4.26	5.20	0.82	FALSE
KPT 09	KPT 09.D2	13.83	8.30	1.67	FALSE
KPT 14	KPT 14.D3	11.73	6.30	1.86	FALSE
KPT 15	KPT 15.D2	10.33	5.50	1.88	FALSE
KPT 15	KPT 15.D3	9.71	6.30	1.54	FALSE
KPT 19	KPT 19.D1	6.95	7.80	0.89	FALSE

HH code	HH day code	DRY Fuel consumption	Total SA	DRY fuel consumption/SA	Outlier?
KPT 24	KPT 24.D2	3.41	7.90	0.43	FALSE
KPT 08	KPT 08.D1	26.02	8.40	3.10	TRUE*
KPT 08	KPT 08.D2	25.43	5.40	4.71	TRUE
KPT 08	KPT 08.D3	16.05	5.90	2.72	TRUE
KPT 10	KPT 10.D1	39.75	11.40	3.49	TRUE
KPT 10	KPT 10.D2	31.36	11.40	2.75	TRUE
KPT 14	KPT 14.D1	20.85	6.30	3.31	TRUE
KPT 14	KPT 14.D2	19.43	6.30	3.08	TRUE

* FALSE=not an outlier record, TRUE=outlier record

Similarly, the fuel consumption and SD could be presented as below:

Unit: kg/SA

Average dry wood Equivalent	**0.98**
Standard deviation	**0.83**
Number of valid test	**83**

SA fuel saving analysis

Fuel saving analysis			
	Unit	Project	Baseline
Description	-	Iron bar with rocks	Iron bar only
Mean Wood equivalent consumption	kg/SA	0.98	1.49
t-value	-	1.66	1.66
Std dev	kg/SA	0.83	1.37
COV	-	0.85	0.92
Sample size	#	83	83
Mean Wood equivalent saving	kg/SA		0.51
Std Error	kg/SA		0.18
			Saving in %
Lower value of Mean Wood equivalent saving	kg/SA	0.21	14.4%
Mean Wood equivalent saving	kg/SA	**0.51**	**34.0%**
Upper value of Mean Wood equivalent saving	kg/SA	0.80	53.7%

The statistical analysis showed that the mean saved dry fuel wood consumption is 0.51 kg/SA which equivalent to 34% of saving.

Due to uncertainty of statistical analysis, this result varies from 0.21 Kg/SA (reduced 14.4% of wood consumption) to 0.80 Kg/SD (reduced 53.7% of wood consumption).

8.5. Qualitative survey

At the end of the KPT survey (end of AFTER phase), the cooks (90% women) were asked about their experiences by the following set of questions:

57. How do you think about the smoke level of new solution?	*Much less*	*Less*	*Same*	*More*	*Much more*
58. How do you think about the time saving of new solution?	*Much less*	*Less*	*Same*	*More*	*Much more*
59. How do you think about the fuel saving of new solution?	*Much less*	*Less*	*Same*	*More*	*Much more*
60. How do you think about the convenience level of new solution?	*Much less*	*Less*	*Same*	*More*	*Much more*
61. Will you still continue to use this solution?	*Yes and also introduce to my neighbor, friends*	*Yes at my family*	*To test more before answer*	*No*	
62. If Answer to the above question is "NO", Please explain why					

The feedback from cooks were very positive on using of the new cooking innovation.

In particular, all of the households observed that with a rocks bed, the stove emits less smoke than before, 73% of the respondents (22 households) said that it reduced much less smoke compare to the traditional stove before.

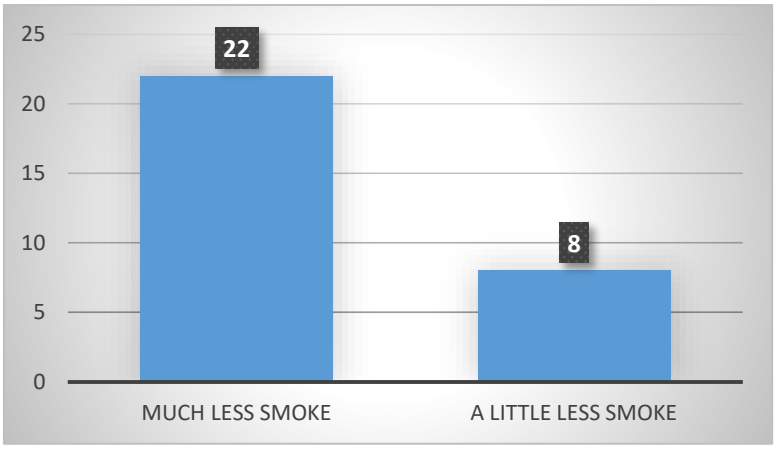


Figure 12. Smoke level of rocks bed stove compare to traditional stove

All the households stated that cooking with the rocks bed was also faster than by the traditional stove.

