Ethio Resource Group
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GTZ SUN ENERGY Project

Water Boiling Test Results

Institutional Rocket and Tikikil Stoves
(Draft)

February 2010

1. Introduction

This report presents Water Boiling Test (WBT) results of five different types of household and institutional rocket stoves. Each of these stoves are described below.

Deluxe Tikikil

An assessment has been conducted in early November 2009 to evaluate Tikikil and institutional rocket stove producers and users. Some of the feed-backs obtained from Tikikil stove users indicated the need for a bigger version of Tikikil to accommodate larger pots. During the assessment, it was also learnt that Tikikil, which was initially designed for household use, is also used by commercial users such as hotels and restaurants. When it comes to the application of household Tikikil for hotels and restaurants, it has two major limitations. First, the existing sheet metal the crown part of the stove is made up with is primarily designed for household use. Thus, it will not last longer with the intensity and frequency of use in commercial establishments. Secondly, pots with capacity of 10 liters and above, with diameter of about 30 centimeters and larger, are commonly used in restaurants and hotels. The household Tikikil accommodates pot sizes of 25 centimeter in diameter and smaller. To address this market segment, a more robust Tikikil is designed and manufactured with a sheet metal of 1 mm thickness. It accommodates pot sizes of 32 cm in diameter and smaller. Because of its convenience for commercial application in terms of accommodating larger pot sizes and robustness, it was given the name *Deluxe*. Two variation of Delux Tikikil were manufactured.

Deluxe Tikikil-1

Deluxe Tikikil 1-
It uses the standard clay liner used for the household rocket stove. Production of the stove is using cut templates for different parts of the stove. The base plate does not have the cement mix insulation.

Deluxe Tikikil 2 -
Production method of this stove is similar to that of institutional rocket stove. The height of the clay liner and the fuel inlet are slightly increased by 60 mm and 40 mm respectively compared to that of standard liner for household Tikikil. This is to avoid the need for frequent removal of ash during longer cooking.

Deluxe Tikikil-2

Double skirt Tikikil

Double skirt Tikikil is primarily designed to meet the request from households in refugee settlements in Ethiopia. Unlike most households in Ethiopia, these refugee households use larger pot sizes for their daily cooking. This stove has two skirts - a fixed larger skirt and a smaller removable one. With a larger skirt, it accommodates pots as big as 27 cm diameter. The smaller skirt is used when smaller size pots are used. The materials used for the production of double skirt Tikikil are similar to that used for ordinary household Tikikil.

Double skirt Tikikil

Chimney Institutional Rocket Stove (CIRS)

IRS

Along with the chimneyless institutional rocket stove (IRS), an institutional rocket stove with chimney has been manufactured. The CIRS manufactured has an 18 cm by 18 cm combustion chamber with a power to cook up to 120 liters of food. IRS greatly reduces smoke or indoor air pollution (IAP) level in a kitchen but CIRS totally eliminates it.

CIRS has inner and outer skirts with insulative material in between to protect the outer skirt from heating up.

CIRS

Deluxe Tikikil -1	Deluxe Tikikil - 2	Double skirt Tikikil	Institutional Rocket stove with chimney
			

2. Test Methodology

Shell Foundation Household Energy Project (SF HEP) WBT version 3 test protocol was used to evaluate the performances of the stoves. A pot size of 32 cm diameter and ten litres of water was used to test Deluxe Tikikil stoves. These results were also compared against that of a carefully tended Open Fire tested with 10 liters of water. The double skirt stove was tested with the smaller skirt using a 24 cm diameter pot with five litres of water. These results were also compared with earlier results of ordinary single skirt household Tikikil. Three tests were conducted on each of these stoves.

The chimney institutional rocket stove was also tested using the same SF HEP protocol. Even though SF HEP is primarily designed for testing household stoves, the principles can also be applied for testing institutional stoves. However, in the absence of larger capacity weighing balance, SF HEP protocol is not convenient to apply for testing institutional stoves with very large volume of water. Measuring such a large volume of boiling water in a similar way as in the case of the household stove is difficult and unsafe. Alternatively, the total weight of the water can be obtained by weighing and adding several smaller volumes with a bucket. This method, however, is time taking and allows so much of the water to evaporate unaccounted affecting the accuracy of the results to a greater significance.

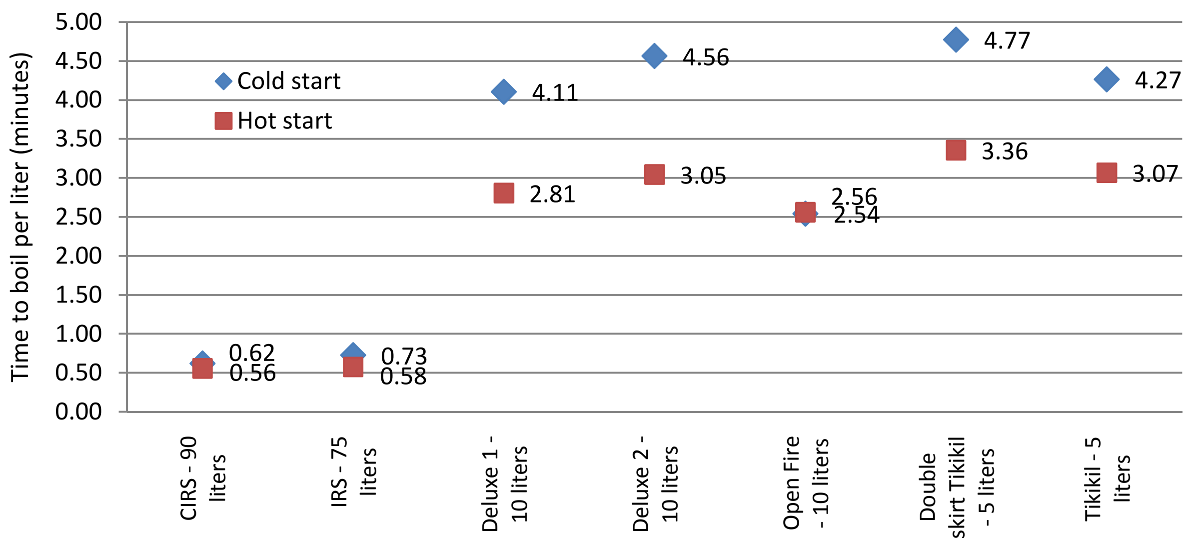
In the method applied for testing CIRS, the pot was filled with measured amount of 90 kg of water at the beginning. The pot was neither weighed nor removed from the stove. Instead the depth of the water was measured and the weight was calculated. This tells exactly the volume and the weight of water at the original height Based on the temperature of the water and the drop in height the volume and hence the weight of evaporated water can pretty easily calculated. This method provides a better accuracy. Three tests were also conducted. Test results of IRS and Open Fire tested with 75 liters of water are also presented in this report.

