

REPORT ON HELVETAS IMPROVED COOK STOVE
PERFORMANCE TESTING
IN BAN NAM KHA, XIENG KUANG

Tests funded by and carried out in
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April 2011

Vientiane



Lao Institute for Renewable Energy

LIRE

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Bruce Gardiner

About us

LIRE is a non-profit organisation dedicated to the sustainable development of a self sufficient renewable energy sector in the Lao PDR. The institute offers agronomical, technological and socio-economic research services, and works to provide a free public resource of information and advice on the use of renewable energy technologies in Laos. LIRE strives to support the development of the country by exploring commercially viable means to establish renewable energy technologies in rural parts of the country, in areas without connection to the national grid and with little access to technical expertise.

Helvetas is a Swiss Association for International Cooperation, founded in 1955. Helvetas has more than 40'000 members in Switzerland supporting its activities. Helvetas works in Eastern Europe, Asia, Africa and Latin America. Helvetas started to work in Lao P.D.R. in 2001 with the Laos Extension for Agriculture Project (LEAP) funded by the Swiss Agency for Development and Cooperation (SDC). Helvetas in Laos has been focusing mainly on the agriculture sector, addressing issues related to organic agriculture promotion and food security in the country. Other sectors such as Education and Culture, Civil Society and State which are part of Helvetas' working areas shall gain more and more importance. Helvetas Laos and its partners are currently implementing 6 projects across the country.

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1. Abstract

The comparison in performance between the Helvetas fixed, multi-pot stoves and the traditional three-legged stove showed that the improved stoves have distinct advantages in terms of reduced fuel use and improved indoor air quality. However, these benefits depend on operating the stoves correctly and some design improvements can still be made.

2. Introduction

LIRE, (Lao Institute for Renewable Energy), was commissioned by Helvetas to test the performance of their recently introduced, fixed, multi-pot stoves. These stoves are quite established in Vietnam, but are new the Lao situation. Here in Lao, they are intended to supplement or indeed replace the traditional stove, which is a three-legged pot stand, made from rebar construction steel.

The 3 stoves tested:

Stove 1



Stove 2 with traditional stove still in use nearby



Stove 3



3. Testing Parameters for Cook stoves

Testing Improved Cook Stove Performance

Evaluating the performance of an improved cook stove is more complicated than it might first appear. Some tests are standardized and can be used with any stove anywhere. Others are more culture-specific. Yet others are quite complicated involving large sample groups over long periods. There are three internationally accepted tests which are used to compare the performance of improved cook stoves:

1. The Water Boiling Test, (WBT), usually conducted in a laboratory setting.
2. The Controlled Cooking Test, (CCT), usually conducted in the homeowner's kitchen
3. The Kitchen Performance Test, (KPT), always conducted in the homeowner's kitchen

The Water Boiling Test allows two or more stoves to be compared using a standardized and replicable set of test procedures. However, it does not indicate with much accuracy, how the stove will perform in real world use, cooking a variety of foods, by a variety of cooks. The Controlled Cooking Test, where a specific meal is cooked repeatedly by several cooks under controlled conditions, gives a better idea of stove performance and fuel consumption. The clearest picture of stove performance is obtained by running a Kitchen Performance Test, where many cooks participate in an extensive test over several weeks in their own kitchens, to assess fuel consumption in a real world setting.

We decided to undertake only the Water Boiling Test (WBT), in Ban Nam Kha, as a beginning step in evaluating the Helvetas fixed stoves. To make the tests comparable between the traditional stove and the improved stoves we decided to test only one combustion chamber per improved stove. That meant putting pots on both pot holes connected to that combustion chamber. Typically, the front hole was larger and could accommodate a pot with 5 litres of water. The back hole was usually smaller, so we used a pot that would hold 3 litres of water. The Aprovecho spreadsheet can handle up to 4 pots on the same stove. The test was also modified to become a Regional Water Boiling Test by reducing the simmer time from 45 minutes to 30 minutes, which more accurately reflects local cooking practices.

The typical Water Boiling Test consists of:

- Cold Start Boil phase, where 5 litres of cool water are brought to the boil as quickly as possible.
- Optional Hot Start boil phase where another 5 litres of cool water are brought to the boil as quickly as possible.
- Simmer phase where the water is simmered for 45 minutes, (or in our case, 30 minutes).

(Note: Since pig food was usually prepared early in the morning on the stoves we tested, and the stoves were still warm when we arrived, I decided to conduct all Boil tests as "Hot Starts".)

Note on Thermal Efficiency

“It is also important to acknowledge that over-reliance on thermal efficiency can lead to misleading results, particularly in the simmering phase. Because thermal efficiency accounts for sensible heat as well as evaporative losses, it rewards for the generation of steam. In most cooking conditions, excess steam production does not decrease cooking time, as the temperature in the pot is fixed at the boiling point. Thus, producing excess steam, while it does reflect wood energy transferred to the cooking pot, is not necessarily a good indicator of stove performance. As we stated elsewhere, we wish to de-emphasize the role that thermal efficiency plays in discussions of stove performance and stress other, more informative indicators such as the burning rate and specific consumption at high and low power, and the turn down ratio, which indicates the degree to which power output from the stove can be controlled by the user”.

From ‘Water Boiling Test for Charcoal’ – Aprovecho Research Center.

Key measurements are taken, such as:

- Weight of water at beginning and end of each phase
- Weight of wood at beginning and end of each phase
- Temperature of water at beginning and end of each phase
- Time taken for each phase.

This data is then entered into an Aprovecho Excel spreadsheet that makes the calculations and evaluates the stove performance in terms of certain variables.

