Performance Assessment Study

on

“Energy Efficient Improved Heating Stoves (Advanced Bukhari)”

Research & Development Division
Department of Renewable Energy
Ministry of Economic Affairs
Thimphu: Bhutan

June 2018

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Acronyms

ADA	Austrian Development Agency
AED	Alternate Energy Division, DRE, MoEA
BES	Bhutan Eco Stove
BLSS	Bhutan Living Standards Survey
BSSEC	Bhutan Statistical Services & Environmental Consultancy
COP21	21st Conference of the Parties to UNFCCC
COV	Coefficient of Variation
DRE	Department of Renewable Energy, MoEA
EDD	Energy Data Directory 2015
EEHS	Energy Efficient Heating Stove
EPTP	Stove Manufacturers Emissions & Performance Test Protocol
g	gram
h_c	Thermal efficiency
HH	Household
HRT	Heat Retention Time
NDC	Nationally Determined Contribution
kg	Kilogram
kW	Kilowatt
M^3	Cubic Metre
MoEA	Ministry of Economic Affairs
NCV	Net Calorific Value
Nu	Ngultrum
PCD	Planning and Coordination Division, DRE, MoEA
SD	Standard Deviation
SRBE	Sustainable Rural Biomass Energy
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

1. Executive Summary

According to the Bhutan Living Standards Survey of 2017, 66% of Bhutan's population live in rural areas. In the same study, it was reported that 33.3% of these rural households use wood as source of energy for cooking. While electricity is the primary fuel for household energy use, the study reported that 25.2% of households use *Bukhari* for heating homes. Although, Bhutan has achieved 99.9% electrification, this study shows that a substantial number of households still depend on fuel wood as source of energy for either cooking or heating or both. The Energy Data Directory 2015 reported that Bhutan consumed 637,232 MT of fuel wood for cooking and heating purposes. This clearly calls for interventions to assure sustainable consumption of fuel wood.

The National Forest Inventory Report, Vol. I, 2016 that was carried out by the Department of Forests and Park Services under Ministry of Agriculture and Forests reported that Bhutan has a total forest coverage of 71%. Due to the vast forest coverage, Bhutan is a net sink for greenhouse gases with an estimated sequestration potential of 6.3 million tonnes of CO_2 against an emission of 1.6 million tonnes of CO_2 equivalent in 2000 (NDC 2015). In 2015, at the COP21, Bhutan made a pledge to remain carbon neutral. This has become one of the compelling drivers to pursue low emission development activities on one hand and to boost efforts to conserve the forest coverage on the other hand. While it is an added benefit that almost all of Bhutan's electricity needs are met through hydropower generation, which is a clean energy source, heavy reliance on hydropower also necessitates maintaining catchment areas. Therefore, it is important to maintain the catchment areas for sustainable hydropower generation, and at the same time, fulfil the carbon neutral commitment. Even otherwise, Article 15 of the Constitution of the Kingdom of Bhutan mandates the Government to ensure a minimum of 60% of Bhutan's total land to be maintained under forest cover for all time.

The Department of Renewable Energy's continuous efforts through policy interventions and development initiatives to reduce fuel wood consumption is geared to achieve the Country's sustainable development and climate change mitigation targets. One of such initiatives is the promotion and roll out of improved cook stoves and energy efficient heating stoves, which was carried out under the Sustainable Rural Biomass Energy (SRBE) project.

Under the SRBE project, the Department successfully rolled out 1,610 energy efficient heating stoves in 2015. The project was aimed to reduce Greenhouse gas emission in the households through integrated and sustainable resource production, utilization and promotion of sustainable biomass energy technologies using market based approaches.

An impact assessment study was conducted in 2016 under the SRBE project to study the fuel wood consumption, the health benefits, and the consumers' satisfaction with regard to the distributed improved cook stoves and energy efficient heating stoves. The study indicated that most of the sampled consumers felt that their fuel wood consumption had decreased and there were some improvement in their health due to use of energy efficient heating stoves instead of traditional stoves. However, the study did not reveal the performance of the stoves.

This study is to focus on the stove performance and report on the efficiency of the energy efficient heating stoves based on field tests. In-house team with basic testing equipment conducted the tests. As per the Global Alliance for Cook stoves, field tests are crucial to justify claims on fuel consumption or greenhouse gas emissions resulting from stoves while elaborate and precise laboratory tests can be conducted to make such claims.

This this study, it was found that the energy efficient heating stoves were well received by the users. The EEHS was reported to be robust but heavy due to thick metallic plates and clay bricks. Most of the households reported that there was no smoke leakage due to the stove. The system performance was therefore, good. On the other hand, the cooking capability of the EEHS was not ideal with a low burn rate and long water boiling time. The energy efficient heating stove is not suitable as primary device for cooking since some forms of cooking such as frying needs quick heating capacity. However, it is inferred that the EEHS can be used for boiling water and warming food. Further, the energy efficient heating stove was especially designed for higher heat retention capacity compared to ordinary *Bukhari*. The study found that the average heat retention time was 5 hours 37 minutes and 5 hours 30 minutes for 1-pot and 2-pot EEHS respectively. Lowest heat retention was estimated at 4 hours. The ordinary *Bukhari* on the other hand was tested to have a heat retention time of 1 hour. Therefore, the study draws inference that the energy efficient heating stove provides higher heat retention capacity although not consistently achieving 7 hours of HRT as tested during design phase. Most of the users surveyed in this study reported reduced fuel wood consumption and all of the users reported reduced smoke and better indoor air quality after using EEHS.

2. Introduction

2.1. Background

2.1.1. The improved heating stove, which was also alternatively called the Advanced Bukhari, was designed and tested in Austria under the ADA funded project: Increasing Wood Efficiency – Rural Stoves for Bhutan in 2006. A few samples of the Advanced Bukhari were constructed and installed in select locations (Jamyang Resort and Golf Course canteen in Thimphu) but were not rolled out in mass scale. The recommended selling price of the Advanced Bukhari was Nu. 16,000, which was estimated to be Nu. 30,000 in 2014.

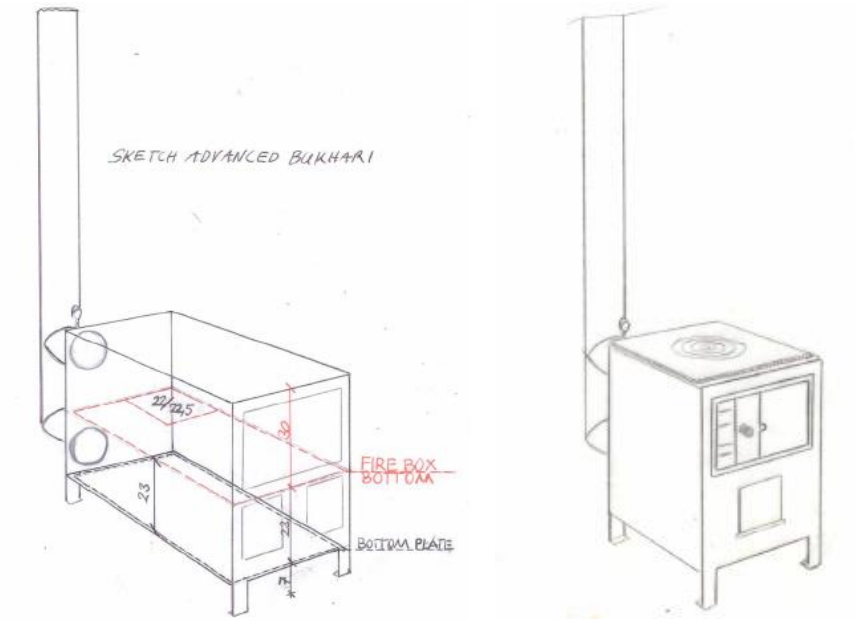

Figure 1: Sketch of *Advanced Bukhari* (Big and Small), ADA Project Nr. 2249, 2006

2.1.2. In 2014, through the SRBE project, an Austrian cook stove expert was hired to provide hands-on training on stove fabrication and construction to local fabricators and the technicians of the Department of Renewable Energy. Two types of heating stoves were introduced within the scope of the SRBE project. With technical expertise from the Austrian cook stove expert and practical input from local fabricators, the Department optimized the design to suit local context and minimize cost while not compromising on the quality and stove performance. Therefore, these energy efficient heating stoves, which are also called *Advanced Bukhari* were designed to consume less firewood and provide longer heat retention capacity as compared to the traditional heating stoves – *Bukhari* and have competitive costing.

2.1.3. The energy efficient heating stoves were distributed on cost-sharing basis, where 70% of the cost was provided by the project and the remaining 30% were borne by the beneficiaries. The production cost of 2-pot and 1-pot energy efficient heating stoves were Nu. 10,694 and Nu. 8,185 respectively and after subsidy, the cost to consumers were Nu. 7,486 and Nu. 5,730 respectively. The energy efficient heating stoves were distributed in Thimphu, Paro, Haa, Bumthang, Wangdue Phodrang, Punakha and Chukha dzongkhags.

2.1.4. An impact assessment study was conducted in 2016 under the SRBE project to study the fuel wood consumption, the health benefits, and the consumers' satisfaction with regard to the distributed improved cook stoves and energy efficient heating stoves. The study indicated that most of the sampled consumers felt that their fuel wood consumption had decreased and there were some improvement in their health due to use of energy efficient heating stoves instead of traditional stoves. However, the study did not reveal the performance of the stoves.

2.1.5. In May 2016, the Department carried out field tests to assess the performance of the energy efficient heating stoves at end users presuming that the stoves have been used for at least one winter after the rolling out of energy efficient heating stoves in 2015.

2.2. Scope of Study

This study was proposed in order to assess the performance of energy efficient heating stoves under real conditions to gauge the actual heat retention capacity and other performance. While the impact assessment study conducted by SRBE in 2016 indicated a satisfactory performance as perceived by the users, it was important to carry out field tests to study the actual performance of the energy efficient heating stoves. Therefore, the scope of this study includes the following:

- Identifying typical household from the beneficiaries using the energy efficient heating stoves.
- Carrying out field visits and recording site data.
- Carrying out water boiling test (WBT) to estimate the efficiency of the stoves.
- Measuring the heat retention capacity or the thermal efficiency of the stoves
- Estimating the fuel wood consumption reduction as compared to the traditional stoves.

- Assessing the performance of the energy efficient stoves in terms of its physical stability, smokeless operation, ease of operation, additional functionality of the stove for cooking or warming food and customer satisfaction on space heating.

2.3. Objective

2.3.1 To determine the efficiency of the energy efficient heating stoves.

2.3.2 To assess the overall performance of the energy efficient heating stoves and identify areas of improvement.

3. Technical Specifications

3.1. Design of Energy Efficient Heating Stoves

3.1.1. The energy efficient heating stoves or the Advanced Bukhari were originally designed and tested in Austria under the ADA funded project: Increasing Wood Efficiency – Rural Stoves for Bhutan in 2006. In 2014, the EEHS was modified for use in Bhutan under the SRBE project. These stoves consume less fuel wood and retain heat for longer hours as compared to the traditional Bukhari. There are two types of the EEHS:

A. 1-Pot Improved Heating Stove (*Advanced Bukhari+*) designed for domestic users; and
B. 2-Pot Improved Heating Stove (*Advanced Bukhari++*) for commercial users.

3.1.2. The 1-Pot Improved Heating Stove (*Advanced Bukhari+*) has a dimension of 56cm x 40cm x 60cm with dried clay bricks layered inside the stove for heat retention. The stove has a special chamber below the firebox, which channels the flue gas from firebox across the clay bricks before escaping into the chimney. This unique design in the improved heating stove ensures that heat is absorbed from flue gas making the stove more efficient. The top cover of the stove also known as heating plate is made of mild steel (MS) sheet (4 mm) and does not have mud layering underneath it. This is to enable the users to heat food or boil water quicker on top of it.

3.1.3. The larger one, known as the 2-Pot Improved Heating Stove (*Advanced Bukhari++*) has dimension of 92cm x 40cm x 60cm. This stove is suitable for commercial purposes particularly for use in restaurants and resorts. The design of this heating stove is similar to the 1-pot improved heating stove but is longer in size. The heating plate on the top of the stove is made of 6 mm MS plate with special reinforcement underneath and hence can withstand high heat and load.

3.2. Working Principle of Energy Efficient Heating Stoves

3.2.1. The energy efficient heating stove is an advancement in design over traditional *Bukhari* in terms of heating efficiency of the stove. The energy efficient heating stove uses same type of fuel as traditional *Bukhari* but facilitates efficient burning of wood to give more heating duration for same amount of fuel wood hence, consuming lesser fuel wood.

3.2.2. When the fuel wood starts to burn, the damper located in the double smoke pipe and the ash pan door is kept open to allow a continuous draft to keep the fuel wood burning. As the fuel wood starts to burn properly, the user can regulate/ control the fire by closing or opening the damper and the ash pan door, which regulate the amount of fresh air flowing to the fire. However, the ash pan door should not be closed completely as this will limit the fresh air and lead to extinguishing of the fire. When the user wishes to stop using the *Bukhari*, the damper and the ash pan door can be closed. This will force the heated flue gas inside the combustion chamber to go through the clay bricks chamber below the firebox and finally goes out through the double smoke pipe in to the chimney. In this process, the heat contained in the flue gas is absorbed by the clay bricks and is radiated long after the fire has died. This gives the advanced *Bukhari* a long heating duration, lesser fuel wood consumption, and better efficiency.

4. Research Methodology

4.1. Methodology

4.1.1. An in-house research team was formed by the Department. The details of the research team and the test equipment used during the field tests are given in Annexure I. The team developed the test data sheet (Annexure II) and survey questionnaire (Annexure III).