Additional three tests were conducted with CIRS using a different WBT procedure. The purpose of conducting these test were to compare the performance of institutional rocket stoves with the results of another type of locally manufactured institutional stove and Open Fire tested several years before[1]. The procedure used to test the locally made institutional stove and Open Fire was tailored to resemble the actual cooking practice of the end users that the stoves were proposed to. With this WBT procedure a known mass of water was boiled and simmered for 45 minutes. Measurements were taken only at the beginning and end of the test after completion of the simmering phase without any interruption in between. The time taken to boil the water is the only intermediate data taken. The amount of fuel consumed was adjusted for moisture contents and remaining char embers. From this test, the overall efficiency of the stove and the fuel consumption index were calculated. See explanation of results in the Annex 1.

3. Performances of stoves

A. Time to boil

The time taken to bring a liter of water to boiling temperature is depicted for each stove in the graph below.



[1] The Test Programme for Turbo Stove within the UN World Food Programme's Refugees Project and School Feeding Project in Ethiopia, Result on the Water Boiling Test, UNWFP, Addis Ababa, Ethiopia,29/March/2001.

For the institutional stoves and Open Fire, the boiling time is similar in both cold and hot start phases. In the case of the institutional stoves, the heat taken up by the liner and insulation mass is almost negligible compared to the amount of heat released. Moreover, the slight decrease in time to boil during the hot power phase becomes unnoticed when distributed to the total volume of water boiled. Since Open Fire does not have any mass to heat up, the cold and hot start phases are almost similar. There could be, however, a small difference due to the heating up of the pot supports and the ground. Deluxe Tikikil and Double skirt Tikikil stoves, however, took more time to boil a liter of water in the cold start phase than they did in the hot start phase. This is mainly due to the amount of heat that was partly taken to heat up the clay liner mass during the cold start high power phase.

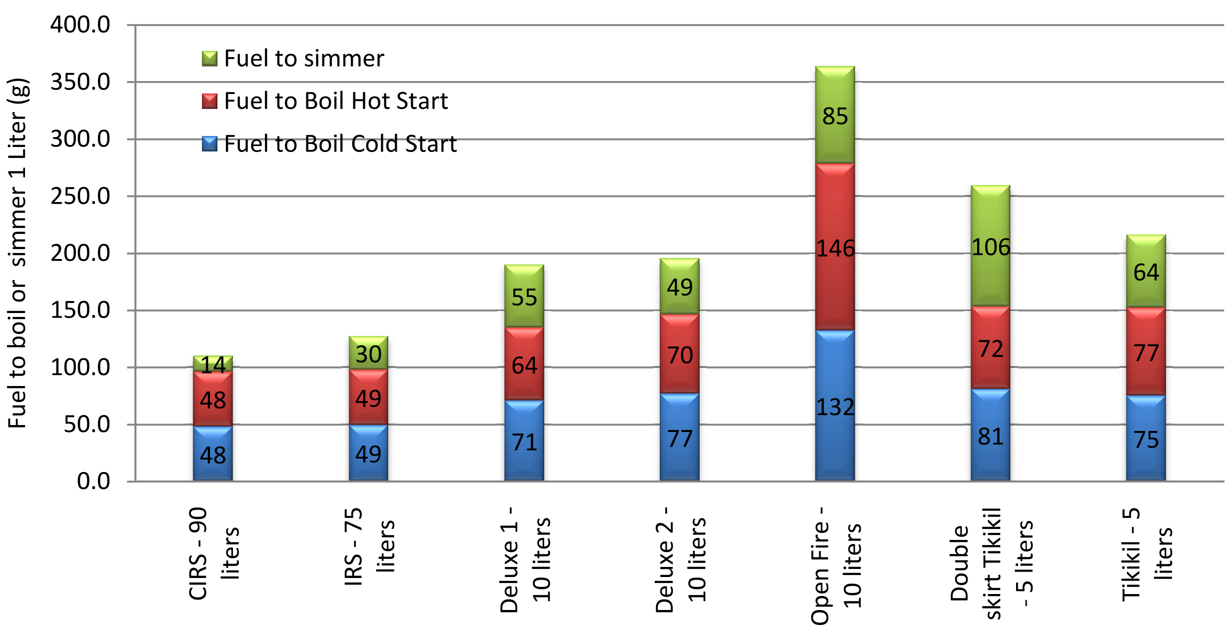
The boiling time per liter of water is less than a minute for both institutional stoves. There is no significant difference between CIRS and IRS in terms of boiling time per liter of water.

Comparison of the two Deluxe Tikikil stoves shows that Deluxe Tikikil-1 takes half a minute less time to boil a liter of water in cold start when compared to Deluxe Tikikil-2. During hot start, there is no significant difference between the two stoves. Open Fire with 10 liters of water took about half a minute less time to boil a liter of water compared to that of Deluxe Tikikil stoves in the high power hot start phase. Comparison of time to boil a liter of water by Open Fire to that of Deluxe Tikikil stoves in the cold start phase shows that Open Fire took from 1.5 to 2 minutes less time.