The most important variables calculated include:

- Specific Fuel Consumption (Amount of fuel consumed)
- Turn Down Ratio (Degree to which the power output can be controlled by the user)
- Thermal Efficiency (Amount of available energy from the fuel that was delivered to the pot)
- Burning Rate (Rate at which fuel was consumed)

4. The Stoves tested

We tested four stoves in Ban Nam Kha, namely:

- Stove #1 – A Helvetas fixed improved stove made from common construction bricks in the home of Me Wang Law Yang. It had a concrete top, six pot holes and three combustion chambers and one chimney.
- Stove #2 – A Helvetas fixed improved stove made from common construction bricks in the home of Mr Huang Paw. It had a concrete top, four pot holes and two combustion chambers and one chimney.
- Stove #3 – A Helvetas fixed improved stove made from clay in the home of the village leader. It had a concrete top, five pot holes and three combustion chambers and one chimney.
- Stove #4 – A traditional three-legged pot stand stove made from rebar construction steel.

The stoves were built around October 2010 and thus have been in service for 5 or 6 months. Please see accompanying photographs for details.

5. The testing of the stoves

The Tests

To get a bare minimum of statistical validity, each stove was tested three times. Starting on April 6th 2011, we conducted four Water Boiling tests per day for three days. (4 stoves x 3 tests each = 12 tests). Most tests were conducted by myself or Mr Chanhthpasouth, the other member of the LIRE team. However, we did take the opportunity to train some other participants in how to conduct the WBT. These included Mr Phone (Mason), Mr Khampaseuth and Mr Lo Vang (Helvetas), Ms Thongsy, Mr Chansy and Ms Saysamone (Provincial Department of Science and Technology).

As might well be expected in a non-laboratory village setting, not all conditions were able to be controlled. Some of the variables beyond our control included, occasional high winds while testing the traditional stove outside, not having access to the same traditional stove and pot for all three tests, variations in wood species and moisture content, and having to use one pot that was slightly smaller than the pot hole, as it was only one close enough in size that would hold five litres of water. However, I feel these factors did not detract significantly from the validity of the results. Since on the fixed stoves, the pot holes are generally arranged two per combustion chamber, we tested these stoves with a primary pot containing 5 litres of water in the front hole and a smaller pot with 3 litres on the back hole. The fixed improved stoves were built to use specific pots in specific holes. The pot should completely fill the pot hole. The Aprovecho spreadsheet allows for the testing of up to four pots on the same stove.

6. The test results

6.1 Specific Fuel Consumption (SFC)

One of the most reliable indicators of stove performance is Specific Fuel Consumption. As we can see in the 'Average Specific Fuel Consumption' chart below, the three fixed improved stoves performed considerably better than the traditional stove. Stove #2 performed particularly well during the simmer phase.

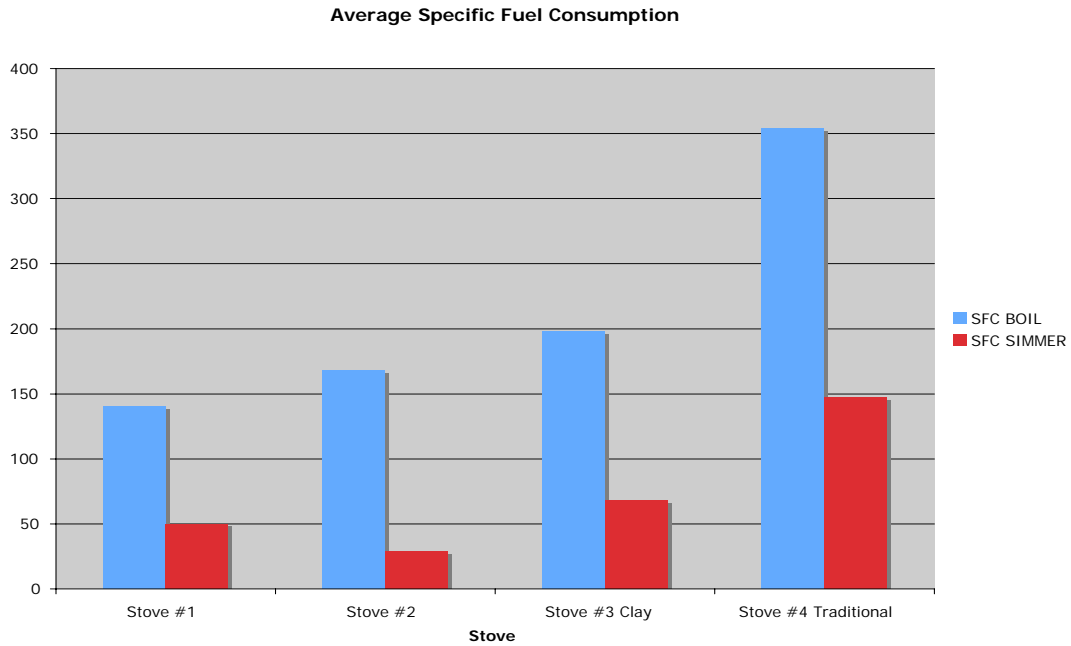


Chart 1 Average Specific Fuel Consumption of the stoves

However, the extent of the over-consumption of fuel by the traditional stove in the Boil phase might be somewhat exaggerated in the above chart due to operator inexperience and windy conditions. In the 'Specific Fuel Consumption Boil' chart below shows that the traditional stove can be operated more efficiently when the operator has more experience, (Test #2), and the wind conditions are calmer.