4.1.2. **Sample size determination**: 1,610 energy efficient heating stoves were distributed on cost sharing basis where 1372 (85%) were 1-pot type and 238 (15%) were 2-pot type. The energy efficient heating stoves were distributed in Bumthang, Thimphu, Chukha, Wangdue Phodrang, Paro, Haa and Trongsa dzongkhags. With the confidence level of 95% and confidence interval of 5%, the sample size was calculated as 310 against the population size of 1,610. However, due to the constraints of time, resources, and large number of non-active users, a small sample size was deemed appropriate. While it was planned to carry out field tests in all dzongkhags with beneficiaries, only Thimphu and Paro could be covered due to budget constraints. Therefore, 13 households from these dzongkhags were selected based on whether the stove was in use. The samples selected consisted of 4 households using 2-pot type and 9 households using 1-pot type energy efficient heating stoves. The Thimphu sample represented 4% of the 1-pot type energy efficiency heating stoves in Thimphu and 5% of the 2-pot type, while the Paro sample had 1% and 9% representation respectively. The sample distribution is given in Table:

Table 1 : Sample size and distribution

Region	No. of Energy Efficient Heating Stoves Distributed			Sample Planned to be Tested		Sample Tested	
	1-pot	2-pot	Total	1-pot	2-pot	1-pot	2-pot
Bumthang	430	52	482	6	1	0	0
Thimphu	336	68	404	4	2	7	2
Chhukha	207	30	237	3	1	0	0
Wangdue Phodrang	170	44	214	3	1	0	0
Paro	147	23	170	2	1	2	2
Haa	33	13	46	1	0	0	0
Trongsa	39	5	44	1	0	0	0
Others	10	3	13	0	0	0	0

4.2. Testing Protocol

4.2.1. The Global Alliance for clean cook stoves has developed standard tests such as the latest water boiling test WBT Version 4.2.3, kitchen performance test (KPT) and Controlled Cooking Test (CCT) among others. Some of the basic instructions for laboratory tests specifies the following:

- A stove should be seasoned prior to testing to drive off moisture
- Fuel should be between 1.5cm x 1.5 cm to 3 cm x 3 cm
- A 7-litre pot with 5 litres of water should be used unless the stove is designed for smaller pots or there are region-specific limitations.
- Same fuel and standard size pot should be used for comparison of stoves

However, these testing protocols are specifically developed for cook stoves and hence, do not consider efficiency of space heating. Safety and durability are also not addressed in these testing protocols.

4.2.2. The primary observation was on the heat retention time. Basic water boiling test was also carried out to test the cooking performance of the EEHS.

4.2.3. Depending on the available sizes of the cooking pots, the amount of water (1 litre – 4 litres) was used. The size and shape of the rooms also differed from household to household so the rooms were measured (Annexure V). Humidity of the room was recorded. The type of fuel wood used also varied across the households the wood type was also recorded. Nevertheless, to maintain uniformity, the amount of fuel wood to be used was pre-determined: 6 kg of wood was used as fuel load for 1-pot improved heating stove while 8 kg of wood was used as fuel load for 2-pot improved heating stoves.

4.2.4. To minimize user errors, the point of measurement was kept uniform for all tests (Annexure II).

5. Performance Analysis

5.1. Water Boiling Test

5.1.1. The water boiling test was performed to assess the heating (cooking) performance of the energy efficient heating stoves and to determine the thermal efficiency.

5.1.2. For the water boiling test, the team conducted the cold-start high-power phase, of the three phases specified the WBT Version 4.2.3 for cook stove testing in controlled laboratory settings. The test was started with the energy efficient heating stove at room temperature and fired up using the household's fuel wood bundle of either 6 kg or 8 kg depending on the type of the stove. The second and third phases of water boiling test i.e. hot start high power phase and the simmer phase were not conducted for this study.

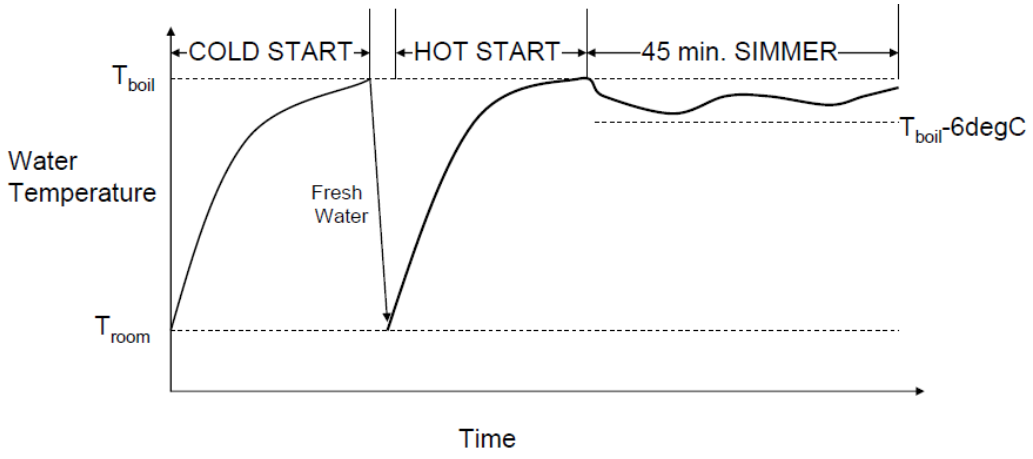

Figure 2: Three phases of water boiling test (Source: Nordica MacCarty)

5.1.3. The fuel wood types used by the household were mostly soft wood such as blue pine, chir pine (Pinus roxburg*hii)*, and *bji shin*g (Euglenaus latifolia) while one household used oak wood. For this study, the default NCV of Pinus Ponderosa (17.364 kJ/ kg) with a fuel carbon content of 0.5 by mass was used for calculation.

5.1.4. The quantity of fuel wood consumed was difficult to measure during the WBT due to which the burning rate (r_{cb}) was calculated based on the complete combustion of fuel wood over one test duration.

$$r_{cb} = \frac{amount\ of\ dry\ fuel\ consumed}{\Delta\, t}$$

5.1.5. Depending on the type of pot that was available in the sampled household, amount of water used was mostly 2 litres while some tests used 1, 3 or 4 litres of water (Table 2 and Table 3). The flat-bottom pot with water was placed in the middle of the top plate of the stove.

5.1.6. 1-pot energy efficient heating stove, 6 kg of fuel wood was used while 8 kg of wood was used for 2-pot stove. The fuel wood was not cut to size but the average length of the logwood was 40cm to 60 cm while the diameter varied from 2cm to 8cm. The fuel wood used were naturally air-dried.

5.1.7. The following tables show the test results of the energy efficient heating stoves tested in 13 different households in Thimphu and Paro:

Table 2: WBT Test Result of 1-pot Energy Efficient Heating Stoves

HIGH POWER TEST (COLD	units	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Average	St Dev	COV
Household No.		House #2	House #3	House #4	House #5	House #6	House #7	House #9	House #10	House #13			
Room Temperature	°C	16.2	18.7	20.3	21.0	22.7	23.1	14.3	22.9	21.1	20.0	3.1	15.4%
Humidity	%	52.0	59.0	57.0	50.0	46.0	62.0	56.0	40.0	49.0	52.3	6.9	13.2%
Fuel moisture content	%	12%	13%	13%	11%	10%	14%	12%	9%	11%	12%	0.02	13.2%
Volume of water	Litre	2	2	1	1	2	2	4	1	3	2.00	1.0	50.0%
Time to boil	min	55.0	30.0	35.0	25.0	30.0	28.0	45.0	10.0	40.0	33.1	12.8	38.7%
Temp-corrected time to boil	min	53.0	29.8	34.8	24.5	29.4	29.5	42.9	10.8	40.0	32.7	12.0	36.6%
Burning rate	g/min	10.7	20.0	8.0	16.0	17.8	21.3	11.0	17.8	20.0	15.8	4.8	30.2%
Thermal efficiency	%	6%	7%	7%	5%	8%	7%	18%	13%	8%	9%	4%	45.7%
Specific fuel consumption	g/liter	444.1	331.3	456.7	573.9	340.8	301.4	163.9	249.9	213.0	341.7	130.4	38.2%

Table 3 : WBT Test Result of 2-pot Energy Efficient Heating Stoves

HIGH POWER TEST (COLD	units	Test 10	Test 11	Test 12	Test 13	Average	St Dev	COV
Household No.		House #1	House #8	House #11	House #12			
Room Temperature	°C	20.8	20.4	25.1	19.6	21.5	2.5	11.5%
Humidity	%	59.0	69.0	46.0	57.0	57.8	9.4	16.3%
Fuel moisture content	%	13%	15%	10%	13%	13%	0.02	16.3%
Volume of water	Litre	1	2	2	2	1.75	0.5	28.6%
Time to boil	min	11.0	30.0	45.0	45.0	32.8	16.1	49.3%
Temp-corrected time to boil	min	11.3	30.5	43.7	44.4	32.5	15.5	47.7%
Burning rate	g/min	25.0	25.0	23.5	26.7	25.0	1.3	5.1%
Thermal efficiency	%	9%	4%	3%	4%	5%	0.03	54.6%
Specific fuel consumption	g/liter	346.0	531.5	740.0	601.9	554.8	163.9	29.5%

5.1.8. The thermal efficiency (h_c) of a stove is defined as "a measure of the fraction of heat produced by the fuel that made it directly to the water in the pot" as per Global Alliance for Clean Cook stoves. It is an estimate of the total energy produced by the fire that is used to heat the water in the pot and is calculated as:

$$\boldsymbol{h}_{\mathrm{c}} = \frac{\Delta\, \boldsymbol{E}_{\mathrm{water}} + \Delta\, \boldsymbol{E}_{\mathrm{water\ evap.}}}{\boldsymbol{E}_{\mathrm{released}}}$$

Where E is the energy consumed/ released. This is then derived as:

$$\boldsymbol{h}_{\mathrm{c}} = \frac{4.186(75(\Delta\, \boldsymbol{t}_{\mathrm{c}})(\boldsymbol{w}_{\mathrm{cv}} + \boldsymbol{w}_{\mathrm{cr}}) + 2260(\boldsymbol{w}_{\mathrm{cv}})}{(\Delta\, \boldsymbol{t}_{\mathrm{c}} T)(\boldsymbol{f}_{\mathrm{cd}})(\boldsymbol{NCV})}$$

Where:

$\mathbf{w_{cv}}$ is the mass of water vaporized (g)

$\mathbf{w_{cr}}$ is the effective mass of water boiled (g)

$\mathbf{f_{cd}}$ is the equivalent dry wood consumed (kg)

$\Delta\, \boldsymbol{t_c}$ is the time to boil water

$\Delta\, \boldsymbol{t_c}T$ is the temperature corrected time to boil water

4.186 J/g-K is the heat capacity of water

2,260 J/g is the enthalpy of vaporization of water

5.1.9. In this study, the thermal efficiency is only calculated for the high power test in line with the Stove Manufacturers Emissions & Performance Test Protocol (EPTP). This is mainly because the point of vaporization varies with place of test and due to unavailability of measuring tool or appropriate pot for the test. However, if the low power phase is carried out, then low-power thermal efficiency can be calculated.

5.1.10. The thermal efficiency measured (Table 3 and Table 4) only accounts for the cold start high power thermal efficiency of the stove. The average thermal efficiency of the 1-pot energy efficient heating stove is 9% while the average thermal efficiency of the 2-pot energy efficient heating stove is 5%. This thermal efficiency calculated is a measure of the energy transferred from fuel to the pot. However, this is not a complete representation of the thermal efficiency of the heating stove for which the primary function is to provide space heating. Much of the heat is dissipated from the top plate and the side plates. The lower efficiency of the bigger stove, which has wider area of heat dissipation, also confirms this inference.

5.1.11. The average burning rate was 15.8 g/min and 25.0 g/min respectively for 1-pot and 2-pot stoves. The wider space volume within the 2-pot stove could be the reason why fuel wood burned faster in the latter.

5.1.12. The following graph depicts the temperature of the top plate recorded during test. The graph shows that considerable amount of heat was generated during the WBT (up to 75 minutes from the start of fire up to the point when water starts to boil) and even afterwards up to 4 – 5 hours which indicates a good space heating capacity. In addition to this, the temperature profile shown in the graph clearly indicates the capability of stove to heat as well as cook food on top of the stove. The temperature of the stove was measured to be between 200°C to 320°C on an average for over two hours, which shows that EEHS is suitable to be used also for cooking food or keeping food warm.

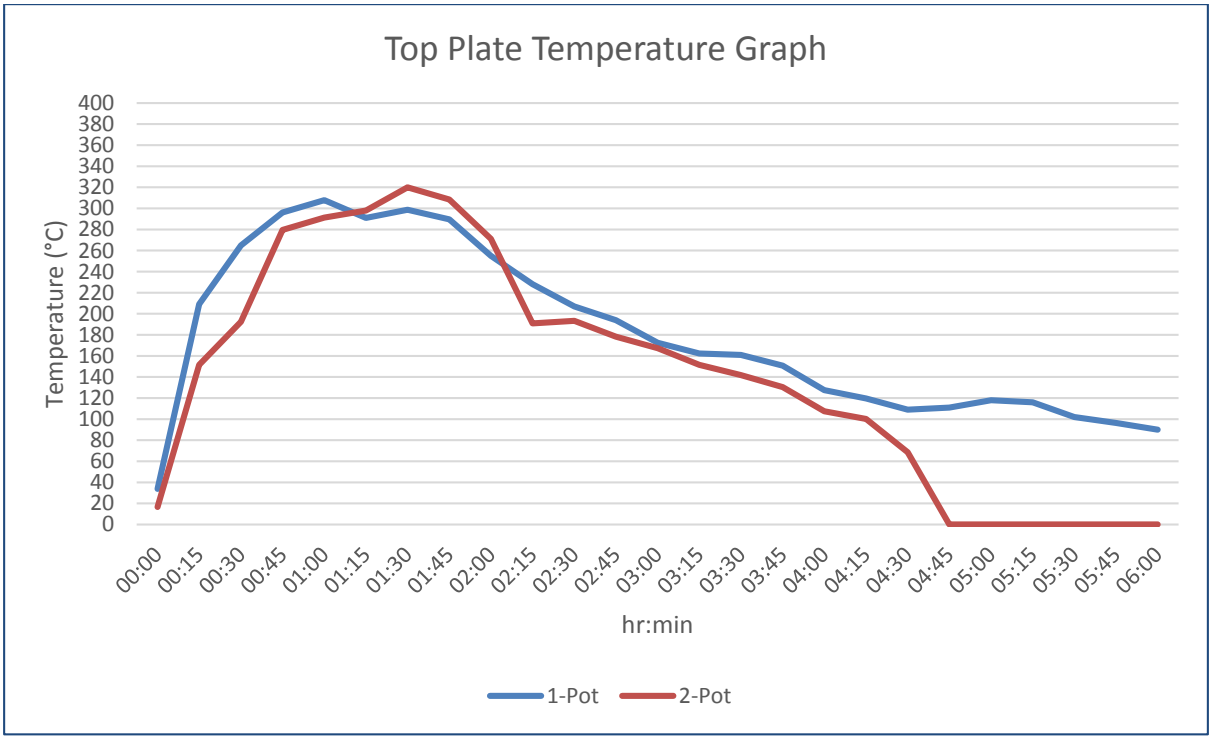

Figure 3 : Temperature graph of the top plate of EEHS

5.2. Heat Retention Time

5.2.1. The energy efficient heating stoves were designed to have high heat retention capacity, longer lifetime and lesser fuel wood consumption. The stove was tested during the design phase to have radiating heat up to 7 hours after fire goes off. In this study, the temperature change was recorded for 15 minutes-interval until the system reached a steady rate of drop in temperature. The final heat retention time per HH is the time taken to reach the initial room temperature or 18°C[1] whichever is higher.