The boiling time taken by Double skirt Tikikil is slightly longer, less than half a minute, but not significant compared to ordinary household Tikikil.

B. Fuel consumption

Fuel consumption refers to the amount of fuel consumed to bring a liter of water to boiling temperature. The figure below shows the fuel consumed by each stove to boil a liter of water.



Institutional Rocket Stoves

In terms of fuel consumption, the two institutional stoves performed similar in both high power cold start and hot start phases. For the simmering phase, CIRS took 14 grams of fuel per liter of water simmered. This is less by half than that consumed by IRS. Both CIRS and IRS have similar size of combustion chambers which are designed to cook from 90 to 120 liters of food. With 75 liters of water, IRS definitely performed under capacity, and this could have led to the evaporation of more water. Moreover, IRS was simmering at higher fire power than CIRS was doing. These are the main reasons for the higher consumption of fuel in the simmering phase of IRS compared to that of CIRS. The table below shows the percentage difference between the stoves by fuel consumption and thermal efficiencies.

Type of Test	**Fuel consumption (gm/ liter)**		**Efficiency (%)**	
	CIRS - 90 liters	**IRS - 75 liters**	**CIRS - 90 liters**	**IRS - 75 liters**
High Power cold start	47.80	49.19	0.41	0.42
High power hot start	48.19	48.50	0.40	0.48
Simmering	13.78	29.53	0.44	0.39
% Diff. high power cold start	*2.8*		*2.0*	
% Diff. high power hot start	*0.7*		*17.4*	
% Diff. simmering	*53.3*		*10.3*	

Comparison of stoves with different amount of water might not be accurate but could be indicative of the performances of the stoves.

Deluxe Tikikil Stoves

Comparison of the two Deluxe Tikikil stoves by fuel consumption indicates a slight but not significant difference in all the three phases. During the high power phases, Deluxe Tikikil 1 took less fuel but the consumption seemed to have increased in the simmering phase. The high power fuel consumption by Open Fire, tested with 10 liters of water, is almost double to that of the Deluxe Tikikil stove. See table below for the comparison of Deluxe stoves and Open Fire.

Type of Test	**Fuel consumption (gm/ liter)**			**Efficiency (%)**		
	Deluxe 1 - 10 liters	**Deluxe 2 - 10 liters**	**Open Fire - 10 liters**	**Deluxe 1 - 10 liters**	**Deluxe 2 - 10 liters**	**Open Fire - 10 liters**[2]
High Power cold start	70.73	76.72	132.12	0.34	0.31	0.17
High power hot start	63.92	69.60	146.18	0.34	0.32	0.15
Simmering	55.14	49.06	85.26	0.34	0.35	0.24
% Saving - cold start	*46.5*	*41.9*		*51.8*	*46.3*	
% Saving - hot start	*56.3*	*52.4*		*56.5*	*53.8*	
% Saving - simmering	*35.3*	*42.5*		*30.3*	*32.2*	

As indicated in the above Table, the fuel saving by the Deluxe Tikikil stoves over Open Fire is higher in the high power phases ranging from 42 to 56%. The saving is reduced to 35% and 43% for Deluxe 1 and Deluxe 2 respectively. Fuel saving calculated from the thermal efficiency is also presented in the table above for comparison. The comparison by thermal efficiency accounts the fuel consumed and the amount of water evaporated as well.

[2] Note that the higher efficiencies in Open Fire are the result of extremely careful tending of the fire. Efficiencies as low as 10 to 12% were also obtained in previous tests with more relaxed fire tending.

Double skirt Tikikil

Double skirt Tikikil consumed 10 gram less fuel per liter of water boiled in the hot start phase compared to that it consumed in the cold start phase. In the simmering phase, unlike the institutional and Deluxe Tikikil stoves, double skirt Tikikil consumed more fuel to simmering than to boil a liter of water. This is partly due to the difficulty to reduce and maintain the firepower to the minimum required. In other words, the minimum power maintained during the simmering phase was slightly higher when simmering 5 liters than it was with 10 liters. Hence, more water is evaporated with smaller volume of water which makes the fuel consumption per liter of water simmered higher. However, previous test results with single skirt household Tikikil showed fuel consumption per liter of water simmered as low as 64 grams. See the graph above.

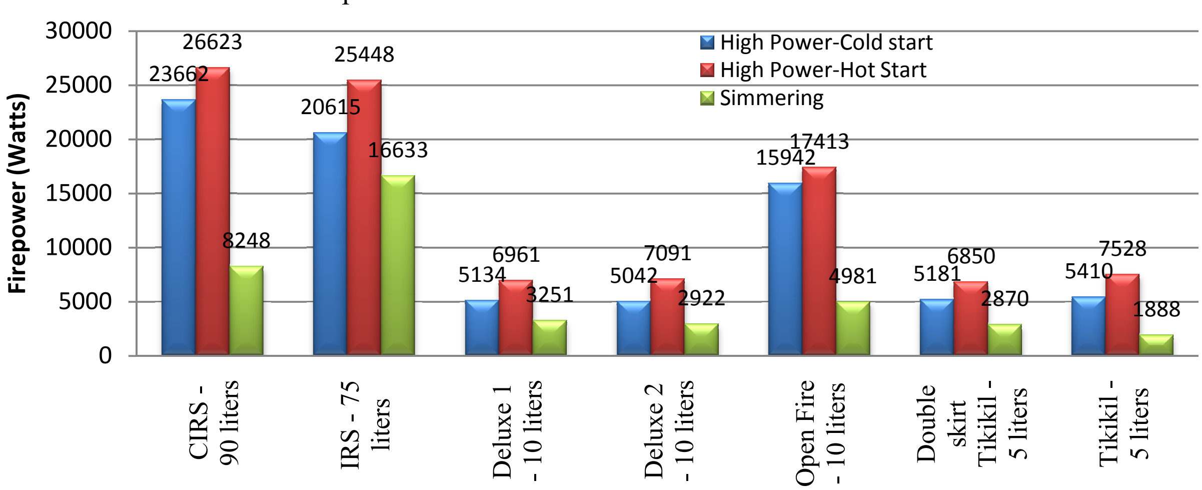
Comparison of double skirt Tikikil and single skirt household Tikikil, both tested with 5 liters of water, is presented in the Table below. Percentage fuel saving is calculated based on fuel consumption index and thermal efficiencies.