Specific Fuel Consumption Boil

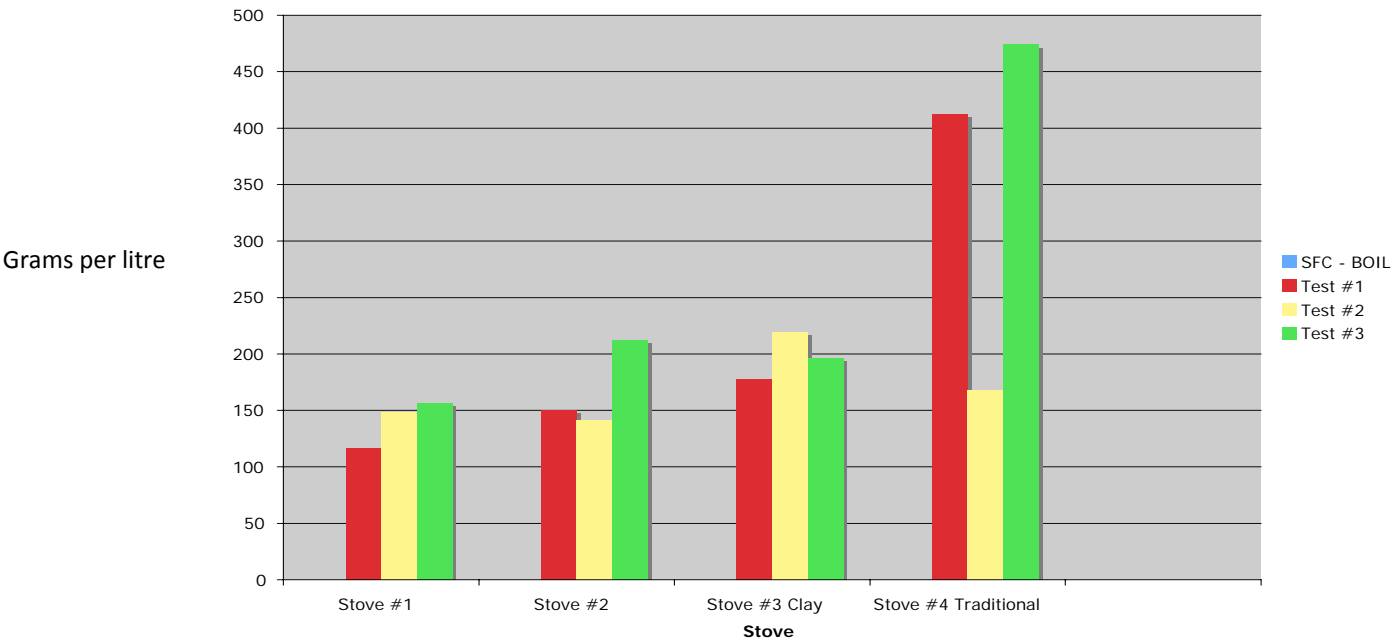


Chart 2 Specific Fuel Consumption of the boiling stoves

In the chart 'Specific Fuel Consumption Simmer' below, we see that the operator for Test#2 on the traditional stove did not manage to return such a good result during the Simmering phase. It is significant to note that all three charts show that the two brick stoves, #1 and #2, outperformed the stove made of clay,#3 in terms of fuel consumed.

Specific Fuel Consumption Simmer

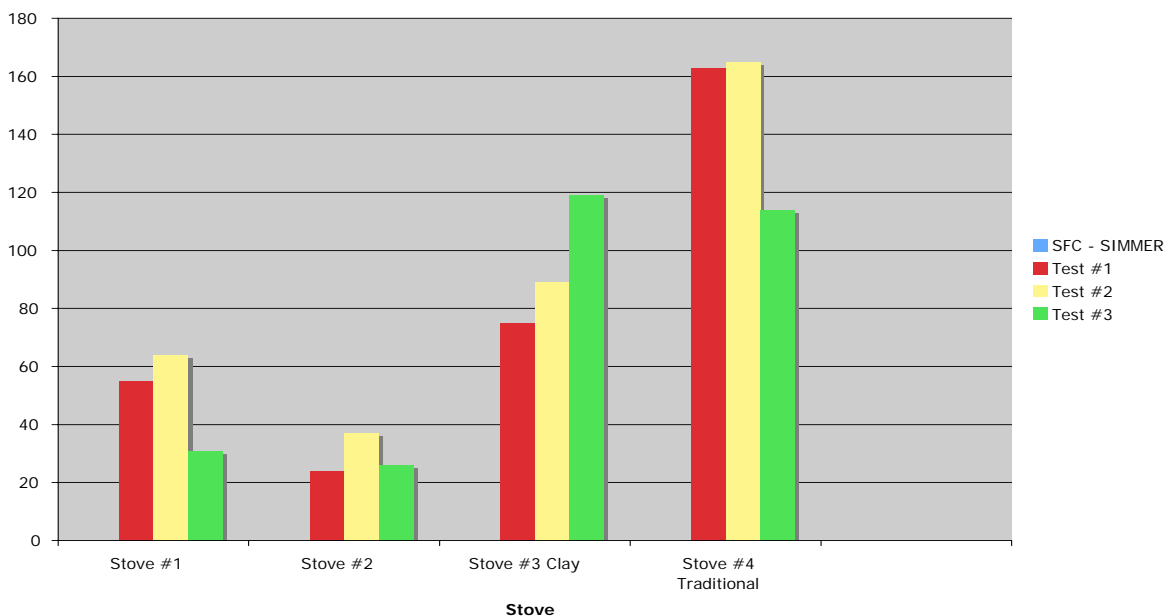


Chart 3 Specific Fuel Consumption of the simmering stoves

6.2 Turn Down Ratio (TDR)

The Turn Down Ratio of a stove represents the degree to which the stove’s output can be controlled by the user. In this case, the Fire Power was controlled by removing sticks from the fire. The TDR is arrived at by dividing the Fire Power during the Boil phase by the Fire Power during the Simmer phase. A stove with a high Turn Down Ratio is generally considered likely to save more fuel than one with a low TDR.

As can be seen in the chart ‘Average Turn Down Ratio’, Stoves #1 and #2 considerably outperformed Stoves #3 and #4, with #2 having a very high TDR indeed. Stove #2’s strong performance in the Simmer phase may in part be due the use of a conical shaped pot, specially designed for steaming, which restricts the escape of steam. This pot was used as it was the only one that was close in size to the pot hole and would hold 5 litres. However, since the pot was smaller than the pot hole, some fuel energy escaped through the gap. It is very difficult to quantify the exact effect of these two variables.