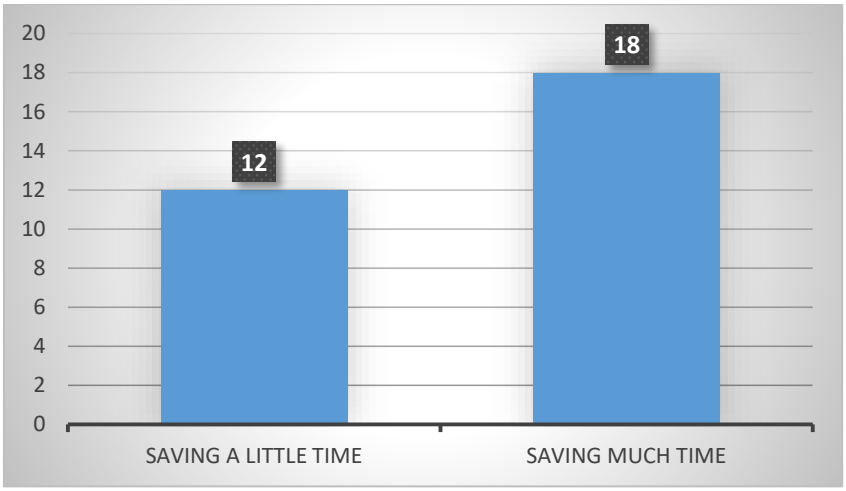


Figure 13. Time saving level of rocks bed stove compare to traditional stove

Similarly, all households reported that this innovation could save fuel, 57% of them (7 households) said that they used much less fuel.

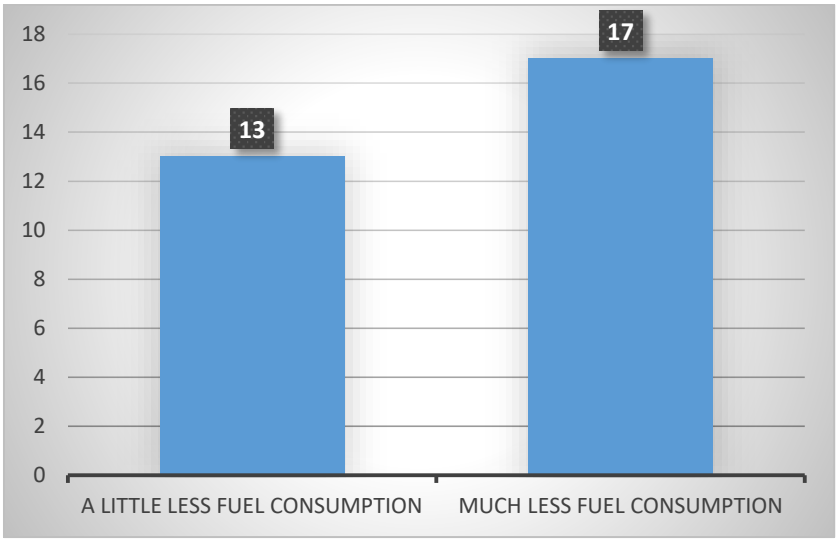


Figure 14. Fuel saving level of rocks bed stove compare to traditional stove

With application of the rocks bed cooking innovation, the households were requested to remove the ashes before any cooking event, which requires a behavioral change. The surveyors also interviewed the households about the difficulties of following that practice.

Interestingly, most cooks said that it is more convenience for them to follow the instruction of cleaning ashes because this burden is compensated by its benefits.

23% (7 households) of them do not have problem with removing the ashes before cooking and one household (3%) felt that it was very inconvenience for them to do that every time.