Type of Test	by fuel consumption		by efficiency	
	Double skirt Tikikil - 5 liters	Tikikil – 5 liters	Double skirt Tikikil - 5 liters	Tikikil – 5 liters
High Power cold start	80.93	75.18	0.28	0.26
High power hot start	72.32	76.88	0.29	0.25
Simmering	106.16	63.92	0.28	0.30
Diff. high power cold start	-7.7		5.8	
Diff. high power hot start	5.9		12.3	
Diff. simmering	-66.1		-8.0	

The fuel consumption indexes of both cold and hot start high power tests show small differences between the double skirt Tikikil and the single skirt Tikikil stoves. However, the difference in the simmering phase is significant. On the other hand, comparison by the efficiency terms shows that performances of these stoves are similar in the simmering phase as well. This difference, therefore, could be primarily due to differences in tending the fire.

C. *Fire power*

Fire power indicates the rate at which the fuel burns. The Table below shows the fire power for each of the stoves discussed in this report.



In general, the fire power during the hot start high power phase was always higher than that of the cold start in all stoves. The hot liners in rocket stoves, and perhaps the hotter ground and pot supports in Open Fire, seem to have contributed for an enhanced rate of fuel burning. This was the primary reason for shorter boiling time in the hot start phase.

Institutional rocket stoves

Fire powers for the institutional stoves during high power cold start phase are about 20.6kW and 23.7kW for IRS and CIRS respectively. The corresponding fire powers for the hot start phase are 25.4kW and 26.7kW accordingly. During simmering phase the fire power for CIRS is 8.2kW while that of IRS is 16.6kW. CIRS seems to have been more carefully tended than IRS as the fire power for IRS is much higher.

Deluxe Tikikil stove

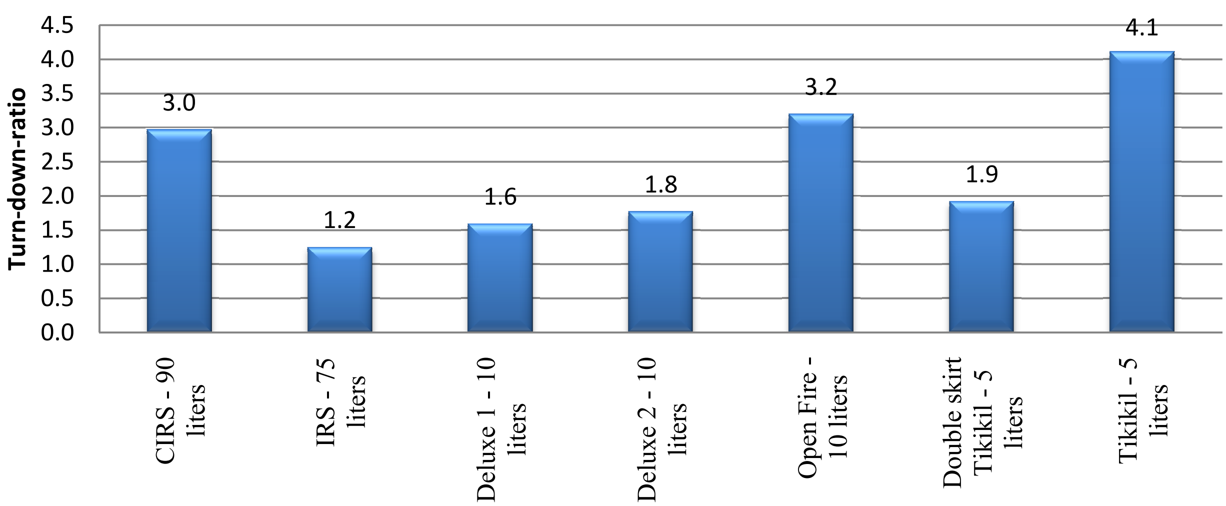
In all three phases the two Deluxe Tikikil stoves have similar fire power. The fire power obtained for the high power cold star, hot start, and simmering phases are 5kW, 7kW and 3kW respectively.
Open fire, with same 10 liters of water, showed 16kW, 17kW and 5kW fire power for the high power cold start, hot start and simmering phases respectively.

Double Skirt Tikikil

The fire power for double skirt Tikikil is 5.2kW, 6.9kW and 2.9kW corresponding to the cold start, hot start and simmering phases. The fire power for single skirt Tikikil, with the same 5 liters of water, was 5.4kW, 7.5kW and 1.9kW for the cold start, hot start and simmering phases respectively. It can be noted that Tikikil has been more carefully tended resulting in a firepower lower by 1kW than that of the double skirt Tikikil

D. Turndown ratio

Turndown ratio is the ratio of firepower at high power to that of simmering. It is a measure of flexibility of the stove for regulating the fire power. In principle, higher turndown ratio can be obtained with stoves with capacities of burning fuel at very high and very low rates. In practice, with solid fuels it is very much depends on how well the fire is tended. With extremely careful fire tending, an Open Fire can have higher turndown ratio. The figure below shows the trundown ratio for the stoves tested.