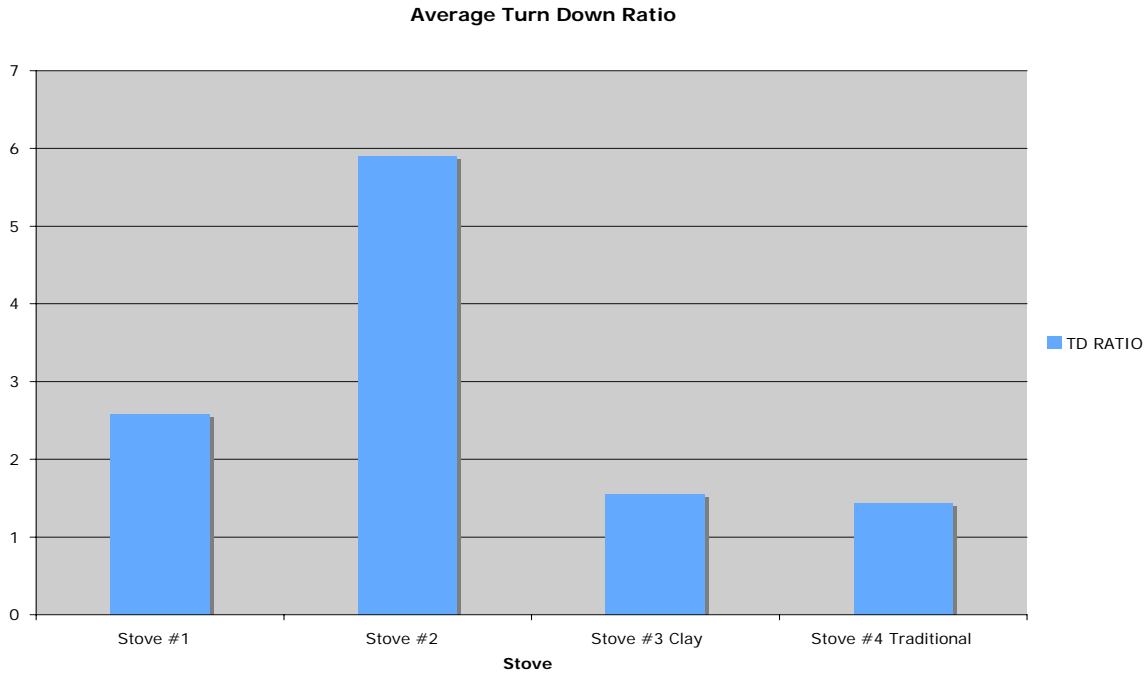


Chart 4 Average Turn Down Ratio of the stoves

6.3 Thermal Efficiency (TE)

As mentioned above, Thermal Efficiency, as an indicator of stove performance, must be looked at carefully, in order not to be swayed by a stove’s brute Fire Power and steam generating ability. Here is another word of advice from the Aprovecho Research Center, (slightly edited for the sake of space and comprehensibility):

Thermal Efficiency and Specific Consumption

“Examining two hypothetical examples points out the difference between “efficiency” and “specific consumption”. The task is to maintain 5 liters of 97 degree C water within 6° of the boiling point for 30 minutes. One of the stoves has a good turndown ability and is able to maintain the temperature of the water at 97°. The other stove lacks turndown ability and applies too much power which causes the water to reach a full boil and vaporizes lots of water. It is assumed that both stoves have equal fuel consumption per gram of water vaporized.

Stove 1

<i>Simmer time</i>	<i>30 minutes</i>
<i>Wood burned</i>	<i>250 grams</i>
<i>Water vaporized</i>	<i>500 grams</i>
<i>Water remaining</i>	<i>4.5 liters</i>

Stove 2

<i>Simmer time</i>	<i>30 minutes</i>
<i>Wood burned</i>	<i>750 grams</i>
<i>Water vaporized</i>	<i>1500 grams</i>
<i>Water remaining</i>	<i>3.5 liters</i>

Calculating “Efficiency” and “Specific Consumption” for the two stoves results in:

Efficiency of Stove 1 = 25.1%

Efficiency of Stove 2 = 25.6%

The “Efficiencies” of these two stoves are virtually identical and one would assume that there was very little difference between them. Examining the “Specific Consumptions” tells a very different story. Stove 1 would be the better choice since it uses ¼ as much wood as Stove 2 to produce the same output (liters of water which have been simmered for 30 minutes). Repeated testing at Aprovecho Research Center has shown that “Specific Consumption” is the more reliable measure of stove performance.”