5.2.2. Room temperature was recorded for all households at the start of the fire. Since the test was conducted at different time of the day, the initial room temperature was different across the households and accordingly the time taken to increase the room temperature varied.

5.2.3. The graph in figure 4 shows the temperatures recorded at a distance of 1 meter from the stove. The average heat retention time was 5 hours 37 minutes and 5 hours 30 minutes for 1-pot and 2-pot EEHS respectively. Lowest heat retention was estimated at 4 hours.

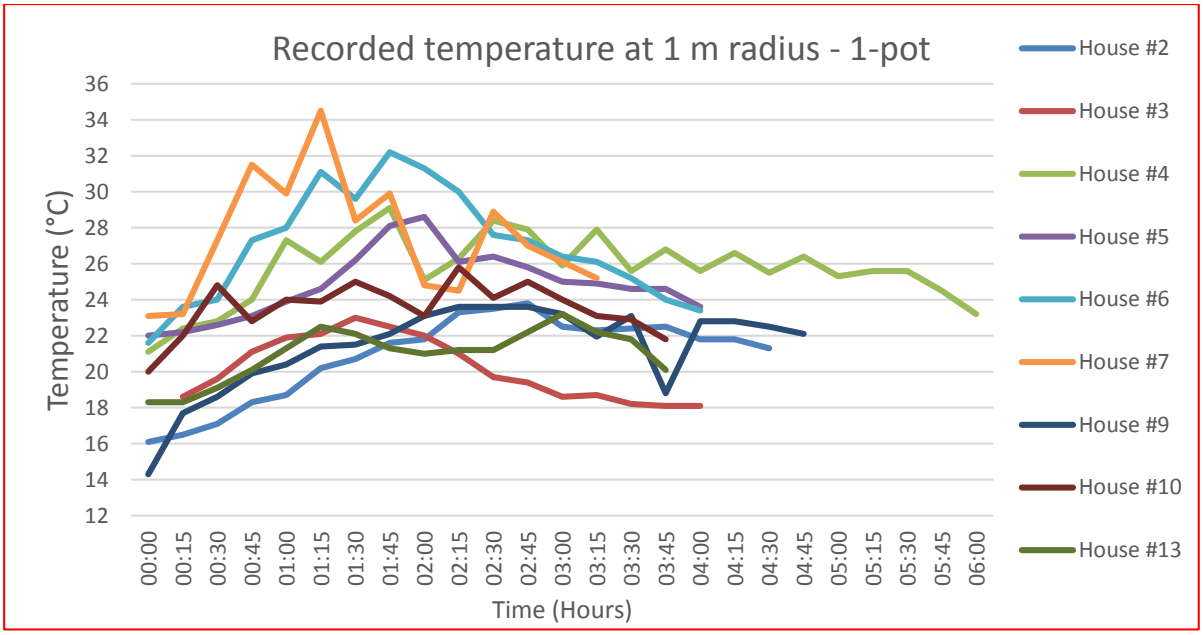

Figure 4 : Temperature graph at 1m distance from stove for 1-pot

[1] 18°C is the World Health Organisation's standard for comfortable warmth for a normal adult.

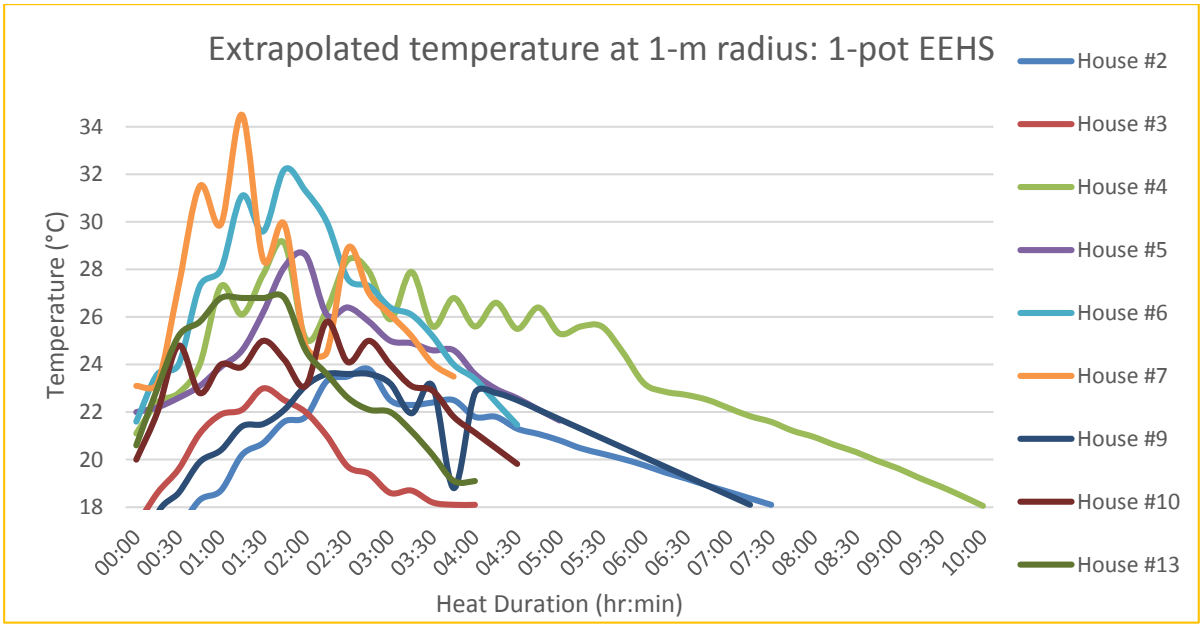

Figure 5: HRT of 1-pot EEHS

5.2.4. The maximum room temperature reached during the test at 1 m radius from stove was 34.5 °C, which was recorded for **house #7** that uses 1-pot EEHS (Figure 5). The Room floor plan for **house #7** shows that it has the least room volume of 18.7 m^3. This could be one of the reasons for the fast heating of the room from 23.1 °C to 34.5 °C in 1 hour 15 minutes while in the case of **house #10** of 96.4 m^3 size, it took 2 hours 15 minutes to reach 25.8 °C from 20 °C. It can also be seen from the room floor plans (Annexure V) of these two households that **house #7** has only one door that opens to outside. On the other hand, **house #10** had seven doors including one that opens to outside.

5.2.5. For those households using 2-pot EEHS, **House #1** had the highest room volume of 91.6 m^3 and the smallest room was 27.7 m^3 for **House #12.** The **House #1** had two doors opening to the outside and one door to the kitchen. It was seen that it took two hours to raise the room temperature from initial 19.5 °C to maximum of 23.9 °C. In case of **House #12** it was seen that it took three hours to raise the temperature of the room from 18.3 °C to 23.2 °C. Although the room volume in case of **House #12** was 30% smaller than **House #1** the time required to raise the temperature was more. It was because the main door was opened frequently and since the room was small, the heat quickly dissipated to the outside, hence, taking longer time to heat the room.

5.2.6. The following graph depicts the temperate recorded for 2-pot EEHS at 1 m distance from the EEHS which is the parameter used in this study to reflect the HRT of the stove.

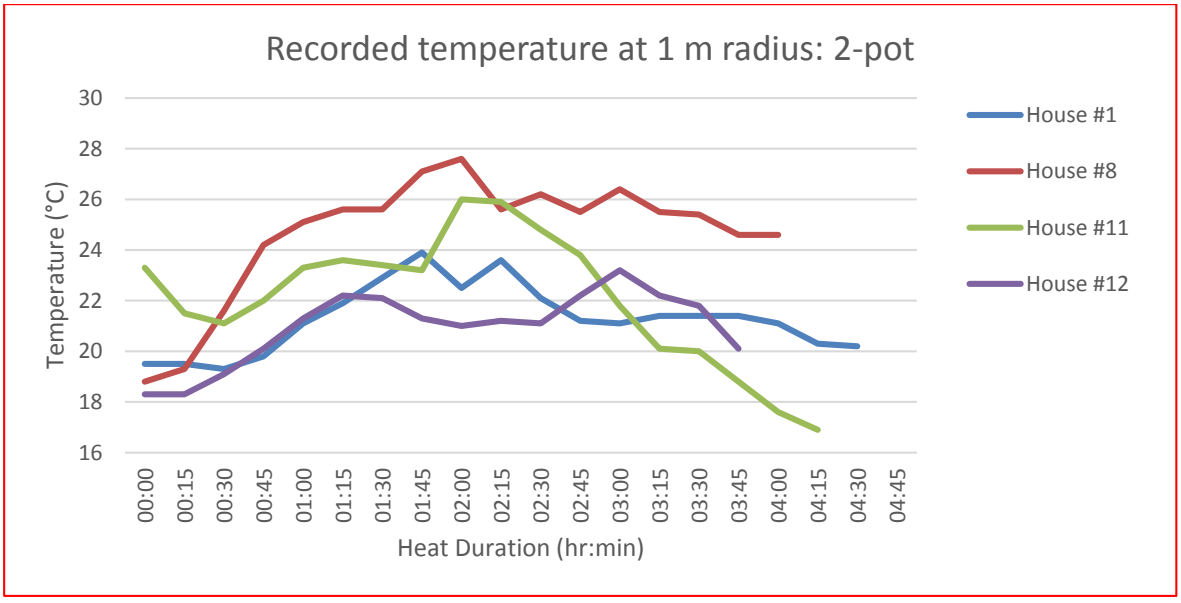

Figure 6 : Temperature graph at 1m distance from stove for 2-pot

5.2.7. The following graph (Figure 7) has been plotted with extrapolated data to reflect the total HRT of each system. The data was extrapolated from when the temperature reached its peak up to the point where the temperature stabilized to a value close to its initial room temperature or 18°C.

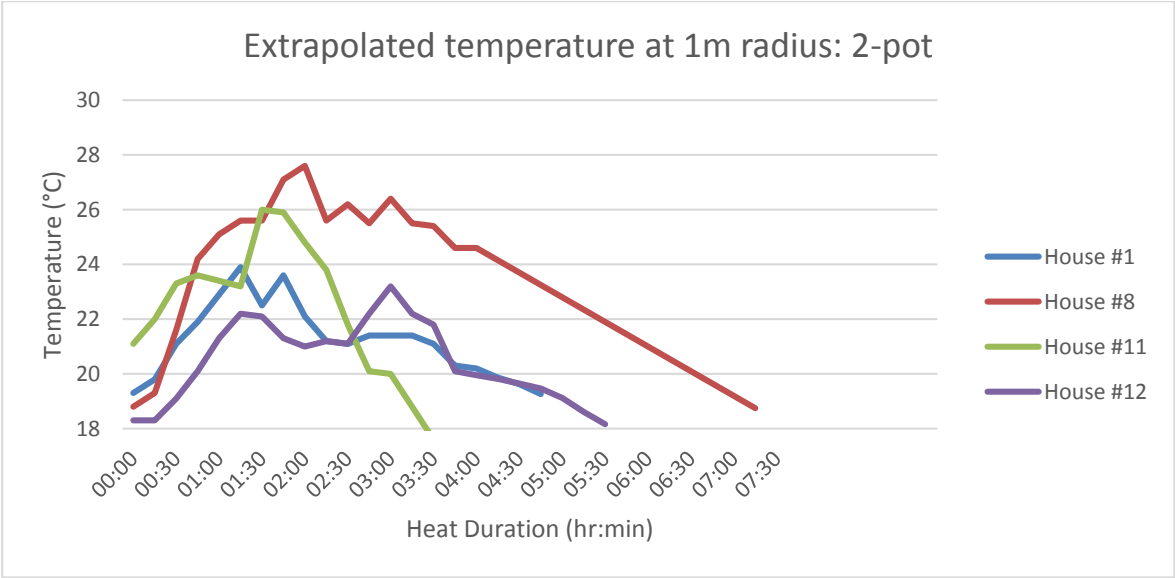

Figure 7: HRT of 2-pot EEHS

5.2.8. The average HRT of the EEHS was calculated to be 5 hours 35 minutes with the 1-pot EEHS recording longer HRT by 7 minutes only. However, when the

stoves with or without clay bricks were compared, the EEHS with clay bricks installed as required performed better in terms of better HRT. On an average, the EEHS with clay bricks had 6 hours 20 minutes of calculated HRT while the EEHS without clay bricks had 4 hours 21 minutes of calculated HRT.

Table 4 : Heat Retention Time for Energy Efficient Heating Stoves

Type of Construction	Average HRT for 1-pot (Hours)	Average HRT for 2-pot (Hours)
EEHS without bricks	4.08	4.75
EEHS with clay bricks	6.38	6.25

5.2.9. The table above shows the calculated HRT for 1-pot and 2-pot energy efficient heating stoves. Five households from the sampled households had removed the clay bricks. Therefore, the heat retention time was compared for not only the 1-pot and 2-pot types but also on whether clay brick walls and partitions were used within the stoves. It is evident from the study that the use of bricks in the stove increases the heat retention time of the stove and thereby improves the space heating capacity.