CIRS and Open Fire with 10 liters of water showed bigger turndown ratio. However, the level of effort in regulating the fire in Open Fire was extremely tedious. An Open Fire, without additional tending effort, can have a turndown ratio as low as 1.3. Both Deluxe Tikikil stoves have similar turndown ratio.

4. Conclusion and Recommendation

The findings of this and previous WBT tests show that Tikikil and the institutional rocket stoves showed fuel savings of 40% and above over extremely carefully tended Open Fire. More fuel saving could be achieved in actual cooking conditions in the households where fuel tending with Open Fire is often less careful. It is time now to verify the WBT results of Tikikil with actual cooking by conducting controlled cooking tests (CCT) to be followed by a kitchen performance test (KPT).

With regard to the Deluxe Tikikil stoves, the project team needs to decide on one for further CCT, KPT or promotion. In terms of performance both prototypes of Deluxe Tikikil stoves are similar. Considering, ease of production and costs, the one labled Deluxe Tikikil-1 seems to have taken less material. In addition to this, Deluxe Tkikikil-1 is easier to manufacture as it uses the standard household liner and that parts are assembled from pre-cut templates. It can be manufactured by both Tikikil and IRS producers. On the other hand, larger fuel inlet on Deluxe Tikikil-2 makes ash and embers removal from the combustion chamber easier. However, the need for a longer liner and the relatively more time taking manufacturing process are drawbacks. It can only be manufactured by IRS producers. Based on these criteria Deluxe Tikikil-1 seems more appropriate for further promotion.

For the chimney institutional stove, the appropriate chimney height may need to be identified. Unlike the case in households, kitchen heights in institutions vary greatly. The prototype chimney institutional rocket stove was tested with a chimney riser height of about two meters. A two meter chimney height would still keep the smoke under the roof in most institutional kitchens. For complete elimination of smoke from a kitchen, a chimney height of at least three meters is needed. The effect of the additional chimney could affect the performance of the stove. Therefore, it is worth that the project team should assess and identify the typical chimney height appropriate for most institutional kitchens and conduct WBT to determine its performance.

Annex A1: Comparison of CIRS and other stoves using a different procedure

Additional three tests were conducted with CIRS using a different WBT procedure. The purpose of conducting these tests were to compare the performance of institutional rocket stoves with the results of another type of locally manufactured institutional stove and Open Fire tested several years before using a different procedure[3]. The locally manufacture improved institutional stove was also a sunken-pot type but different from rocket stoves. This procedure was tailored to resemble the actual cooking practice of the end users in Bonga refugee settlements who were using the Open Fire stove for mass cooking. With this WBT procedure, a known mass of water was boiled and simmered for 45 minutes. Measurements were taken only at the beginning and end of the test after completion of the simmering phase without any interruption in between. The time taken to boil the water was the only intermediate data taken. The amount of fuel consumed was adjusted for moisture contents and remaining char embers. From this test, the overall efficiency of the stove and the fuel consumption index were calculated.

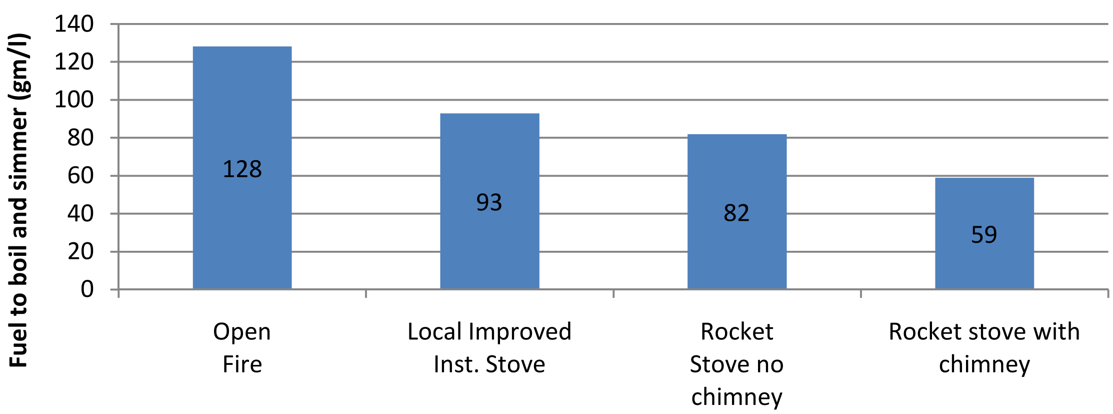
Since the test results were taken from different sources, the weight of water that the stoves were tested is not similar. The locally made institutions stove and Open Fire were tested with 80 liters of water. The chimneyless institutional stove (IRS) results were deducted by combining the high power cold start phase and the simmering phase from previous test results with 75 liters of water. Since all stoves are not tested with equal amount of water, the presentation below should rather be taken as an indication of their performances rather than a comparison.

The performances of the stoves are described in terms of fuel consumption, overall thermal efficiency, time required to bring a litre of water to boil and fire power. The results are discussed below. Note that

Fuel Consumption

The fuel consumption by each stove to boil and simmer a litre of water is presented in Figure A1.1 below. Fuel consumption in this case is calculated by dividing the equivalent dry wood consumed by the amount of water remaining at the end of the simmering phase. Since a certain mass of water is evaporated during the test, the final weight of water is always less than the initial weight of water. The calculation for the fuel consumption index doubly discredits the stoves performance as it does not account the energy consumed to evaporate the water.