From ‘Thermal Efficiency’ – Aprovecho Research Center

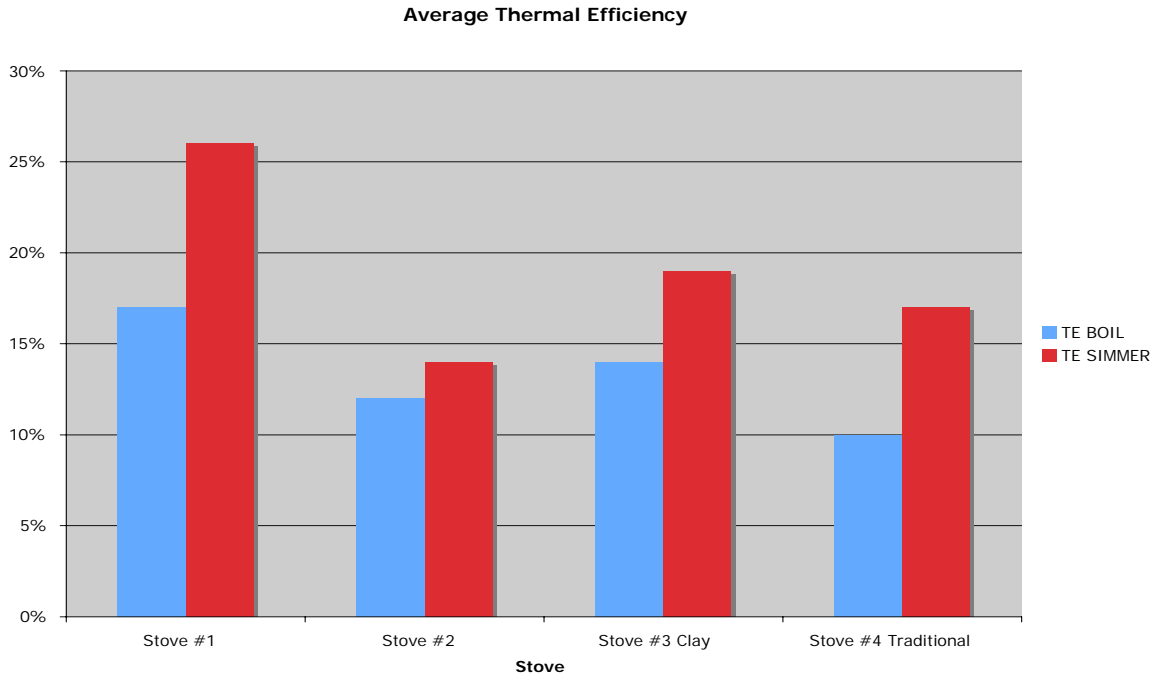


Chart 5 Average thermal efficiency of the stoves

The ‘Average Thermal Efficiency’ chart above confirms what the preceding charts illustrated, but with one notable exception. The above chart shows that Stove #3, made of clay, is somewhat more thermally efficient than the traditional stove #4. However, it also indicates that Stove #2 is less thermally efficient than the other three stoves. This is a surprise, as Charts 3 and 4 indicated that Stove #2 had the best performance characteristics of all four stoves. In Chart 5 Stove #2 is shown to have a lower thermal efficiency than the other improved stoves, but this is not the whole picture. As stated before, a simple percentage number representing Thermal Efficiency is not the best measure of stove performance. Stove #2 performed very well as measured by Specific Fuel Consumption during the Simmer phase and also demonstrated a high Turn Down Ratio. It performed less well during the Boil phase and this most likely pulled down its overall rating in the Thermal Efficiency calculations. The highest numbers for overall Thermal Efficiency are usually 25 to 35 %, with simmering efficiency always being higher than boiling. A TE of 15% can be acceptable depending on the stove design. Below 10% indicates a poorly performing stove. The thermal efficiencies indicated in the above chart fall roughly into the ranges that would have been expected.

Below is a table from a USAID Stove Evaluation Program in Uganda. Here we can see thermal efficiencies of 14 to 15% for the best performers to under 10% for the worst performers.

Thermal Efficiency					
Stove type	No. of tests	Cold start	Hot start	Simmering	Average
6-brick stove	8 tests, 4 stoves	13.6%	14.3%	15.4%	14.4%
Open fire	6 tests, 2 fires	13.7%	12.5%	15.5%	13.9%
Trad. mud stove	7 tests, 3 stoves	10.9%	9.3%	15.8%	12.0%
Trench stove	8 tests, 2 stoves	8.5%	10.1%	17.4%	12.0%
Lorena 2-pot	6 tests, 2 stoves	8.8%	7.5%	10.8%	9.0%
Lorena 2-pot	6 tests, 2 stoves	4.8%	4.5%	10.3%	6.5%
Note: Stoves are ranked by average efficiency over the three test phases.					

Table 1 USAID stove evaluation project Uganda –Average Stove Efficiencies from boiling tests

6.4 Fire Power

Fire power is how much heat a stove can develop.

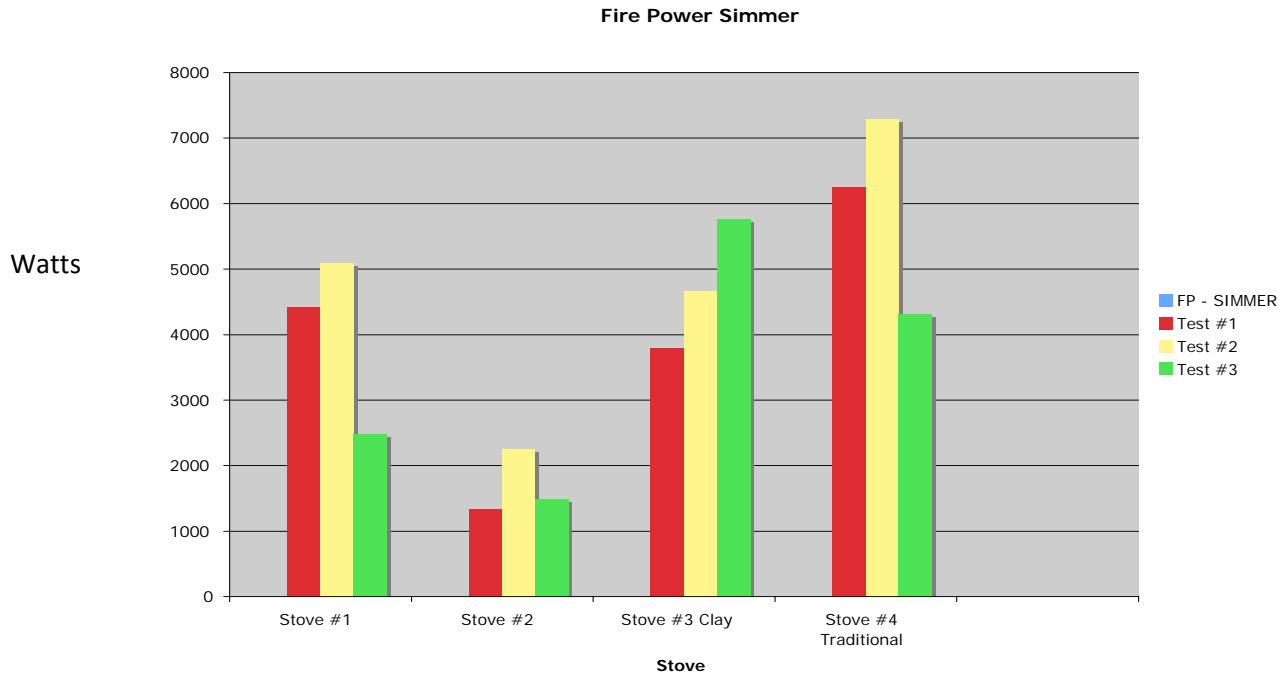


Chart 6 Fire Power of Stoves

As can be seen in the ‘Fire Power Simmer’ chart above , Stove #2 only needed an average of 1,700Watts to keep 5 litres of water at a simmer, whereas, Stove #4 needed nearly 6,000Watts to achieve the same task. In summary, High Turn Down Ratio = Lower Specific Consumption = Better Overall Performance.