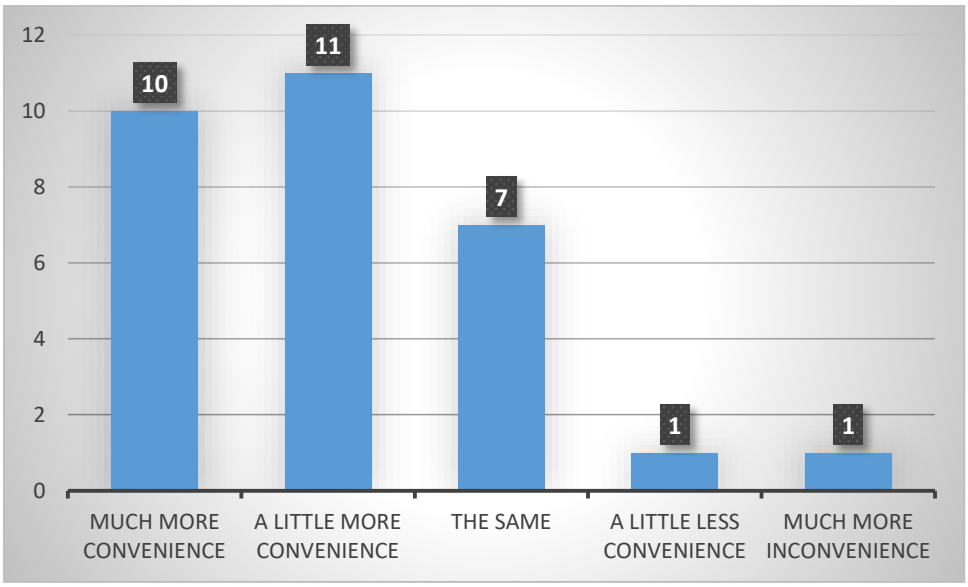


Figure 15. Convenience level of rocks bed stove compare to traditional stove

When asked about the willingness of continue using the new cooking innovation, all the households said that that will use at their home. 83% (25 households) of them were even more inspired with this innovation and would introduce to their neighbor and friends.

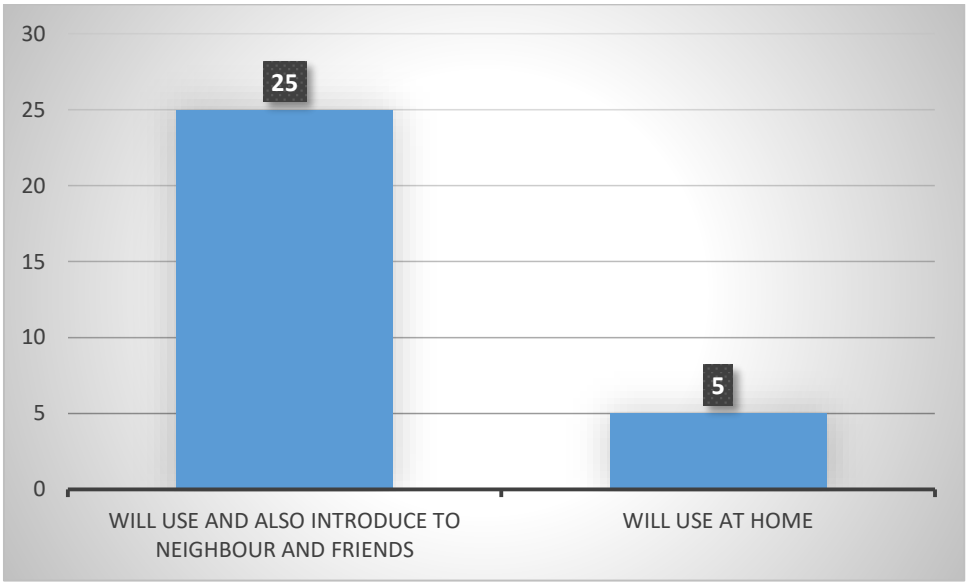


Figure 16. Willing ness to keep using the rocks bed innovation

9. Closing remarks

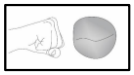
KPT team at the SNV Office in Hanoi

For this study, SNV likes to express its gratitude to the Vietnam Women Union, the participating households, and to the highly dedicated team of young surveyors for their great cooperation. SNV ensured the data has been collected objectively, unbiased and dealt with adequately. The village people in all photos have signed a written (GDPR) consent that their picture can be used, but not for commercial endeavors.

Finally it hopes this report satisfied the expectations of Sun24 who entrusted us on this important work to test a very innovative and remarkable technology that deserves a place high on the list of technological solutions to improved cooking.

Annex 1. Rock bed instruction

Stone Grate - Air under fire at all times



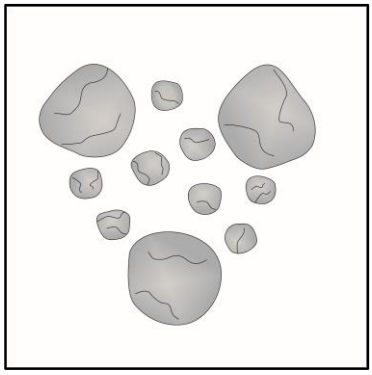
Round (not flat) stones

5-10 cm tall.