Figure A1.1: Fuel consumption to boil and simmer one litre of water



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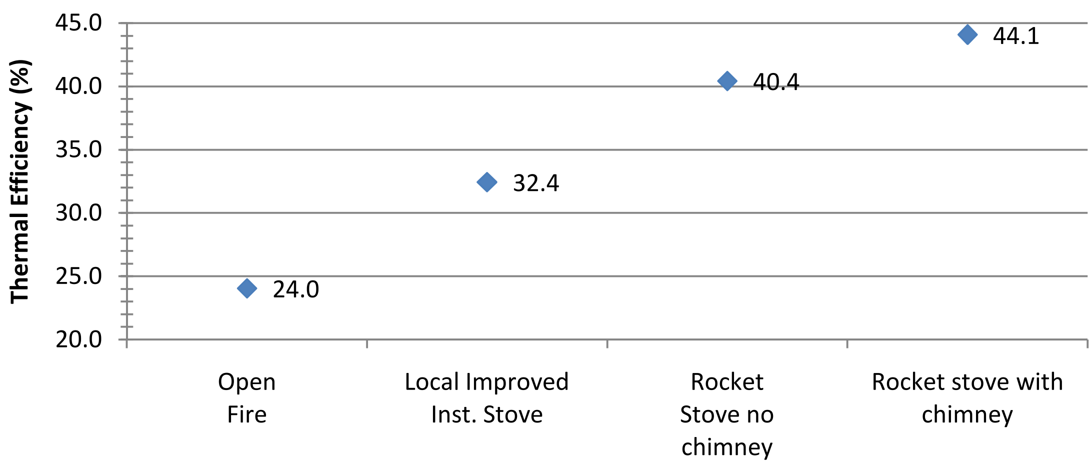
[3] The Test Programme for Turbo Stove within the UN World Food Programme's Refugees Project and School Feeding Project in Ethiopia, Result on the Water Boiling Test, UNWFP, Addis Ababa, Ethiopia, March 2001.

CIRS seems to have consumed the least amount of fuel per litre of water boiled and simmered (59gm/l) compared to the other stoves. The rocket stove without chimney (IRS) consumed more fuel, 82gm/l, than CIRS to simmer a liter of water. One of the reasons for the low performance of IRS could be that the stove was a little bit oversized to boil 75 liters as it is primarily designed for 90 to 120 litres of water. Compared to CIRS, IRS evaporated 2kg of more water. Open Fire and the locally manufactured institutional stove consumed 128gm/l and 93gm/l respectively.

Overall Thermal Efficiency

The performances of the stoves in terms of overall thermal efficiencies are presented in Figure A1.2 below.

Figure A1.2: Overall thermal efficiency of the stoves



As can be seen from the Figure above, Open Fire performed the lease with an overall efficiency of 24%. The highest efficiency is obtained by CIRS followed by IRS and the local institutional stove with thermal efficiencies of 44.1%, 40.4% and 32% respectively.

Fuel Saving Compared to Open Fire

Fuel savings of the improved stoves were compared against that of Open Fire. As mentioned above, this comparison may not be very accurate as each stove was tested with different weight of water but is indicative to estimate the relative fuel savings. Table A2.1 below shows the relative fuel saving in terms of fuel consumption index and thermal efficiencies. Thermal efficiency accounts the energy consumed per output more accurately than fuel consumption index. However, in reality, most cooking might not need to evaporate more water and hence accounting the amount of water evaporated might not be needed. In this case, the fuel consumption index should be taken as the governing indicator of stove performance. It is also important to compare stoves in terms of thermal efficiency as it accounts energy input and output more precisely.

Table A2.1: Comparison of stoves with Open Fire

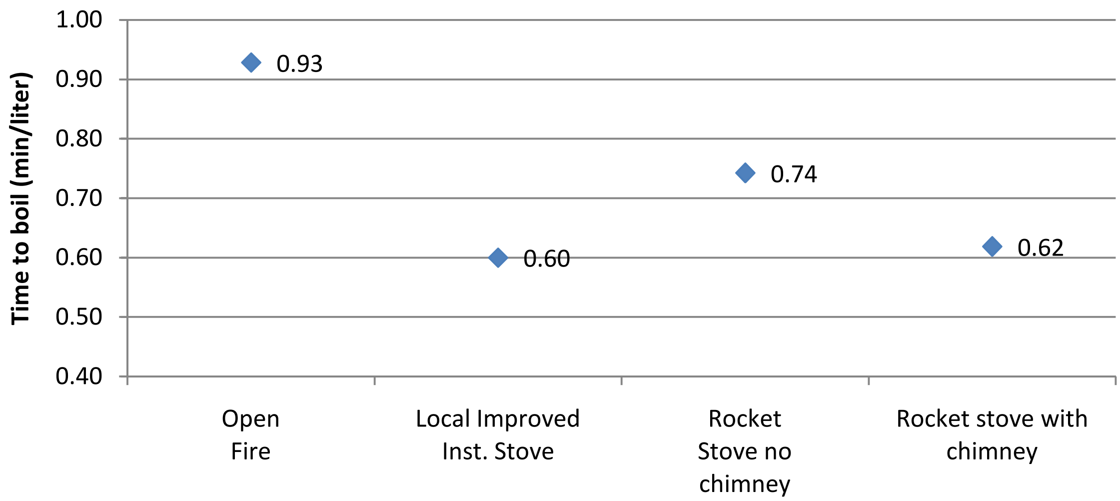
Fuel saving over Open Fire	Stove Type		
	Local Improved Inst. Stove	Rocket Stove With no chimney	Rocket stove with chimney
Based on specific fuel consumption	27.6%	36.2%	54.0%
Based on thermal efficiency	25.9%	40.5%	45.4%

The fuel saving over open fire, based on specific fuel consumption to boil and simmer a litter of water is 54%, 36.2% and 27.6% for CIRS, IRS and Locally manufactured improved institutional stove respectively. On the other hand, the fuel saving over open fire based on thermal efficiencies is 45.4%, 40.5% and 25.9% for CIRS, IRS and the local made improved institutional stove accordingly.

Time to Boil

Figure A1.3 below shows the time taken by each stove to bring one litre of water to boiling. In should be noted that all stoves took less than one minute to bring a litre of water to boiling temperature. Open Fire taking 0.93 minutes was the longest time taken to boil.