6.5 Minutes to Boil

This metric falls into both Performance and User Satisfaction categories. In the ‘Minutes to Boil’ chart below we see a familiar pattern where Stoves #1 and #2 outperform Stove #3 and #4. The excessive time to boil in Test#1 for Stove #4 may be put down to operator inexperience.

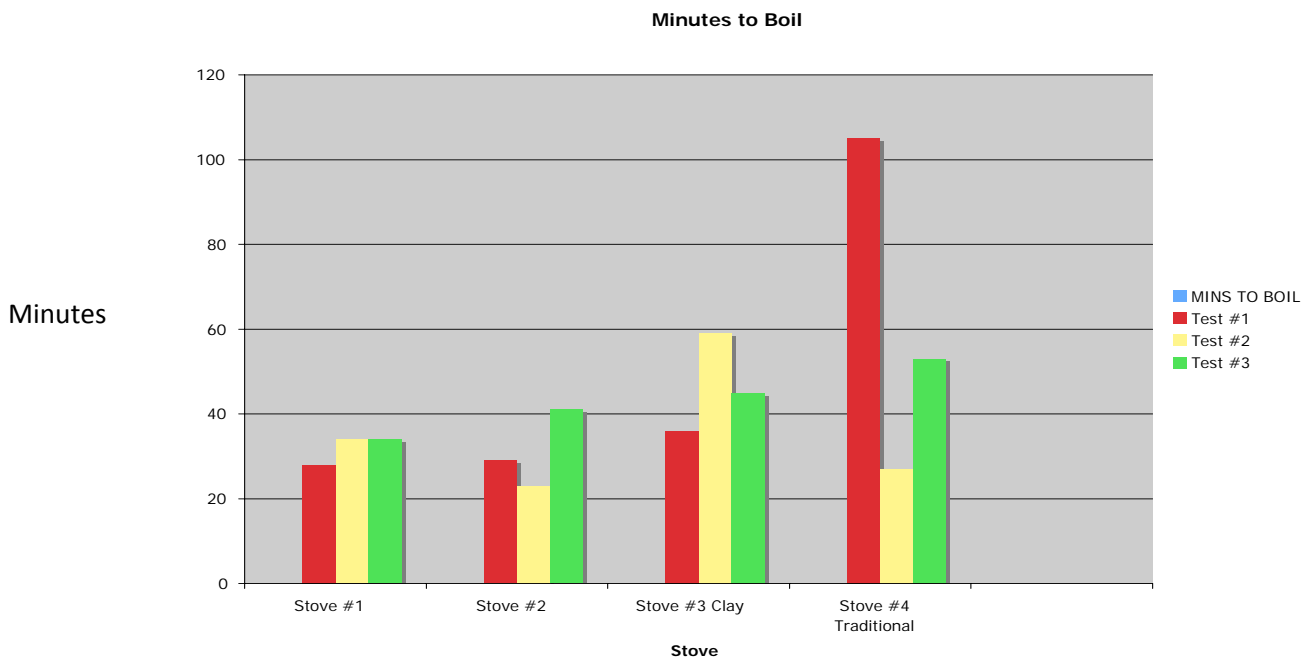


Chart 7 Minutes to Boil

6.6 Indoor Air Pollution

We took measurements of Particulate Matter (PM) and Carbon Monoxide (CO) levels with an Indoor Air Pollution meter while the WBTs were being conducted. The chart 'PM and CO readings Stove #1 Test #1' below, is an example of the data collected. The table 'PM and CO Concentrations' is a summary of the Average and Highest readings.

Unfortunately, not a great deal can be realistically deduced from this data. The variables are so many and so diverse that it would be foolhardy to draw any solid conclusions. The kitchens varied considerably in layout, amount of ventilation, proximity of ventilation source to stove etc. Other factors include: large amounts of smoke being released when we took the burning sticks out of the stove to weigh them and one pot not fitting the pot hole and thus spewing smoke for the whole test (Stove #2). The improved stoves can be operated with fewer emissions than open fires, though it requires smaller sticks, more careful operation and extending the chimney above the roof. Unfortunately we were not able to operate the traditional stove inside a kitchen, for a direct comparison with the fixed stove.

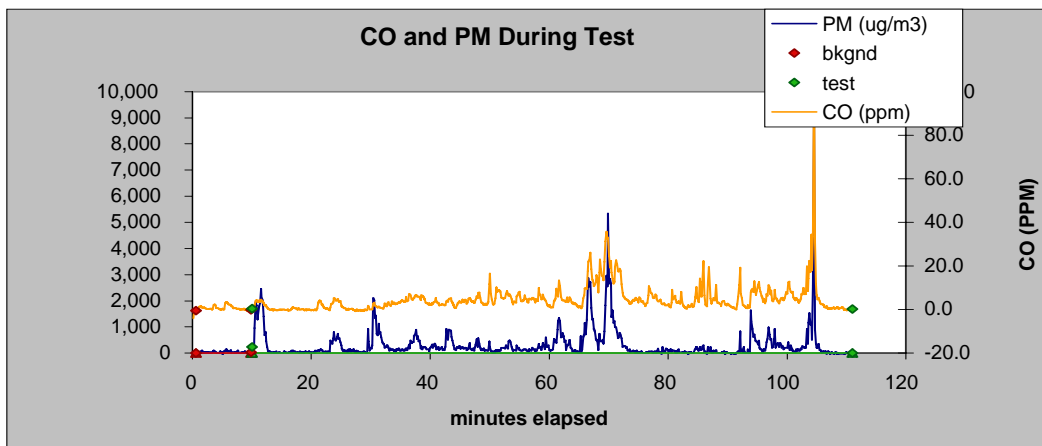


Chart 8 PM and CO readings Stove 1 Test 1

PM and CO readings Stove #1 Test #1

PM and CO Concentrations Table

	STOVE 1	STOVE 2	STOVE 3
FIRST TEST			
PM CONCENTRATIONS	ug/m3		
AVERAGE	318	63	163
HIGHEST	9,416	51,000	4,140
HIGHEST 15 MINUTES	777	2,967	416
CO CONCENTRATIONS	ppm		
AVERAGE	4.9	0.5	5.8
HIGHEST	111.1	74.3	29.1
HIGHEST 15 MINUTES	10.2	19.5	11
SECOND TEST			
PM CONCENTRATIONS	ug/m3		
AVERAGE	326	1,068	35
HIGHEST	8,180	25,170	8,520
HIGHEST 15 MINUTES	991	3,692	1,257
CO CONCENTRATIONS	ppm		
AVERAGE	3.9	12	0.4
HIGHEST	47.9	70	29.2
HIGHEST 15 MINUTES	9.5	20	10.5
THIRD TEST			
PM CONCENTRATIONS	ug/m3		
AVERAGE	540	32	11
HIGHEST	44,880	20,850	34,080
HIGHEST 15 MINUTES	1,467	956	505
CO CONCENTRATIONS	ppm		