5.2.10. Various parameters that could affect the stove performance were recorded to understand the record the factors affecting the performance of the EEHS. As evident from the graph in figure 8 below, there was no conclusive relation between certain parameters such as the room size. However, the HRT seem to be affected by the humidity, which is also a parameter, used to estimate the moisture content of the fuel wood used. Figure 9 shows that the HRT is higher for higher humidity in the room.

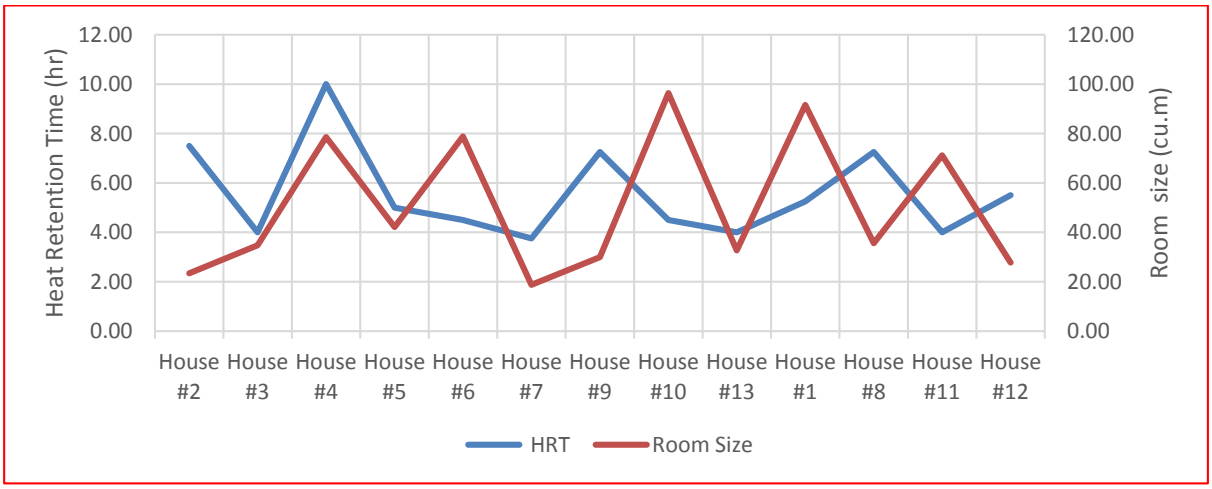

Figure 8: Heat Retention Time in comparison to the room size

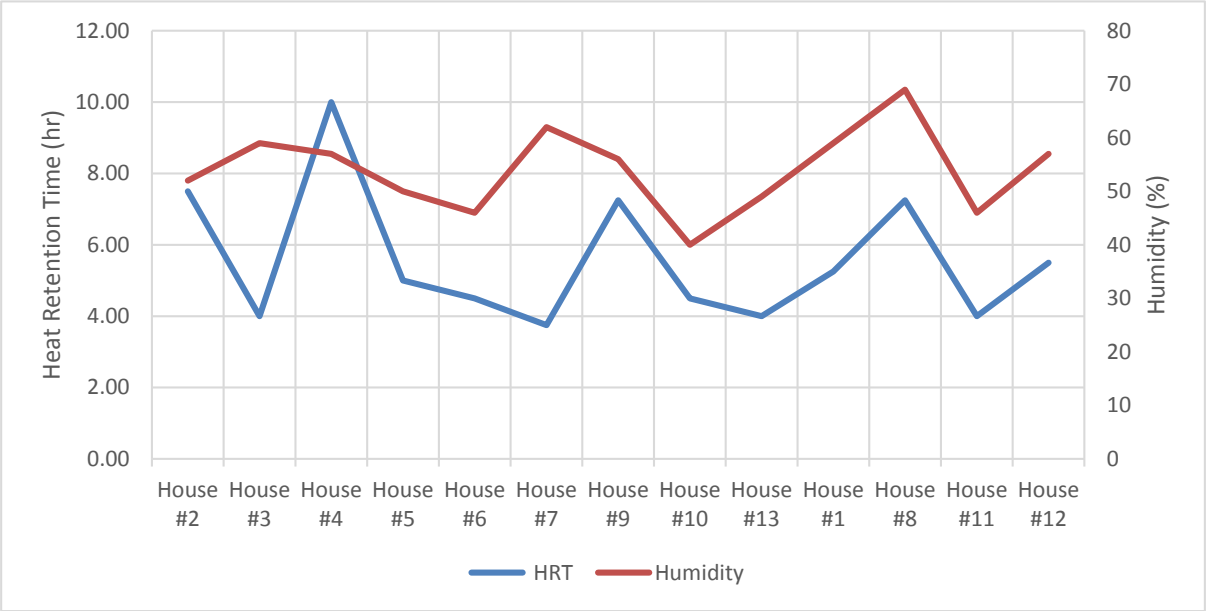

Figure 9: Heat Retention Time in comparison to the humidity

5.2.11. Individual analysis of the energy efficient heating stoves per household is as follows:

- **Test 1: House#2**- It took 1 hour 30 minutes to completely burn 6 kg of firewood. Temperature variation was seen between 33 °C and 220 °C. The side plate had the similar performance characteristics as the top plate throughout. The readings were taken for the duration until the temperature reduced to room temperature at 1 m away from stove. At 1 m radius, the temperature was measured to the maximum of 23.8 °C, which is an increase of 7.7 °C from the initial temperature. The humidity was measured at 52 % before start of fire. The exit temperature from the ceiling was 27.9°C when room temperature was 21.3 °C. System check was done before start of fire and the system condition was found in proper order.

- **Test 2: House#3**- It took 1 hour 45 minutes to completely burn 6 kg of firewood. Temperature variation was seen from 40 to 305 degree Celsius. The side plate had the similar performance characteristics as the top plate. The readings were taken for the duration until the temperature reduced to room temperature at 1m away from stove. At 1 m radius, the temperature was measured to maximum of 27.2 °C, which is an increase of 9.1 °C from the initial temperature. The humidity was measured at 59 % before the start of fire. The exit temperature from the ceiling was 25.2 °C when room temperature was 18.1 °C. During the system check, it was found out that the clay bricks were improperly installed in the system, which was rectified.

- **Test 3: House#4**- It took 1 hour 30 minutes for complete combustion of 6 kg of firewood and it lasted for next four and half hour. Temperature variation was from 23.8 °C to 263 °C. The side plate had the similar performance characteristics as the

top plate. At 1 m radius, the temperature was measured to max of 29.1 °C, which is an increase of 8 °C from the initial temperature. The humidity was measured at 57 %. The exit temperature from the ceiling was 23.2 °C when room temperature was 18.1 °C. The system condition was found in proper order when system check was done.

- **Test 4: House#5**- It took two hours for complete combustion of 6 kg of firewood. Temperature variation was from 22 to 364.1 °C Celsius. The side plate had the similar performance characteristics as the top plate. At 1 m radius, the temperature was measured to max of 28.6 °C, which is an increase of 6.6 °C from the initial temperature. The humidity was measured at 50 %. The exit temperature from the ceiling was 44.2 °C when room temperature was 23.6 °C. The system condition was found in proper order.

- **Test 5: House#6**- The time taken to completely burn 6kg of firewood was 2 hours. Temperature variation on the top plate was from 25 °C to 360 °C. At 1 m radius, the temperature was measured to max of 32.2 °C, which is an increase of 10.6 °C from the initial temperature. The humidity was measured at 46%. The exit temperature from the ceiling was 30.3 °C when room temperature was 23.4 °C. It was found out that the heating plate was slightly bent.

- **Test 6: House#7**- It took one and half hour for complete combustion of 6 kg of firewood. Temperature variation on the top plate was from 93 °C to 404 °C. The side plate had the similar performance characteristics as the top plate. At 1 m radius, the temperature was measured to max of 34.5 °C, which is an increase of 11.4 °C from the initial temperature. The humidity in the room was 62%. The exit temperature from the ceiling was 36.5 °C when room temperature was 25.2 °C. The system has no bricks installed.

- **Test 7: House#9**- The time taken to completely burn 6 kg of firewood was 2 hours 15 minutes. Temperature variation was 15.5 °C to 335 °C. The side plate had the similar performance characteristics as the top plate. At 1 m radius, the temperature was measured to max of 24 °C, which is an increase of 10°C from the initial temperature. The humidity in the room was 56%. The exit temperature from the ceiling was 25 °C when room temperature was 22 °C. The system condition was found in proper order.

- **Test 8: House#10**- It took 2 hours 15 minutes to completely burn 8 kg of firewood. Temperature variation on the top plate was from 16 °C to 350 °C. The side plate had the similar performance characteristics as the top plate. At 1 m radius, the temperature was measured to max of 26 °C, which is an increase of 6 °C from the initial temperature. The humidity in the room was 56%. The exit temperature from the ceiling was 50 °C when room temperature was 22 °C. It was found out that the

heating plate was slightly bent and cleaning lid handle was broken. The clay bricks were not installed in the system.

- **Test 9: House#13**- It took one hour for complete combustion of 6 kg of firewood. Temperature variation on the top plate was from 20 °C to 371 °C. The side plate had the similar performance characteristics as the top plate. At 1 m radius, us the temperature was measured to max of 27 °C, which is an increase of 8 degrees from the initial temperature. The humidity was measured at 49%. The exit temperature from the ceiling was 30 °C when room temperature was 19 °C. There were no bricks used in the system.

- **Test 10: House#1**- The time taken to completely burn 8 kg of firewood was 2 hours. Temperature variation on the top plate was from 20 °C to 540 °C. The side plate had the similar performance characteristics as the top plate. At 1 m radius, the temperature was measured to max of 24 °C, which is an increase of 5 °C from the initial room temperature. The humidity in the room was 59%. The exit temperature from the ceiling was 30 °C when room temperature was 20.2 °C. The system condition was found in proper order.

- **Test 11: House#8**- It took one hour and forty-five minutes for complete combustion of 8 kg of firewood. Temperature variation on the top plate was seen from 19 °C to 308 °C. At 1 m radius, the temperature was measured to max of 28 °C, which is an increase of 9.8 °C from the initial temperature. The humidity in the room was 69%. The exit temperature from the ceiling was 33 °C when room temperature was 29 degrees. The system condition was found in proper order.

- **Test 12: House#11**- The time taken to completely burn 8 kg of firewood is 1 hour 30 minutes. Temperature variation from 13.3 °C to 256 °C. The side plate had the similar performance characteristics as the top plate. At 1 m radius, the temperature was measured to max of 26 °C, which is an increase of 5 °C from the initial temperature. The humidity in the room was 46%. The exit temperature from the ceiling was 20 degrees when room temperature was 17 °C. The bricks were not used in the system and one of the cleaning lid handle was broken.

- **Test 13: House#12**- It took one hour forty-five minutes for complete combustion of 8 kg of firewood. Temperature variation from 13.2 °C to 340 °C. The side plate had the similar performance characteristics as the top plate. At 1 m radius, the temperature was measured to max of 23 °C, which is an increase of 5 °C from the initial temperature. The humidity in the room was 57%. The exit temperature from the ceiling was 29 °C when room temperature was 20 degrees. The clay bricks provided with the system were not used.

5.3. Fuel Wood Consumption

5.3.1. To estimate the effectiveness of the energy efficient heating stove as a replacement for ordinary heating stoves in terms of incurring lesser fuel wood consumption, the users were asked on the amount of fuel wood consumed before and after the installation of the energy efficient heating stove. While most users responded that there was a reduction in fuel wood consumption, three households responded that there was an increase in fuel wood consumption due to the larger size of the energy efficient heating stoves compared to ordinary *Bukhari*. As per the heat retention tests, the energy efficient heating stoves are more efficient in radiating heat for longer duration compared to traditional *Bukhari* and EEHS without clay bricks. Therefore, it is inferred that energy efficient heating stoves can lead to lesser fuel wood consumption.

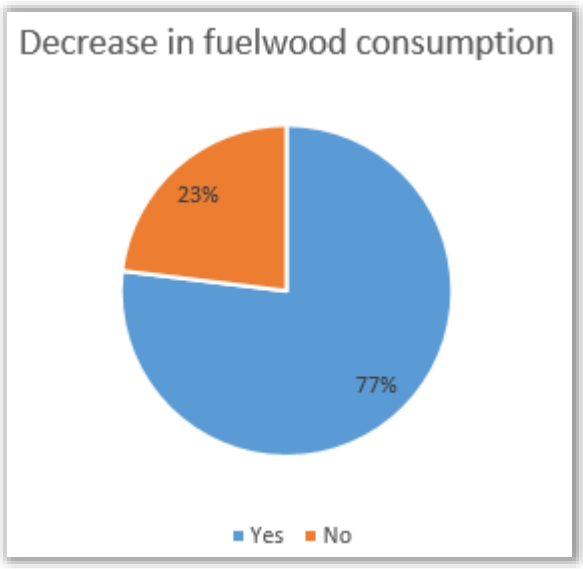

Figure 10 : User feedback on fuel wood reduction

5.4. Consumer Satisfaction and System Performance

5.4.1. For assessment of the system performance, user survey was carried out using the survey questionnaire developed by SRBE (survey on fuel wood consumption, health benefit and overall customer satisfaction of the improved cook stoves, 2016). Users were asked to rate how satisfied they were (very satisfied, satisfied, don't know, not satisfied, not at all satisfied) with the performance of the EEHS in terms of:

- Fuel wood consumption reduction
- Convenience in heating
- Reduced smoke emission
- Better indoor quality

The following graphs show the user satisfaction level at a glance:

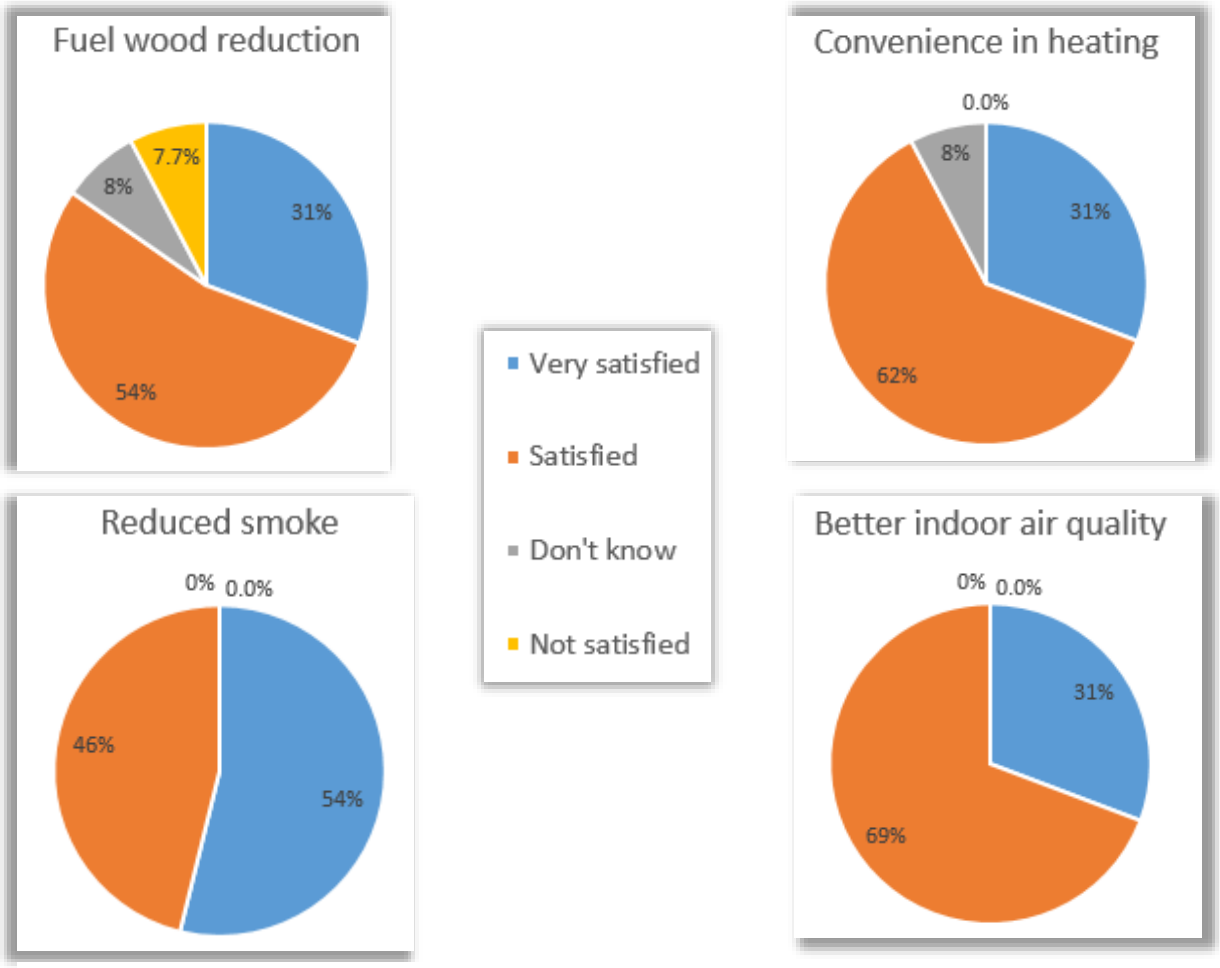

Figure 11: System Performance based on user feedback

5.4.2. The most satisfaction was due to reduced smoke from the energy efficient heating stoves with the capacity to reduce fuel wood being only secondary. The user also showed high satisfaction in the convenience in heating which reflect that the design of the EEHS is user friendly.

5.4.3. Out of the surveyed users, 85% responded that their fuel wood consumption has reduced due to EEHS use with an estimated 620kg per month reduction. However, 7.7% of the users were not satisfied and actually reported an increase in fuel wood consumption.

6. Conclusion

6.1. Key Observation and Inferences

6.1.1. The basic but detailed tests carried out in this study records the performance of the energy efficient heating stoves rolled out by the SRBE project. The study reveals that the EEHS is a good alternative to traditional *Bukhari*. Although, unintended, the study also compared the EEHS which were installed as per specifications and the EEHS which did not use clay brick walls and partitions, and the result showed a clear superiority of the former in terms of heat retention capacity. Therefore, this also proves that the addition of the thermal mass (clay bricks) to the stoves had its intended purpose fulfilled.

6.1.2. The WBT showed that an EEHS is suitable for use as a secondary cooking device. However, given the low thermal efficiency in terms of transfer of heat to the cooking pot, the EEHS is not an alternative solution to improved cook stoves such as the BES for cooking. Depending on the users' needs and the willingness to pay a higher price, materials of high thermal conductivity and durability such as the cast iron can be used as the cooking base on the top plate. The original design made in 2006 had concentric cast iron rings, a feature that was removed due to high cost implications.

6.1.3. The tests carried out for this study used a predetermined amount of fuel wood to enhance comparability of the tests. The average burning rate during the cold start high power test were 19.64 g/min and 25.05 g/min respectively for 1-pot and 2-pot EEHS respectively. While this adds to the previous observation drawn that the EEHS is not the best cooking device, this also shows that the fuel wood consumption rate is lower. To verify on this inference, the user feedback was considered which shows that 85% of the sampled users reported reduced fuel wood consumption.

6.2. Limitations of the Study

6.2.1. The performance of a heating system depends on not only the heating stove but also the fuel (type, dimension, moisture content, amount, etc.,), the pots used (make, dimension, insulation, etc.,) and the user. The current testing protocols try to address the factors affecting the performance of a stove: various specifications and guidelines are developed to minimize uncertainties and improve the results. Even so, these protocols are especially geared towards cooking stoves and standard testing protocols are yet to be developed for space heating stoves.

6.2.2. The sample size was small because the field tests were scheduled in the summer month of June when most heating stoves were not used/ installed; and due to budget and time constraints, only two dzongkhags could be covered.

6.2.3. The research team were not trained to test stoves following standard protocols; and due to budget constraints, the testing equipment were not adequate. This could have induced user errors in the test data.

6.3. Recommendations

6.3.1. As inferred, the performance of a heating system depends mainly on four factors: stove, fuel, pot and user, it is, therefore, recommended that studies to establish national data should be carried out after efforts on minimizing errors in the four parameters are taken care of. This could be achieved by:

6.3.2 Following a set testing protocol while also taking into consideration how one type of test relates to other tests of stove performance.

- Using a complete set of testing equipment based on a standard testing protocol, and using standard size fuel and pot for repeatability and comparability.
- Carrying out both laboratory tests and field tests for better results.
- Training the operators and running trial tests before conducting actual tests.
- Carrying out survey with appropriate representative samples including control data.

6.3.3 As per the user feedback and field observation made by the research team, there is room for improvement in design of the energy efficient heating stove:

- The edges of the EEHS should be rounded for better flow of flue gases;
- Use cast iron plate for improved cooking performance;
- Decrease the length of the EEHS to reduce fuel wood, reduce the weight of the stove, and ease operation;
- Provide inclination to the double exit smoke pipe; and
- Increase the length of the grate. However, the effects of this should be tested for optimized effects.

7. References

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7.2. National Statistics Bureau, 2017, Bhutan Living Standards Survey Report.

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7.4. Global Alliance for Clean Cook stoves, *Water Boiling Test, version 4.2.3*

7.5. National Environment Commission, 2015, Nationally Determined Contribution (NDC).

7.6. SRBE, 2016, Assessment of fuel wood consumption, health benefits, & customer satisfaction.

7.7. Morgan DeFoort, Christian L'Orange and Cory Kreutzer, Stove Manufacturers Emissions & Performance Test Protocol (EPTP)

7.8. D Petrocelli and A M Lezzi, 2015 Journal of Physics.: Conf. Ser. 655 012021: A note on calculation of efficiency and emissions from wood and wood pellet stoves.

7.9. Regional Cook stoves Testing and Knowledge Centre (RTKC), Centre for Rural Technology, Nepal, 2016, Test Report on Bhutan Eco Stove (BES) and Bhutan Multi-purpose Stove (BMS)

8. Annexures

8.1 Annexure I: Research Team and Equipment List

8.1.1 Research Team:

1. Dawa Chhoedron, Executive Engineer, R&DD, DRE, MoEA
2. Sherab Jamtsho, Executive Engineer, R&DD, DRE, MoEA
3. Dechen P. Yangki, Executive Engineer, R&DD, DRE, MoEA
4. Tibinda Powdel, Engineer, R&DD, DRE, MoEA
5. Chime Wangmo, Engineer, PCD, DRE, MoEA
6. Galey Dorji, Engineer, PCD, DRE, MoEA
7. Sonam Wangchuk, Assistant Engineer, AED, DRE, MoEA
8. Sonam Dorji, Junior Engineer, R&DD, DRE, MoEA

8.1.2 Testing Equipment Used:

1. Temperature gun
2. Digital Spring balance
3. Immersion thermometer
4. Room temperature and humidity sensor
5. Measuring tape

8.2 Annexure II: TEST DATA SHEET

Date: / /

Location:

Dzongkhag: _____ Gewog/ Thromde: _____

Beneficiary name: _____ Customer Requisition

No:_____ Contact Details: _____

Stove:

1-pot ☐ 2-pot ☐

1. Before taking data, make the plan of the room. (Location of the stove, windows and doors) Use the diagram given in the data sheet.
2. Gaps/ openings in the walls, window joints and doors of the room: (record the presence or absence of gaps)

   _____

   _____
3. Room volume: length _____ **cm**, breadth _____ **cm**, height _____ **cm**
4. Room temperature: _____ **^{0}C**
5. Room humidity: _____ **%**

System Check:

1. Clay bricks (Firebox chamber/ flue gas chamber)- Broken/ intact
2. Heating plate (bend or not)
3. Fire door: bent or not
4. Ash pan bent or not
5. Cleaning lid: properly installed or not
6. Chimney: IN to double smoke pipe/ OUT of double smoke pipe
7. Damper: Functioning properly or not

Fuel wood consumption:

1. Type of fire wood: (Soft wood/ hard wood/ briquette/etc.)
2. Name of wood: _____
3. Initial weight of firewood: 1-pot 6 **(kg)**
4. Initial weight of firewood: 2-pot 8 **(kg)**
5. Initial surface temperature of stove _____ **(^{0}C)**
6. Room temperature before starting the fire: _____ **(^{0}C)**
7. Record time at the start of fire: _____ **hh:mm**

Measurement:

1. Record time at the end of fire: _____ **hh:mm**
2. Time taken to burn the firewood: _____ **(min)**
3. Record time at the end of heat:_____(hh:mm)

Table1: Temperature record data sheet

		Temperature (^{0}C)	

Sl. No.	Time (10 min interval)	Surface of stove		At 1-meter radius from the stove	Near the wall	Chimney (Start of chimney) A	Chimney (Point of contact with ceiling) B	Distance between A and B	Remarks (fire door open, damper position, etc.)
		Top	Side (Average of Left and right surface)						
1	00:00 (Start of fire)	*(Please use the separate data sheet enclosed as annexure-I to record the following data)*							

Note: Record at 15 minutes interval until the fire is out, and then record at least in the interval of 30 minutes until the temperate of system equals to room temperature.

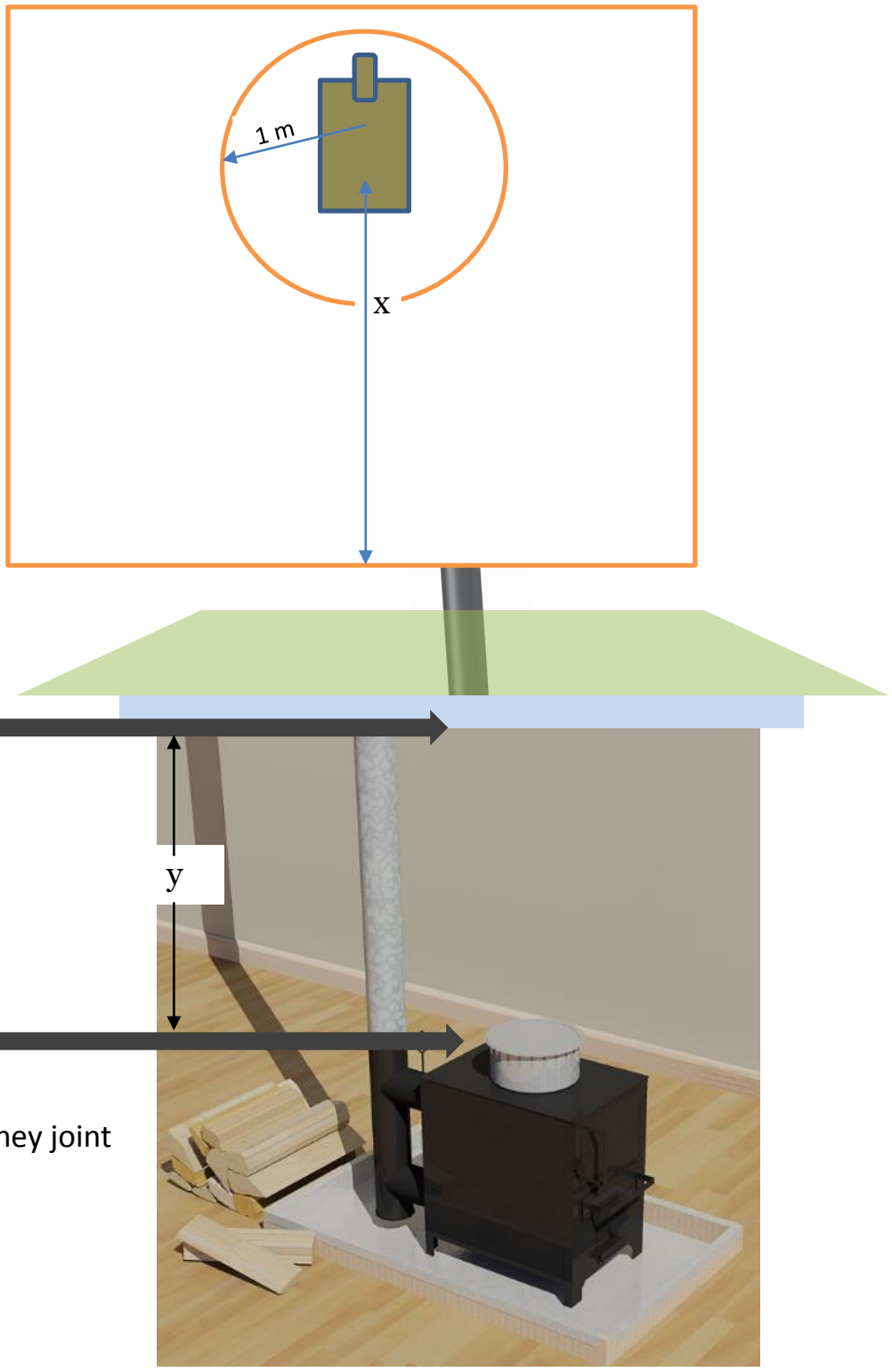
Basic Water Boiling Test:

Set the timer (00:00 min) to record the actual time to boil the water in the pot.