Figure A1.3: Time required to boil one litre of water

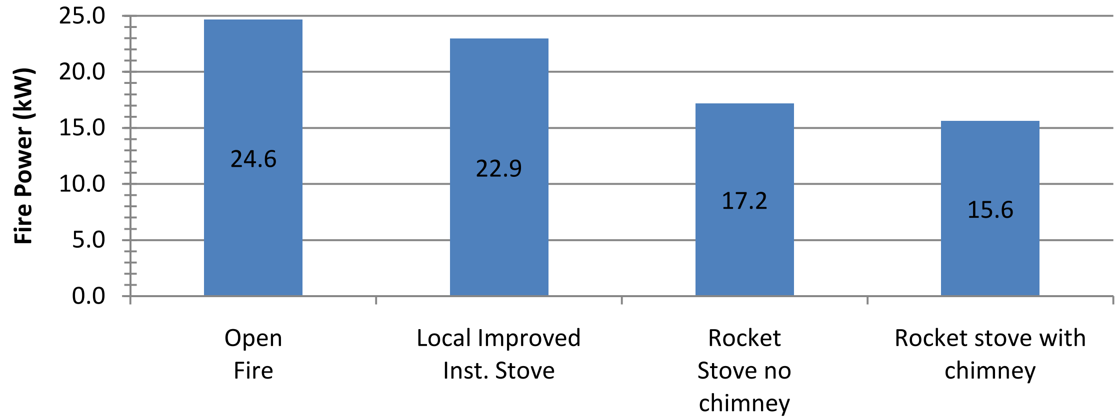


Local institutional stove took the shortest time to boil a liter of water, 0.60 minute, followed by CIRS and IRS each taking 0.62 minute and 0.74 minute respectively.

Fire Power

The firepower for each stove is indicated in Figure A1.4. Open Fire showed the highest fire power 24.6kW followed by the locally designed improved stove, 23kW. The rocket stoves with and without chimney showed similar firepower of 16 and 17kW respectively.

Figure A1.4: Fire Power for different stoves



However, the firepower by IRS for 75 liters of water is much higher than that of CIRS for 90 liters of water. This could also be another reason for evaporation of more water in IRS.

Annex A2: Raw data

Type of Test	units	CIRS					IRS				
1. HIGH POWER TEST (COLD START)		**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Temperature corrected time to boil	min	57.01	54.08	56.76	55.95	1.62	54.99	54.76	53.73	54.49	0.67
Burning rate	g/min	71.94	78.47	75.66	75.36	3.28	71.58	70.29	55.09	65.65	9.17
Thermal efficiency	--	0.41	0.40	0.41	0.41	0.00	0.42	0.40	0.42	0.42	0.01
Specific fuel consumption	g/litre	47.06	50.20	49.38	48.88	1.63	52.32	53.78	40.14	48.75	7.49
Temp-corrected specific consumption	g/litre	46.38	48.15	48.86	47.80	1.28	54.81	53.14	39.61	49.19	8.33
Firepower	watts	22,587.59	24,639.82	23,757.56	23,661.66	1,029.47	22476.42	22072.25	17297.13	20,615.27	2,880.69
2. HIGH POWER TEST (HOT START)	**units**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Temperature corrected time to boil	min	51	52	48	50.32	1.98	40.51	50.39	38.96	43.29	6.20
Burning rate	g/min	79	82	93	84.79	6.92	84.55	69.06	89.53	81.04	10.67
Thermal efficiency	--	0.42	0.39	0.39	0.40	0.02	0.51	0.49	0.46	0.48	0.02
Specific fuel consumption	g/litre	43	46	49	46.07	3.02	45.37	46.01	47.08	46.15	0.87
Temp-corrected specific consumption	g/litre	46	48	51	48.19	2.36	48.47	48.67	48.37	48.50	0.15
Firepower	watts	24,917	25,885	29,067	26,623.11	2,171.44	26547.26	21684.86	28111.51	25,447.87	3,351.41
3. LOW POWER (SIMMER)	**units**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Burning rate	g/min	31.73	20.91	26.17	26.27	5.41	60.64	47.86	50.42	52.97	6.76
Thermal efficiency	--	0.50	0.41	0.40	0.44	0.06	0.43	0.34	0.40	0.39	0.04
Specific fuel consumption	g/litre	17	11	14	13.78	3.06	22.39	32.08	34.12	29.53	6.27
Firepower	watts	9,962	6,565	8,218	8,248.16	1,699.03	19040.95	15026.53	15831.11	16,632.86	2,123.91
Turn down ratio	--	2.27	3.75	2.89	2.97	0.75	1.18	1.47	1.09	1.25	0.20