AVERAGE	4.3	1	0.1
HIGHEST	53.6	52	19.8
HIGHEST 15 MINUTES	8.3	21	4.8

Table 2 PM and CO Concentrations Table

7. Observations

The senior consultant will include in this section observations and impressions formed about the Helvetas fixed stoves while working with them. I will also include comments, made to me by the users of the stoves.

- One of the primary benefits of the fixed improved stoves comes from the utilization of a chimney. The stoves produced considerable amounts of smoke when first lit and at certain times when adding new wood or when the wind direction changed direction. However, at other times it was possible to maintain a hot lively fire that produced very little smoke. This is much harder to do in a traditional open fire. None of the chimneys actually exited the kitchen. They went close to the roof, but not far enough to actually evacuate the smoke. Often, when the wind was in the wrong direction, smoke poured back into the kitchen.
- The fact that the fixed stoves are of high mass actually helps them perform better when the stove is fully warmed up. The heat retained in the bricks helps keep the fire temperature up and aids in complete combustion of the volatile gases. However, it takes a considerable amount of fuel wood to get the stove up this temperature. On one occasion I measured 100 degree C on the surface of the bricks and 70 degrees C on the concrete top. This was after the stove had been used to heat pig food.
- The Helvetas fixed improved stoves,(especially Stove #3, made of clay), are somewhat similar to the Lorena stove, pioneered by Aprovecho in Central America in the 1980's. While initialed hailed as an improvement on the traditional stove and popular because of the use of a chimney, they were later found to perform poorly as regards fuel consumption, as much of the heat was being absorbed the high mass of the stove body. The Helvetas stove design suffers from this same fault. When starting the stove cold in the morning, a disproportionate amount of heat is lost the massive stove body and is unavailable to do the cooking task.
- In the homes of Huang Paw, Stove #2 and the village leader, Stove #3, there was a traditional tree-legged stove right next to the improved stove. The ashes in these traditional stoves were always warm and the stoves were obviously still in use. Mr Huang Paw said he only used the fixed stove for pig food and all other meals were cooked on the traditional stove.
- Most of the wood used in the test had only been dried for about one month and was not considered "very dry" by the villagers. Since the forests immediately next to the village is protected, most of the fuel wood is gather from areas up to 2 hours away by foot. Although wood is plentiful, gathering it and transporting it represents a considerable investment of time

and energy. Villagers said that the fixed improved stoves did burn less wood than the traditional stoves. However, they did not provide any heat in the winter, which the traditional stoves did.

- The bricks in Stoves #1 and #2 seem to be holding up well to the thermal cycling they have received in the last 6 months. The clay in Stove #3 is showing signs of deterioration. There is a large crack in the wall of each combustion chamber and some pitting of the clay around the mouth of the combustion chamber, where the wood is introduced.
- My impression is that the villagers tend to use the stoves in the same manner that they have used the traditional stoves in the past. That is, they load the combustion chamber with overly large pieces of wood and allow them to smolder, rather than burn brightly and efficiently.

8. Conclusions

The Helvetas fixed improved cook stoves do represent an improvement over the traditional three-legged stove in several areas, particularly Specific Fuel Consumption and Turn Down Ratio. However, it is difficult, and certainly misleading, to give one number to represent the improvement, especially on the basis of so few tests, under less than ideal conditions. These stoves differ significantly from the traditional three-legged stoves, particularly in the user techniques necessary to get the best performance. If these stoves are used in a manner similar to the traditional stove, that is, larger pieces of wood left to smolder, then performance may not be much better than a traditional stove. It should be remembered that an open fire can be managed to produce a high level of performance, but it rarely is. Where shortage of fuel wood is not an issue, there is much less incentive to manage a fire for maximum efficiency.

These stoves do represent a step forward, particularly as regards indoor air quality, however, considerable design modifications and improved user techniques will be required to significantly increase their ability to save fuel. The trend in stove design nowadays is away from high mass bodies, like the Helvetas fixed stove, and more towards low mass, highly insulated stoves.

Improvements of Helvetas stove include:

- Less fuel consumed for a given cooking task
- Greater ability to adjust the power output of the stove
- Improved indoor air quality due to chimney
- Encouragement to use small pieces of wood due to restricted size of the combustion chamber opening
- Potential for more complete combustion of gases when smaller sticks are used and the stove is thoroughly warmed up