1. Volume of water (V_W) _____ (**l)**
2. Initial Temperature of water (T_W) _____ (**^{0}C)**
4. Water boiling temperature (T_B): _____ (**^{0}C)**
5. Time taken to boil the water: _____ **(min)**

Operation and Maintenance:

- Position of damper: open during the start of fire and maintain about 15 degrees during operation
- Smoke leakages (chimney pipes, heating plate, double smoke pipe)
- Structural damages (specify if any): _____
- If any repaired works have been carried out (specify if any)
- Frequency of cleaning (record) _____
- Are you satisfied with performance of stove in terms of heat radiation/retention?
- Do you have any suggestion for improvement of this stove?
- _____
- _____
- _____
- **Stove orientation/ house plan:**
- Locate the windows and doors in the diagram. Determine the farthest distance of the wall from the stove.



Double smoke pipe & chimney joint

8.3 Annexure III: Survey Questionnaire

A: GEOGRAPHICAL IDENTIFICATION:

Q1. Dzongkhag:.....
Q2. Name of the place: .....

Q3. Type of household:
1. Residence
2. Business Household

Q4. Status of lighting:
1. On-grid
2. Off-grid
3. No electricity (>>Q5)

Q4.1. Year of lighting: .....

Q5. Area: 1. Rural
2. Urban

Q6. Altitude in ..... *masl*

Q7. Average temperature (deg.celcius): .....

B. DEMOGRAPHIC, EDUCATIONAL AND ECONOMIC CHARACTERISTICS

Q8. Gender:
1. Male
2. Female

Q9. Age (in completed years):

Q10. Number of household members:

Male	Female	Total

Q11. Education:
00. No education
Classes 1-15
16. Certificate
17. Diploma
18. Masters & above
19. Monastic

Q12. Occupation:
1. Farmer
2. Govt. employee
3. Corp. employee
4. Pvt. Employee
5. Others (Specify): .....

Q13. Monthly income (Nu.): .....

Q13.1. Monthly expenditure (Nu.): .....

C. DWELLING CHARACTERISTIHS:

Q14. Type of accomodation:
1. Concrete building
2. Traditional house
3. Huts
4. Others (Specify): .....

Q15. Construction material used:
1. Cement and rod
2. Mud and morter
3. Bamboo/poles
4. Barkles
5. Others (specify).....

Q16. Roofing materials used:
1. CGI sheets
2. Tiles
3. Thatched (e.g. with bamboo)
4. Wooden Shingles
5. Others (Specify): .....

Q17. # of rooms: .....
Q17.1. Housing Condition:
1. Proper condition
2. Crack walls
3. Others (Specify): .....

D. ENERGY/FUELWOOD CONSUMPTION:

Q18. What is the **primary** source of heating for your household?

1. Traditional bukhari
2. Kerosene heater
3. Electric space heating
4. Others (specify):.....

Q 19. Fuelwood is obtained from:

1. Forest
2. Sawmill
3. Briquettes
4. Others (specify):.....

E. HEATING HABBITS OF HOUSEHOLD:

Q20. Main type of heating system used before IHS:

1. No heating (>>Q21)
2. Traditional Bukhari
3. Fire place (oven)
4. Electric space heating
5. Kerosene heater
6. Others (Specify): .....

Q21. Kind of IHS installed:

1. 1-Pot
2. 2-Pot
3. Both

Q21.1. How long has your household been using item in *Q21? Mention in the total months:* .....

Q22. The reason for choosing the type in Q21:

1. Affordable & suits our daily chores
2. Produces less smoke and efficient
3. Saves time
4. Better than other energy options
5. Consumes less firewood and retains the heat longer
6. Provided as subsidy
7. Earlier Bukhari was old and needed replacement
8. Others (Specify): .....

**Note: 1 tsew = 20 kgs*
1 headload = 20 kgs

Q23. Before installtion of IHS, the average quantity of fuelwood consumption per month (headload):.....

Q23.1. With installation of IHS, the average quantity of fuelwood consumption per month (headload):.....

Q24. Average hours of heating per day: .....

Q25. Besides IHS, other type of heating used:

1. Electric space heating
2. Kerosene heater
3. Traditional oven
4. Traditional bukhari
5. Others (Specify):.....

Q26.**Monthly average cost per unit (Nu.):

2.Amount paid per litre x # litres per day x 30
3. Nu.215/# of tsews x 30

1. Electricity:.....
2. Kerosene:.....
3. Firewood:.....
4. Others (Specify):.....

F. HEALTH ASPECTS:

Q27.Frequency of hospital visits by family members:

1. Weekly
2. Monthly
3. Quarterly
4. Annually
5. None of these (>>Q31)

Q28. If one of above in Q27, cite ailments:

1. Asthma (breathing problem)
2. Acute Respiratory Infection
3. Cough and cold (flue)
4. Cataract
5. Cardio vascular(heart disease)
6. Lungs problem
7. Others (Specify):.....

Q29. Common health problems due to fuelwood burning:

1. Eye irritation
2. Nasal problems
3. Breathing problems
4. Othes (Specify):.....

Q30. Do you or any one of your family members smoke cigarette?

1. Yes
2. No

G. ENVIRONMENTAL IMPACTS:

Q31. Which species is commonly used for fuelwood for IHS:

1. Hard wood
2. Soft wood
3. Others (Specify):.....

Q32. Corresponding quantity used per month (Kgs):

1. Hard wood .....
2. Soft wood .....
3. Others (Specify): .....

H. PERFORMANCE OF IHS:

Q33. How long does IHS retains heat after the fire is over:

1. Less than 2 hours
2. 2 to 3 hours
3. 3 to 4 hours
4. 4 to 5 hours
5. More than 5 hours

Q34. Other then space heating, what do you use IHS for?

1. Boiling water
2. Warming up food
3. Others (Specify): .....

Q35. How many litres of water do you boil everyday using IHS?

(in litres) .....

I. OPERATIONS & MAINTENANCE:

Q36. Have you ever faced any problems with your system?

1. Yes
2. No (>>Q39)

Q37. If yes, what are the common problems with your system? Rank top 3 from 1-5 [*1=most frequently, 5=least*].

1. Smoke leakage from the pipe joints
2. Smoke leakage from the heating plate
3. Smoke leakage from the joining of double smoke pipe and rear plate
4. No heat retention
5. Slow heat radiation
6. Structural damage (Specify:.....)
7. Others (Specify): .....

Q38.Types of repair works carried out:

1. Repaired chimney joints
2. Repair of clay bricks/mortar
3. Others (Specify): .....

Q39. The overall performance of IHS*[1 = very satisfied, 2= satisfied, 3=Don't know, 4=not satisfied, 5= not at all satisfied]*

1. Fuelwood consumption reduction
2. Convinence in heating
3. Reduced smoke emission
4. Better indoor air quality
4. Others (Specify): .....

Q40. Where did you get information about IHS?

1. SRBE Project Officials
2. News media
3. BBS Annoucement
4. Neighbours/friends/relatives
5. Druk Super Star
5. Others (Specify): .....

8.4 Annexure IV: Test Data Profile

Data Sheet for House No. 1, 2-pot Energy Efficient Heating Stove with clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	10:15	20.5	16.25	19.5	19.4	17.2	16.9	203	damper open/ fire door open/ lot of smoke	
2	*0:15*	10:30	161	40.3	19.5	19.4	44.7	27.9	203	damper open/ fire door open/ little smoke	
3	*0:30*	10:45	216	49	19.3	19.5	65.1	45.2	203	damper closed/ fire door closed/ no smoke	
4	*0:45*	11:00	329	75.4	19.8	19.6	102	60.1	203		
5	*1:00*	11:15	351	113	21.1	20.8	135	67.8	203		
6	*1:15*	11:30	391	141	21.9	22.4	131	76.5	203		
7	*1:30*	11:45	540	330	22.9	22.2	228	142	203		
8	*1:45*	12:00	512	309	23.9	22.6	193	124	203		
9	*2:00*	12:15	469	279	22.5	22.3	183	113	203	Fire out	
10	*2:15*	12:30	202	108	23.6	22.4	50.4	38.8	203		
11	*2:30*	12:45	247	110.5	22.1	22.1	82.8	47.7	203		17.1
12	*2:45*	13:00	209	127	21.2	21.8	58	47.5	203		
13	*3:00*	13:15	188	117	21.1	21.6	56.4	44.5	203		
14	*3:15*	13:30	168	111.5	21.4	21.4	61	41.9	203		
15	*3:30*	13:45	143	110	21.4	21.4	61.1	39.7	203		
16	*3:45*	14:00	130	98.5	21.4	21.4	52.1	36	203		19.5
17	*4:00*	14:15	103	89.7	21.1	21.1	47.1	35.2	203		
18	*4:15*	14:30	82.1	81.4	20.3	20.5	42.3	30.3	203		19.5
19	*4:30*	14:45	68.6	72.3	20.2	21.4	30.2	30.2	203		18.3

Data Sheet for House No. 2, 1-pot Energy Efficient Heating Stove with clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	9:30	33.3	9	16.1	16	15.4	13	172	damper open/ fire door open/ no smoke leakages	
2	*0:15*	9:45	242	25.9	16.5	16.5	115	37.3	172	damper open/ fire door close	
3	*0:30*	10:00	273	62.6	17.1	16.9	163	61.6	172	damper open/ fire door close	
4	*0:45*	10:15	289	90.4	18.3	17.8	170	51.7	172		
5	*1:00*	10:30	296	93	18.7	18.6	193	61.1	172		
6	*1:15*	10:45	257	106	20.2	19.3	147	64.8	172		
7	*1:30*	11:00	216	94.1	20.7	20.4	102	61.8	172	Fire out	
8	*1:45*	11:15	247	85	21.6	21.3	169	65.5	172		
9	*2:00*	11:30	259	101	21.8	21.1	109	63.2	172		
10	*2:15*	11:45	206	102	23.3	23	105	49.8	172		
11	*2:30*	12:00	203	101	23.5	23.2	89	46.1	172		
12	*2:45*	12:15	220	104	23.8	23.3	75.9	43	172		
13	*3:00*	12:30	197	107	22.5	22.6	78.6	38.5	172		
14	*3:15*	12:45	166	99.2	22.3	22.2	48.2	37.7	172		
15	*3:30*	13:00	164	98.7	22.4	21.9	42.3	34.8	172		
16	*3:45*	13:15	144	85.9	22.5	22.3	40.7	38.9	172		
17	*4:00*	13:30	116	85.1	21.8	21.6	39.5	35.5	172	Damper close	
18	*4:15*	13:45	101	77.2	21.8	21.5	36.6	28.1	172		
19	*4:30*	14:00	84.1	72.5	21.3	20.9	35.3	27.9	172		

Data Sheet for House No. 3, 1-pot Energy Efficient Heating Stove with clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	11:55	115	19.5	17.2	17	67.3	31.9	185	damper open/ fire door close/ no smoke leakages	
2	*0:15*	12:10	230	39	18.6	18.4	78.3	35.8	185		
3	*0:30*	12:25	254	47	19.6	19.1	104	40.6	185		
4	*0:45*	12:40	266	62	21.1	20.5	113	45.8	185		
5	*1:00*	12:55	272	79	21.9	20.8	122	56.2	185	damper close/ fire door close	
6	*1:15*	13:10	277	82.2	22.1	21.5	157	58.2	185	damper open/ fire door close	
7	*1:30*	13:25	305	82.7	23	22.6	161	59.7	185		
8	*1:45*	13:40	223	81.4	22.5	22.1	71.6	44.8	185	Fire out	
9	*2:00*	13:55	187	79.7	22	22.1	66.3	33.5	185		
10	*2:15*	14:10	160	78.5	21	20.6	60.9	33	185		
11	*2:30*	14:25	142	72.6	19.7	19.4	48.7	28.9	185		
12	*2:45*	14:40	138	70.8	19.4	19.2	42.9	26.7	185		
13	*3:00*	14:55	91.6	63	18.6	18.4	38.8	23.2	185		
14	*3:15*	15:10	70.6	62.7	18.7	18.7	35.1	25.7	185	damper close/ fire door close	
15	*3:30*	15:25	51.5	56.6	18.2	18.2	31.5	25.1	185		
16	*3:45*	15:40	48.8	50.9	18.1	18.1	30	26.3	185		
17	*4:00*	15:55	40	45.2	18.1	18	28	25.2	185	Damper close	

Data Sheet for House No. 4, 1-pot Energy Efficient Heating Stove with clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	10:30	23.8	22.8	21.1	20.5	24.1	24.2	278	damper open/ fire door close	
2	*0:15*	10:45	143	24.6	22.4	21.7	88.9	29.1	278		
3	*0:30*	11:00	151	34.8	22.8	21.7	82.1	23.6	278	damper closed/ fire door closed	25.6
4	*0:45*	11:15	245	60.5	24	22.6	92.8	33	278		
5	*1:00*	11:30	261	91	27.3	26.5	125	35	278		26.7
6	*1:15*	11:45	246	94.1	26.1	25.5	125	35	278		
7	*1:30*	12:00	263	120	27.8	26.6	146	39.1	278	Fire out	
8	*1:45*	12:15	234	124	29.1	27.6	85.7	34.8	278		
9	*2:00*	12:30	198	128	25.1	24.9	91	33.3	278		
10	*2:15*	12:45	188	129	26.3	26.2	59.3	35.7	278		
11	*2:30*	13:00	179	125	28.4	25.3	75	31.7	278		
12	*2:45*	13:15	174	121	27.9	26.1	78.4	31.8	278		
13	*3:00*	13:30	182	122	25.9	25.8	71.4	29.6	278		
14	*3:15*	13:45	177	125	27.9	25.8	74.6	31.1	278		
15	*3:30*	14:00	162	117	25.6	25.4	54.3	31.5	278		
16	*3:45*	14:15	157	116	26.8	26.3	53	31.3	278		
17	*4:00*	14:30	145	114	25.6	25.6	62.5	29.9	278		
18	*4:15*	14:45	141	109	26.6	26.5	60.9	31	278		
19	*4:30*	15:00	134	107	25.5	25.6	57	29.4	278		