Type of Test	units	Deluxe Tikikil 1 – 10 liters					Deluxe Tikikil 2 – 10 liters				
1. HIGH POWER TEST (COLD START)		**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Temperature corrected time to boil	min	43.55	40.68	38.96	41.06	2.32	43.50	45.82	47.55	45.63	2.03
Burning rate	g/min	16.41	15.88	16.76	16.35	0.44	17.85	15.56	14.77	16.06	1.60
Thermal efficiency	--	0.34	0.35	0.34	0.34	0.00	0.29	0.31	0.32	0.31	0.01
Specific fuel consumption	g/litre	73.20	64.67	66.46	68.11	4.50	84.21	72.93	72.15	76.43	6.75
Temp-corrected specific consumption	g/litre	76.25	67.65	68.29	70.73	4.79	81.91	74.72	73.52	76.72	4.54
Firepower	watts	5151.92	4987.00	5261.95	5,133.62	138.38	5,604.81	4,884.64	4,636.30	5,041.92	503.05
2. HIGH POWER TEST (HOT START)	**units**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Temperature corrected time to boil	min	31.53	26.40	26.29	28.07	2.99	34.07	25.04	32.26	30.46	4.78
Burning rate	g/min	19.22	24.43	22.85	22.17	2.67	19.64	29.33	18.77	22.58	5.86
Thermal efficiency	--	0.36	0.32	0.34	0.34	0.02	0.32	0.29	0.34	0.32	0.03
Specific fuel consumption	g/litre	60.41	63.74	61.91	62.02	1.67	69.55	74.19	62.41	68.71	5.94
Temp-corrected specific consumption	g/litre	63.19	66.58	61.99	63.92	2.38	69.64	76.43	62.74	69.60	6.85
Firepower	watts	6036.02	7672.31	7175.71	6,961.35	838.94	6,167.22	9,210.83	5,893.97	7,090.67	1,841.18
3. LOW POWER (SIMMER)	**units**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Burning rate	g/min	10.76	11.04	9.26	10.35	0.96	8.38	8.36	11.19	9.31	1.63
Thermal efficiency	--	0.34	0.34	0.34	0.34	0.00	0.35	0.35	0.34	0.35	0.01
Specific fuel consumption	g/litre	58.53	59.51	47.38	55.14	6.74	43.99	43.95	59.24	49.06	8.82
Firepower	watts	3379.83	3465.72	2907.60	3,251.05	300.52	2,630.13	2,624.10	3,512.16	2,922.13	510.99
Turn down ratio	--	1.52	1.44	1.81	1.59	0.19	2.13	1.86	1.32	1.77	0.41

Type of Test	units	Open Fire – 10 liters				
1. HIGH POWER TEST (COLD START)		**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Temperature corrected time to boil	min	28.01	24.49	23.78	25.43	2.26
Burning rate	g/min	38.67	55.87	57.77	50.77	10.52
Thermal efficiency	--	0.19	0.15	0.16	0.17	0.02
Specific fuel consumption	g/litre	110.58	146.20	140.27	132.35	19.09
Temp-corrected specific consumption	g/litre	111.77	141.67	142.93	132.12	17.64
Firepower	watts	12,142.37	17,543.31	18,139.69	15,941.79	3,303.88
2. HIGH POWER TEST (HOT START)	**units**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Temperature corrected time to boil	min	27.71	24.73	24.37	25.61	1.83
Burning rate	g/min	48.42	60.66	57.29	55.46	6.32
Thermal efficiency	--	0.16	0.14	0.15	0.15	0.01
Specific fuel consumption	g/litre	135.10	152.00	144.29	143.80	8.46
Temp-corrected specific consumption	g/litre	139.18	154.69	144.67	146.18	7.86
Firepower	watts	15,203.32	19,048.08	17,987.70	17,413.03	1,985.76
3. LOW POWER (SIMMER)	**units**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Burning rate	g/min	14.95	14.92	17.72	15.86	1.61
Thermal efficiency	--	0.26	0.23	0.21	0.24	0.02
Specific fuel consumption	g/litre	82.20	79.38	94.21	85.26	7.87
Firepower	watts	4,695.05	4,684.11	5,564.58	4,981.25	505.21
Turn down ratio	--	2.59	3.75	3.26	3.20	0.58

Type of Test	units	Double skirt Tikikil – 5 liters					Tikikil – 5 liters				
1. HIGH POWER TEST (COLD START)		**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Temperature corrected time to boil	min	30.55	21.42	19.65	23.87	5.85	23.00	21.00	20.00	21.33	1.53
Burning rate	g/min	14.42	16.36	18.72	16.50	2.15	17.73	15.19	18.76	17.23	1.83
Thermal efficiency	--	0.28	0.27	0.28	0.28	0.00	0.25	0.27	0.26	0.26	0.01
Specific fuel consumption	g/litre	92.85	69.46	71.28	77.86	13.01	83.41	64.99	76.71	75.04	9.33
Temp-corrected specific consumption	g/litre	94.10	72.86	75.83	80.93	11.50	79.19	70.64	75.70	75.18	4.30
Firepower	watts	4,527.02	5,138.01	5,876.72	5,180.58	675.86	5,568.45	4,771.01	5,889.38	5,409.61	575.86
2. HIGH POWER TEST (HOT START)	**units**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Temperature corrected time to boil	min	22.60	14.28	13.46	16.78	5.06	16.00	15.00	15.00	15.33	0.58
Burning rate	g/min	16.26	23.24	25.95	21.81	5.00	22.20	22.50	27.23	23.98	2.82
Thermal efficiency	--	0.29	0.29	0.28	0.29	0.01	0.27	0.26	0.22	0.25	0.03
Specific fuel consumption	g/litre	75.57	65.90	67.07	69.51	5.28	72.49	68.59	83.19	74.76	7.56
Temp-corrected specific consumption	g/litre	76.38	69.13	71.45	72.32	3.71	70.61	74.55	85.47	76.88	7.70
Firepower	watts	5,104.07	7,297.31	8,147.82	6,849.73	1,570.46	6,970.80	7,063.74	8,550.85	7,528.46	886.63
3. LOW POWER (SIMMER)	**units**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**	**Test 1**	**Test 2**	**Test 3**	**Average**	**St Dev**
Burning rate	g/min	10.90	9.71	6.81	9.14	2.10	6.10	6.95	4.98	6.01	0.99
Thermal efficiency	--	0.27	0.27	0.29	0.28	0.01	0.30	0.28	0.32	0.30	0.02
Specific fuel consumption	g/litre	131.48	113.75	73.24	106.16	29.85	64.94	74.34	52.50	63.92	10.96
Firepower	watts	3,422.78	3,048.92	2,137.87	2,869.85	660.91	1,916.66	2,183.77	1,564.14	1,888.19	310.79
Turn down ratio	--	1.32	1.69	2.75	1.92	0.74	3.64	3.23	5.47	4.11	1.19