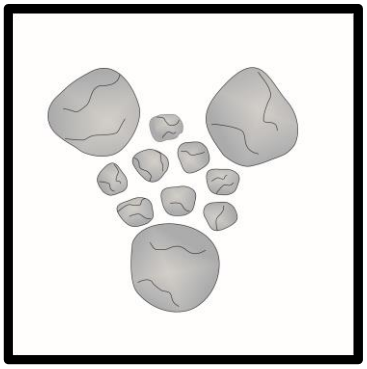
⅓ less firewood and smoke

Stones from rivers and lakes can explode.
Use broken bricks to avoid this risk.

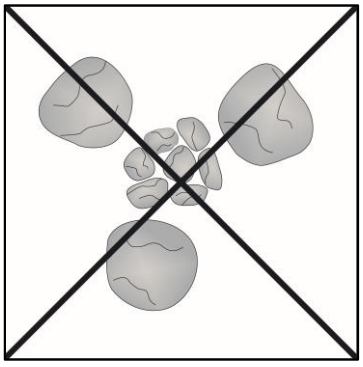
✔ **Better**



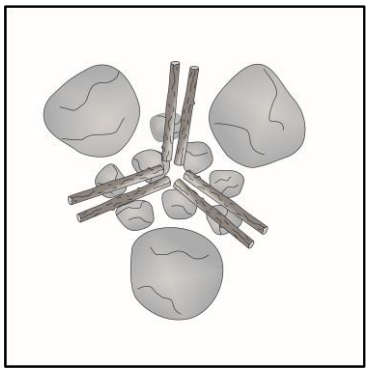
✔ **BEST**



✘ **Too Close**
Not Round



KEEP STONES AT LEAST 2 CM APART! There must be space for ashes to pile up and not reach the firewood.



Keep the firewood above the ash pile at all times.

Air must flow under the firewood at all times.

Do not let the pot touch the firewood.

Small pieces of very dry wood burn cleanest.

The small stones greatly improve the efficiency of the cookstove by:

1. **Allowing air under the fire.**
2. **Catching the embers, allowing them to burn with air all around them.**
3. **Heating the air before it reaches the fire.**

REMOVE ASHES BEFORE EVERY MEAL

https://sun24.solar

*** Use ashes as soap to wash hands.**

Annex 2. List of households attending the KPT survey

Name of interviewer	HH code	Gender of interviewee	Year of birth of interviewee	Address
Nguyễn Hải Lý	KPT 01	Female	1982	Ba Vi, Khanh Thuong, Go Dinh Muon Village
Nguyễn Hải Lý	KPT 02	Female	1993	Ba Vi, Khanh Thuong, Go Dinh Muon Village
Nguyễn Hải Lý	KPT 03	Male	1982	Ba Vi, Khanh Thuong, Go Dinh Muon Village
Nguyễn Hải Lý	KPT 04	Female	1967	Ba Vi, Khanh Thuong, Go Dinh Muon Village
Nguyễn Hải Lý	KPT 05	Female	1964	Ba Vi, Khanh Thuong, Go Dinh Muon Village
Nguyễn Hải Lý	KPT 06	Male	1963	Ba Vi, Khanh Thuong, Go Dinh Muon Village
Nguyễn Hải Lý	KPT 07	Female	1964	Ba Vi, Khanh Thuong, Go Dinh Muon Village
Nguyễn Thị Thảo	KPT 08	Female	1967	Ba Vi, Khanh Thuong, Dong Song village
Nguyễn Thị Thảo	KPT 09	Female	1971	Ba Vi, Khanh Thuong, Dong Song village
Nguyễn Thị Thảo	KPT 10	Female	1980	Ba Vi, Khanh Thuong, Dong Song village
Nguyễn Thị Thảo	KPT 11	Female	1981	Ba Vi, Khanh Thuong, Dong Song village
Nguyễn Thị Thảo	KPT 12	Female	1985	Ba Vi, Khanh Thuong, Dong Song village
Nguyễn Thị Thảo	KPT 13	Female	1963	Ba Vi, Khanh Thuong, Dong Song village
Nguyễn Thị Thảo	KPT 14	Female	1970	Ba Vi, Khanh Thuong, Dong Song village
Nguyễn Thị Thảo	KPT 15	Female	1982	Ba Vi, Khanh Thuong, Dong Song village
Cao Tú Uyên	KPT 16	Female	1974	Ba Vi, Khanh Thuong, Huong Canh Village
Cao Tú Uyên	KPT 17	Female	1985	Ba Vi, Khanh Thuong, Huong Canh Village
Cao Tú Uyên	KPT 18	Female	1975	Ba Vi, Khanh Thuong, Huong Canh Village
Cao Tú Uyên	KPT 19	Female	1954	Ba Vi, Khanh Thuong, Huong Canh Village
Cao Tú Uyên	KPT 20	Female	1984	Ba Vi, Khanh Thuong, Huong Canh Village
Cao Tú Uyên	KPT 21	Female	1951	Ba Vi, Khanh Thuong, Huong Canh Village