Data Sheet for House No. 5, 1-pot Energy Efficient Heating Stove with clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	11:00	22	19	22	21.2	21	20.3	245	damper open/ fire door close	
2	*0:15*	11:15	194	29.2	22.2	21.5	89	38.4	245		
3	*0:30*	11:30	221.2	38	22.6	21.5	98.3	44	245		
4	*0:45*	11:45	236	82	23.1	21.9	118.4	56.1	245	damper open/ fire door close	
5	*1:00*	12:00	301.2	121	23.9	22.6	192	78.3	245		
6	*1:15*	12:15	309	150.1	24.6	23.1	212.5	97.6	245		
7	*1:30*	12:30	348	159	26.2	24.6	233	119.3	245		
8	*1:45*	12:45	364.1	165.3	28.1	27.3	240	128.7	245		
9	*2:00*	13:00	321	160	28.6	27.2	212	106.1	245	Fire out	
10	*2:15*	13:15	228	118.1	26.1	25.3	187.1	97.6	245		
11	*2:30*	13:30	193.2	128	26.4	25.3	143.6	78	245		
12	*2:45*	13:45	176.5	112.3	25.8	25	132	71.2	245		
13	*3:00*	14:00	155.3	106	25	24.2	122.6	63.3	245		
14	*3:15*	14:15	148.8	102.1	24.9	24.1	101.3	58	245		
15	*3:30*	14:30	140.3	105	24.6	24	92.1	53.9	245		
16	*3:45*	14:45	142	109.2	24.6	23.8	84	50.1	245		
17	*4:00*	15:00	138	103.2	23.6	23.6	76	44.2	245		

Data Sheet for House No. 6, 1-pot Energy Efficient Heating Stove with clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	12:00	25	19	21.6	21.5	23	20.6	192	damper open/ fire door close	23.3
2	*0:15*	12:15	212	33	23.6	21.6	266	138	192		
3	*0:30*	12:30	216	66.4	24	22.7	225	108	192	damper close/ door close	
4	*0:45*	12:45	345	101	27.3	25.7	276	144	192		
5	*1:00*	13:00	344	126	28	25.5	230	112	192		
6	*1:15*	13:15	348	149	31.1	26	234	130	192		
7	*1:30*	13:30	360	155	29.6	27.6	230	103	192		
8	*1:45*	13:45	356	156	32.2	29.3	233	107	192		
9	*2:00*	14:00	258	147	31.3	29.1	152	68	192	Fire out	
10	*2:15*	14:15	233	150	30	28	102	56.8	192		
11	*2:30*	14:30	187	145	27.6	26.8	106	59.8	192		
12	*2:45*	14:45	175	137	27.3	26	88.2	43.1	192		
13	*3:00*	15:00	166	123	26.4	25.1	82	40	192		
14	*3:15*	15:15	159	117.2	26.1	25	77.3	36.9	192		
15	*3:30*	15:30	150.4	112	25.2	24.6	74	33.7	192		
16	*3:45*	15:45	144	107.1	24	23.2	70	31	192		
17	*4:00*	16:00	139.3	102.6	23.4	22.5	68	30.3	192		

Data Sheet for House No. 7, 1-pot Energy Efficient Heating Stove without clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	10:45	369	35	23.1	23.1	243	145	140	damper open/ fire door close	
2	*0:15*	11:00	324	78.7	23.2	23.6	161	108	140	damper close/ door close	
3	*0:30*	11:15	382	90.5	27.3	27.8	123	97.7	140	damper close/ door close	
4	*0:45*	11:30	404	113	31.5	31.3	109	87.1	140		
5	*1:00*	11:45	400	144	29.9	28.9	110	88.2	140		
6	*1:15*	12:00	372	158	34.5	33.3	87.5	68.8	140		
7	*1:30*	12:15	338	162	28.4	28.1	59.3	56.8	140	Fire out	
8	*1:45*	12:30	297	158	29.9	28.2	61.7	51.7	140		
9	*2:00*	12:45	246	149	24.8	27.6	49	45.4	140		
10	*2:15*	13:00	242	141	24.5	27.4	50.2	46	140		
11	*2:30*	13:15	188	128	28.9	27	48	42.8	140		
12	*2:45*	13:30	170	121	27	27	46	41	140		
13	*3:00*	13:45	100	115	26.1	26.1	12.5	39	140		
14	*3:15*	14:00	93.9	102	25.2	25	41.9	36.5	140		

Data Sheet for House No. 8, 2-pot Energy Efficient Heating Stove with clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	11:35	19.4	18.7	18.8	18.7	39.6	39.5	187	damper half open/ fire door close	
2	*0:15*	11:50	150	32.6	19.3	19.4	70.1	61.5	187	damper fully open/ door close	
3	*0:30*	12:05	199	65.8	21.6	21.8	120	67.1	187	damper close/ door close	
4	*0:45*	12:20	260	107	24.2	24.4	122	70.6	187		
5	*1:00*	12:35	241	108	25.1	28.5	130	71.1	187		
6	*1:15*	12:50	254	113	25.6	25.5	135	72.6	187		
7	*1:30*	13:05	257	123	25.6	25.3	136	72.5	187		
8	*1:45*	13:20	308	134	27.1	27	102	67.7	187	Fire out	
9	*2:00*	13:35	238	144	27.6	27.4	110	60.8	187		
10	*2:15*	13:50	229	138	25.6	25.8	68	60	187		
11	*2:30*	14:05	223	148	26.2	26.3	60.8	51.3	187		
12	*2:45*	14:20	204	130	25.5	25.5	54.7	45.9	187		
13	*3:00*	14:35	185	125	26.4	26.5	51.4	40.2	187		
14	*3:15*	14:50	153	116	25.5	25.5	51.3	39.2	187		
15	*3:30*	15:05	143	113	25.4	25.8	35	35	187		
16	*3:45*	15:20	121	108	24.6	24.4	30.2	34.5	187		
17	*4:00*	15:35	99.7	102	24.6	24.6	29.3	33.6	187		

Data Sheet for House No. 9, 1-pot Energy Efficient Heating Stove with clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	9:45	15.5	15.5	14.3	14.3	14.3	14.3	190	damper open/ fire door open	
2	*0:15*	10:00	135	23	17.7	17.5	69.4	34.8	190	damper open/ fire door close	
3	*0:30*	10:15	287	42.5	18.6	22.9	134	47.6	190	damper half open/ fire door close	
4	*0:45*	10:30	241	76.75	19.9	25.15	138	47.7	190		
5	*1:00*	10:45	317	98.65	20.4	20.4	130	44	190		
6	*1:15*	11:00	262	134.85	21.4	23.7	172	60.4	190		
7	*1:30*	11:15	284	132.5	21.5	27.5	145	55	190		
8	*1:45*	11:30	335	170.5	22.1	32.15	165	52.5	190		
9	*2:00*	11:45	328	171	23.1	30.1	153	51.1	190		
10	*2:15*	12:00	286	166.5	23.6	30.1	108	43.5	190	Fire out	
11	*2:30*	12:15	251	163.5	23.6	28.5	86.4	38.4	190		
12	*2:45*	12:30	217	151	23.6	23.2	72.1	33	190		
13	*3:00*	12:45	201	138.5	23.2	22.4	70.9	31.7	190		
14	*3:15*	13:00	196	136.5	21.95	22.95	72.7	31.2	190		
15	*3:30*	13:15	185	123	23.1	20.95	65.2	29.3	190		
16	*3:45*	13:30	169	114.5	18.8	22.85	66.1	29.7	190		
17	*4:00*	13:45	139	107.5	22.8	20.2	54.5	27.9	190		
18	*4:15*	14:00	117	95.25	22.8	21.8	50.5	27.1	190		
19	*4:30*	14:15	109	87.35	22.5	22.95	49.4	27.4	190		
20	*4:45*	14:30	96.9	77.5	22.1	21.1	45	25.1	190		

Data Sheet for House No. 10, 1-pot Energy Efficient Heating Stove without clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	10:30	16	16	20	20	16	16	221	damper close/ fire door close	
2	*0:15*	10:45	100	95	22	21	90	79	221		
3	*0:30*	11:00	277	274.5	24.8	21.8	129	40.5	221		
4	*0:45*	11:15	268	243	22.8	21.8	132	63.7	221		
5	*1:00*	11:30	297	234.5	24	22	178	60.6	221	damper half close/ fire door close	
6	*1:15*	11:45	312	230.5	23.9	23.1	152	37.9	221		
7	*1:30*	12:00	350	242.5	25	22.5	208	42.4	221		
8	*1:45*	12:15	330	274.5	24.2	24.1	202	84.7	221		
9	*2:00*	12:30	279	241.5	23.1	23.3	142	40	221		
10	*2:15*	12:45	294	246.5	25.8	25.6	160	80.4	221	Fire out	
11	*2:30*	13:00	309	244	24.1	23.9	109	44	221		17.1
12	*2:45*	13:15	265	231.5	25	25	89	43	221		
13	*3:00*	13:30	252	205.5	24	24	91.6	62.6	221		
14	*3:15*	13:45	250	201.1	23.1	23.1	89.5	60.9	221		
15	*3:30*	14:00	239	200	22.9	22.9	86.5	58.1	221		
16	*3:45*	14:15	215	195	21.8	21.8	83.1	50.1	221		19.5
17											
18											19.5
19											18.3

Data Sheet for House No. 11, 2-pot Energy Efficient Heating Stove without clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	10:15	13.3	10.3	23.3	23	45.2	20.1	240	Damper open/ fire door close	
2	*0:15*	10:30	108.9	34.6	21.5	21.5	60.9	23.1	240		
3	*0:30*	10:45	196.5	111.65	21.1	21.1	95.3	43.3	240		
4	*0:45*	11:00	254	135	22	22	130	48.7	240		
5	*1:00*	11:15	256	161	23.3	23.3	160	61.5	240		
6	*1:15*	11:30	206.5	161	23.6	23.6	104	49.6	240		
7	*1:30*	11:45	172	147	23.4	23.4	86	45.9	240	Fire out	
8	*1:45*	12:00	144	153	23.2	23.2	54.6	40.1	240		
9	*2:00*	12:15	135.5	112.5	26	26	64	37	240		
10	*2:15*	12:30	132.5	110.1	25.9	25.9	63.2	32	240		
11	*2:30*	12:45	130.1	109	24.8	24.8	60.1	31.9	240		
12	*2:45*	13:00	129.8	105.1	23.8	23.8	59.1	29.8	240		
13	*3:00*	13:15	128	101.2	21.8	21.8	56	26.8	240		
14	*3:15*	13:30	125.1	99.8	20.1	20.1	52.1	25.1	240		
15	*3:30*	13:45	123.1	97.8	20	19.8	50.3	23.2	240		
16	*3:45*	14:00	120.3	93.5	18.8	18.8	49.8	21.8	240		
17	*4:00*	14:15	119.5	91.8	17.6	17.6	45.1	20.1	240		

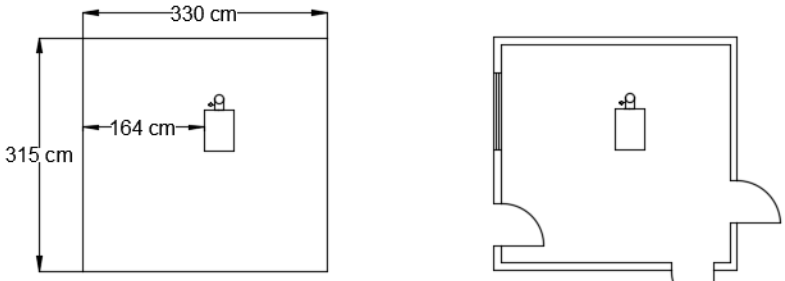
Data Sheet for House No. 12, 2-pot Energy Efficient Heating Stove without clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	10:45	13.2	18.95	18.3	18.3	41.5	27.8	225	Damper open/ fire door close	
2	*0:15*	11:00	186	151	18.3	18.3	58.1	41	225		
3	*0:30*	11:15	158	241	19.1	19.1	85.3	53.9	225		
4	*0:45*	11:30	275	270	20.1	20.1	99.9	60.6	225		
5	*1:00*	11:45	317	276	21.3	21.3	98.8	66.3	225		
6	*1:15*	12:00	340	303	22.2	22.5	107	65.4	225		
7	*1:30*	12:15	311	271	22.1	22.1	93.8	62.1	225		
8	*1:45*	12:30	270	240	21.3	21.3	78.3	57.9	225	Fire out	
9	*2:00*	12:45	242	230	21	21	70.6	47.9	225		
10	*2:15*	13:00	200	192	21.2	21.2	69	36	225		
11	*2:30*	13:15	173	182	21.1	21.2	67	50.2	225		
12	*2:45*	13:30	170	178	22.2	22.2	65	36.2	225		
13	*3:00*	13:45	168.5	170	23.2	23.2	61.8	33.2	225		
14	*3:15*	14:00	160.1	165	22.2	22.2	59.1	31.2	225		
15	*3:30*	14:15	158	160.1	21.8	21.8	55.1	30.1	225		
16	*3:45*	14:30	150.1	159.1	20.1	20.1	50.1	29.1	225		

Data Sheet for House No. 13, 1-pot Energy Efficient Heating Stove without clay bricks											
Sl. No.	**Time (hh:mm)**		**Temperature (^{0}C)**							**Remarks** (fire door open, damper position, etc.)	**Outside temperature (0C)**
			Surface of stove		**At 1-meter radius from the stove**	**Near the wall**	**Chimney** (Start of chimney) **A**	**Chimney** (Point of contact with ceiling) **B**	**Distance between A and B (cm)**		
			Top	**Side** (Average of Left and right surface)							
1	*00:00 (Start of fire)*	10:30	19.9	18.8	20.6	20.6	18.9	20.9	186	Damper open/ fire door close	
2	*0:15*	10:45	302	244	23	23	159	68	186		
3	*0:30*	11:00	322	252	25.2	25.2	157	35.4	186		
4	*0:45*	11:15	371	312.5	25.8	25.8	143	68.4	186		
5	*1:00*	11:30	282	238	26.8	26.8	110	47.3	186	Fire out	
6	*1:15*	11:45	235	228	26.8	26.8	106	44	186		
7	*1:30*	12:00	225	223	26.8	26.8	102	42.2	186		
8	*1:45*	12:15	220	212	26.8	26.8	100.1	40.2	186		
9	*2:00*	12:30	218	209	24.6	24.6	99.9	39.2	186		
10	*2:15*	12:45	215	201.2	23.6	23.6	98	38	186		
11	*2:30*	13:00	210	200	22.6	22.8	97.2	37.2	186		
12	*2:45*	13:15	209	199	22.1	22.1	96.2	36	186		
13	*3:00*	13:30	207	191.6	22	22	93.2	35.6	186		
14	*3:15*	13:45	199.6	190	21.2	21.2	91.8	34	186		
15	*3:30*	14:00	195	189	20.2	20.2	90	32.3	186		
16	*3:45*	14:15	186	178	19.1	19.1	89.9	30.2	186		
17	*4:00*	14:30	175.6	168	19.1	19.1	88.8	30.2	186		

8.5 Annexure V: Room Floor Plan

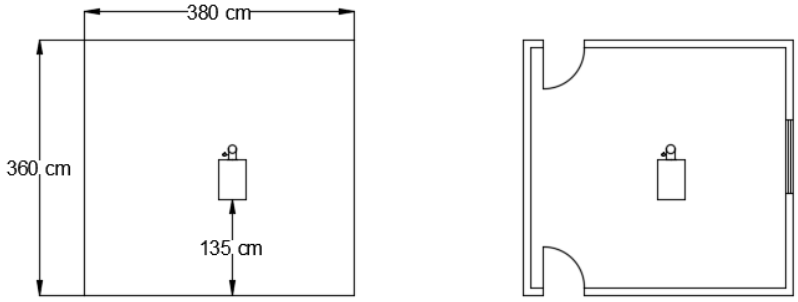
8.5.1 Room floor plan of 1-pot users:

House#2-



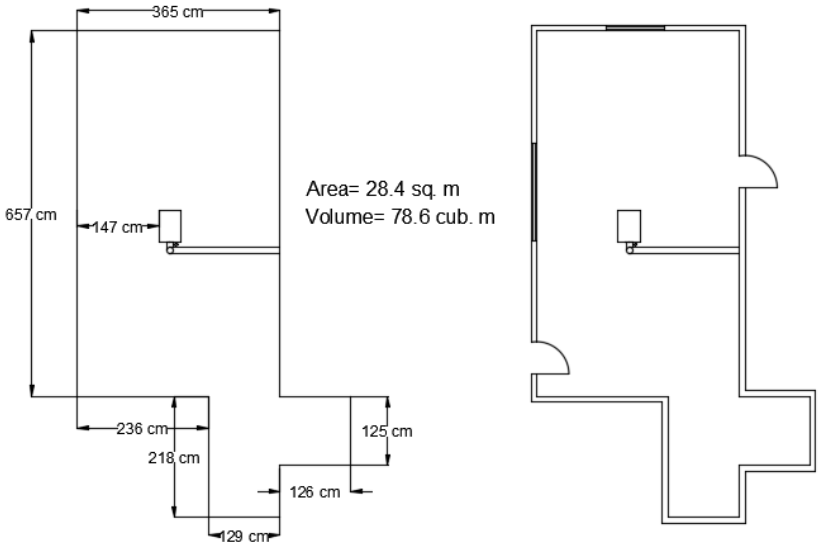
Area= 10.4 sq. m
Volume= 23.4 cub. m

House#3-



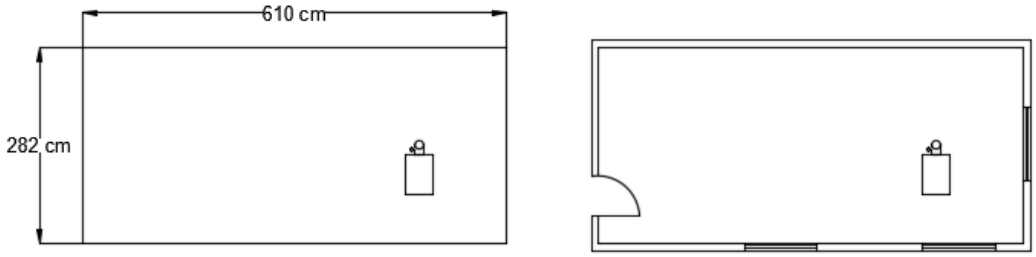
Area= 13.9 sq. m
Volume= 34.7 cub. m

House#4-



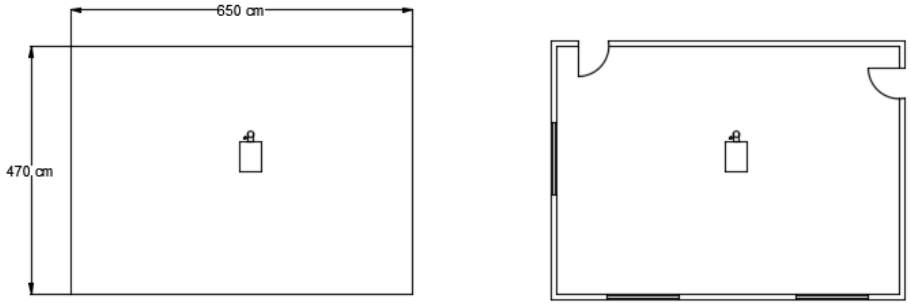
Area= 28.4 sq. m
Volume= 78.6 cub. m

House#5-



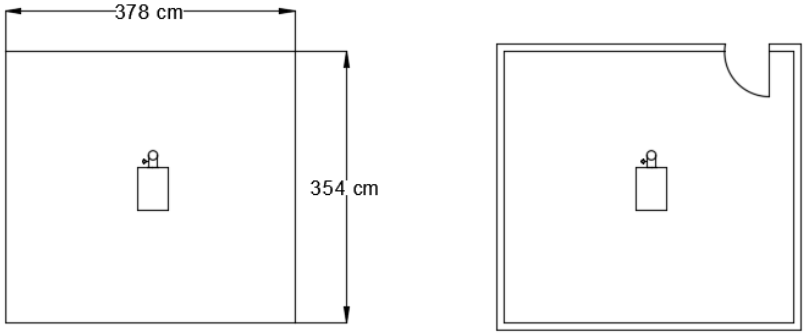
Area= 17.2 sq. m
Volume= 42.1 cub. m

House#6-



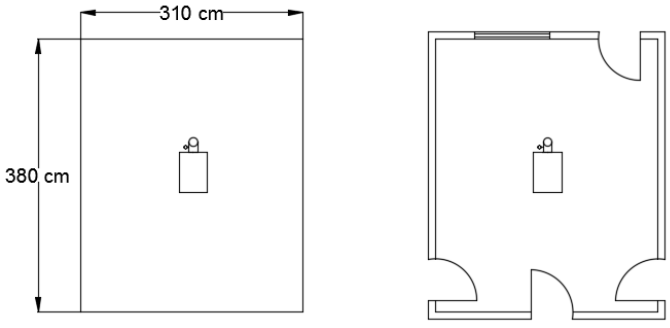
Area= 30.6 sq. m
Volume= 78.8 cub. m

House#7-



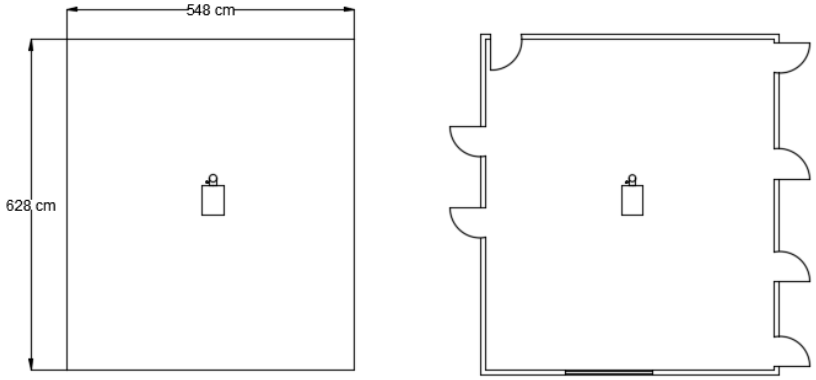
Area= 13.4 sq. m
Volume= 18.7 cub. m

House#9-



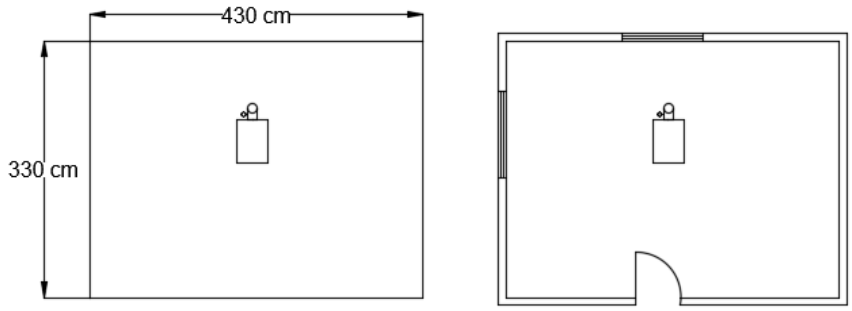
Area= 11.8 sq. m
Volume= 29.9 cub. m

House#10-



Area= 34.4 sq. m
Volume= 96.4 cub. m

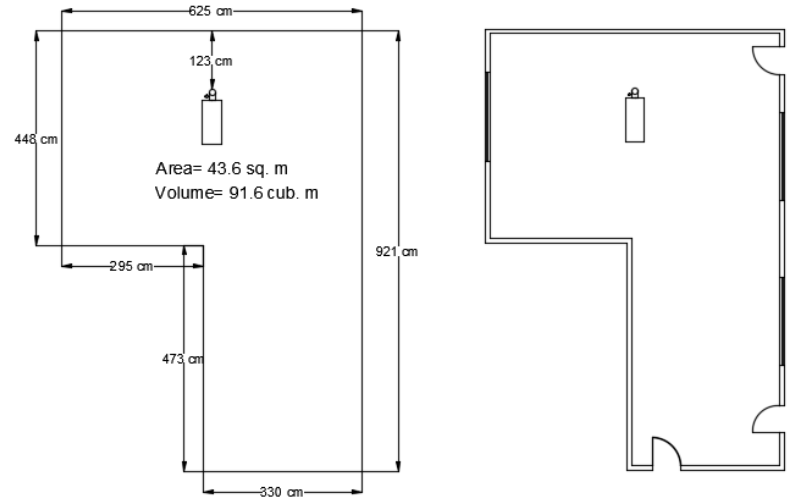
House#13-



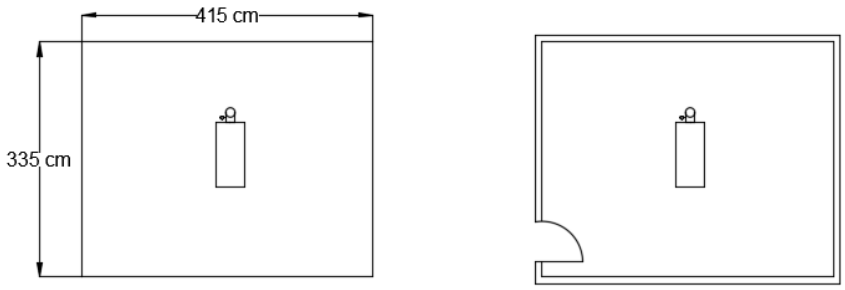
Area= 14.2 sq. m
Volume= 32.6 cub. m

8.5.2 Room floor plan of 2-pot users:

House#1-

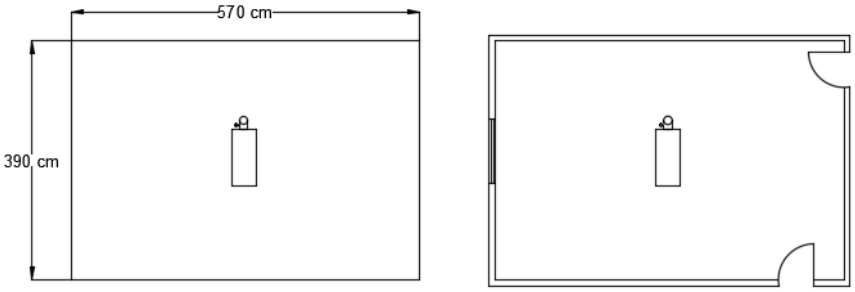


House#8-



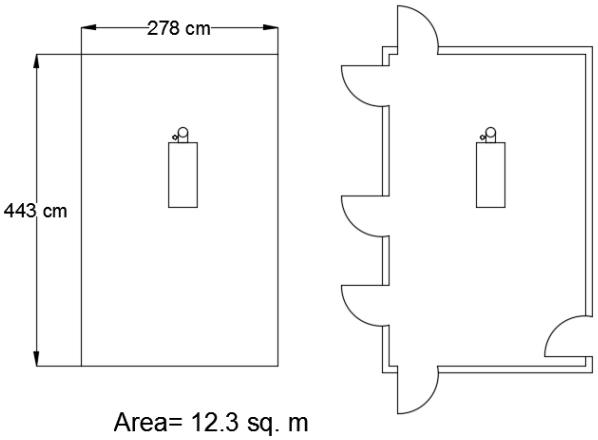
Area= 13.9 sq. m
Volume= 35.6 cub. m

House#11-



Area= 22.2 sq. m
Volume= 71.1 cub. m

House#12-



Area= 12.3 sq. m
Volume= 27.7 cub. m