Name of interviewer	HH code	Gender of interviewee	Year of birth of interviewee	Address
Cao Tú Uyên	KPT 22	Female	1987	Ba Vi, Khanh Thuong, Huong Canh Village
Cao Tú Uyên	KPT 23	Female	1963	Ba Vi, Khanh Thuong, Huong Canh Village
Trịnh Ngọc Quỳnh	KPT 24	Female	1971	Ba Vi, Khanh Thuong, Buoi village
Trịnh Ngọc Quỳnh	KPT 25	Female	1978	Ba Vi, Khanh Thuong, Buoi village
Trịnh Ngọc Quỳnh	KPT 26	Female	1942	Ba Vi, Khanh Thuong, Buoi village
Trịnh Ngọc Quỳnh	KPT 27	Male	1948	Ba Vi, Khanh Thuong, Buoi village
Trịnh Ngọc Quỳnh	KPT 28	Female	1939	Ba Vi, Khanh Thuong, Buoi village
Trịnh Ngọc Quỳnh	KPT 29	Female	1972	Ba Vi, Khanh Thuong, Buoi village
Trịnh Ngọc Quỳnh	KPT 30	Female	1945	Ba Vi, Khanh Thuong, Buoi village

Annex 3. Photos during KPT

Please find more photos and video at:
https://drive.google.com/open?id=14WNkzyq0-qdIt-wYmvgci-4v9P4UbUxl

Annex 4. KPT equipment technical specification

Table 4. KPT equipment

No	Equipment	Technical specification
1	Scale 	Digital Hanging Scale 50kg x 5g10g dual accuracy luggage scale Dual Accuracy: 0-10KG=5g deviation; 10-50KG=10g deviation Measurement in G/KG, OZ, LB(POUND) Retractable steel handle Large LCD display with clear blue back light Tare function Strong steel hook 2 X 1.5v AAA standard battery (not included due to air-flight policy) Colour: blue
2	Moisture measurement equipment 	Wood Moisture Meter. 4 modes for different types of wood. Electrode length: 10mm(0.4") Range: Wood: 0~99.9% Resolution: 0.1% Accuracy: ±0.5% Auto Power OFF: After approx. 15 minutes Operating Temperature: 0 to 40 ?(32 to 104?) Dimensions: 145 X 67 X 32mm (5.7" x 2.6" x 1.3") Weight: 200g (7.0 oz)
3	Survey sheet/Android smart phone	The data collection survey and the analysis were managed via the Akvo FLOW. This apps could help to take pictures as part submission, see the date of the submission, capture GPS

		location, or view data points on the map.

Annex 5. Follow up interview with the households who increased the fuel consumption

Code	BEFORE phase (21/5-24/5)			AFTER phase (28 - 31/5/2019)		
	Day 1	***Day 2***	***Day 3***	***Day 1***	***Day 2***	***Day 3***
KPT08	Boiled water for showering	Boiled water for showering	Boiled water for showering	Boiled more water to take shower (40L)	Boiled more water to take shower (30L)	Boiled more water to take shower (30L)
KPT22			Did not boil water for showering	Skipped breakfast; Had dinner at neighbor's house		
KPT24		Participated in a neighbor's wedding parties. Therefore, their cooking was intermittent.	Participated in a neighbor's wedding parties. Therefore, their cooking was intermittent.	Dinner: 4 male guests, age 15 – 59. Extra cooking: 1 pot of soup and 3 pots of water (capacity: 5 liter)		Breakfast: skipped.
KPT26		Participated in a neighbor's wedding parties. Therefore, their cooking was intermittent.	Participated in a neighbor's wedding parties. Therefore, their cooking was intermittent.	Breakfast: skipped. Dinner: used the leftover cooked for lunch instead of cooking dinner.		
KPT27				Cooked for a pig, 3 times per day. Pot capacity: 5 liters.	Cooked for a pig, 3 times per day. Pot capacity: 5 liters.	Cooked food for a pig, 3 times per day. Pot capacity: 5 liters.
KPT29						The son backed home and had some friends visited
KPT30				Breakfast: skipped		