Recommendations

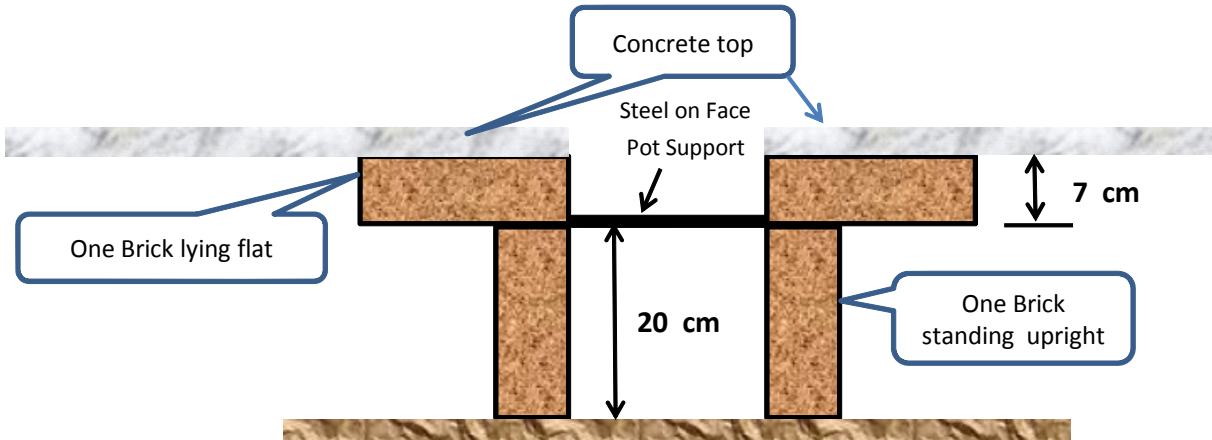
- To improve fuel savings and reduce indoor air pollution yet further, wood should be split into smaller sizes, with 2 or 3 cm x 2 or 3 cm being an ideal size. Many wood piles I observed in the village had sticks of these dimensions or slightly larger. But I also saw large pieces of wood being fed into stoves that could never burn efficiently.
- The fixed improved stoves should have small metal fuel shelves, about 3 to 5cm tall, that the sticks are placed on, leaving an open space below where air enters and is preheated as it passes through the coals. The shelf extends into the stove only as far as the outside edge of the pot hole. That encourages only the tips of the sticks to burn and create a hot lively fire. The tips char and drop off to create a bed of coals through which air passes and is warmed to sustain higher combustion temperatures (see Annex 2 for details). See Design Principle 9 in "Cooking with Less Fuel".
- The height of the combustion chamber should be increased by at least 50% (half a brick or about 10cm). At present, the flames from the fire touch the bottom of the pot which is not the best situation. Ideally, the complete combustion of the wood gases should take place below the pot, not round about it. The flames should not touch the pot. The distance between the fuel shelf and pot should be around 15 to 20cm (see Annex 1 for details)
- The present chimneys, 8cm diameter, are too small. These should be increased to at least 16cm or 20cm. This larger diameter will create a stronger draught and allow a larger volume of air to pass through the stove. Both these factors will tend to create a hotter, more lively fire, which is cleaner and more efficient. The larger chimney will be even more necessary when more than one combustion chamber is in use.
- The chimneys must exit the building and clear the roof by at least 25cm. That way the smoke is entirely evacuated by creating better draught and is unlikely to blow back in again when the wind direction changes.
- In the stoves made from construction bricks, the spaces between the combustion chambers is filled with concrete or mud, thereby increasing the uninsulated mass of the stove. In the future these spaces should be filled with a light insulative material such as pumice, wood ash or black char, made from rice husks, (that are charred rather than burned).
- In stoves made from pure clay, an insulative material such as rice husks or sawdust should be mixed with the clay. This material will burn out during the use of the stove, especially near the combustion chambers, leaving small pockets of air which will help insulate the combustion chambers. Care should be taken to get the proportions correct, as too much insulative material will weaken the mix and make the clay subject to damage from abrasion.
- The users of the stoves should be thoroughly instructed in the techniques for operating the new stoves and how they differ from the techniques of operating open fires. The reasons for and advantages of these new techniques should be explained in detail.

Instructions should include:

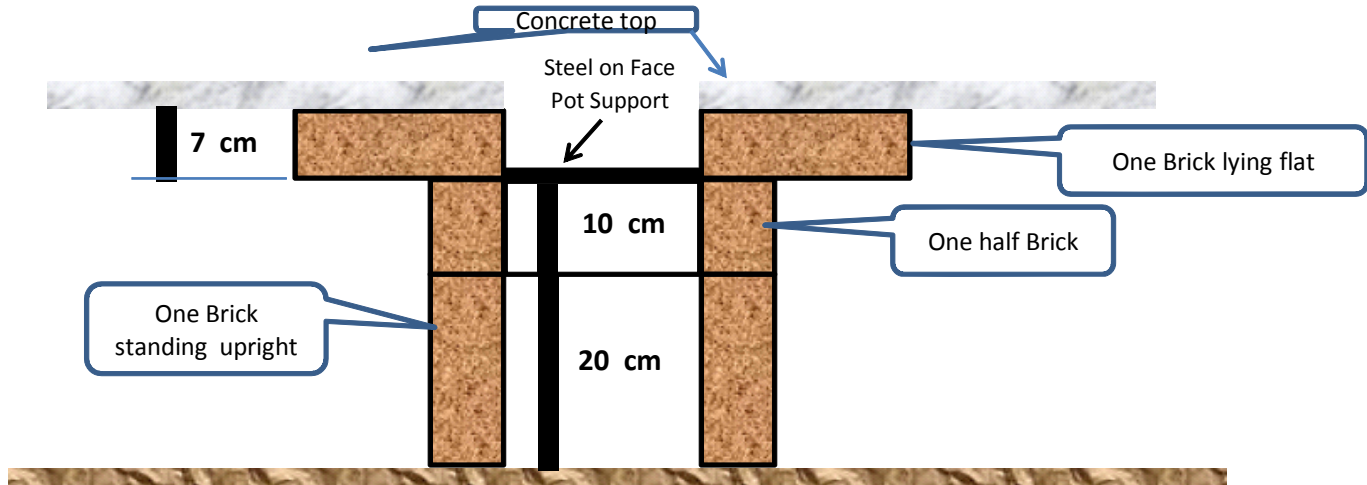
1. Chopping and splitting fuel sticks to a size of approximately 2 or 3cm by 2 or 3cm. After chopping, the sticks should be dried for at least another week. Large sticks and unsplit branches should not be used, nor left to smolder. Fires should be bright and lively.
 2. How to use the fuel shelf to burn only the tips of the sticks, charring them and creating a bed of coals, through which air passes, is pre-heated and maintains higher temperatures in the combustion chamber.
 3. The combustion chambers and the channels between them should be cleaned of ashes before each use of the stove.
 4. Pots should be cleaned of the heavy carbon build-up on the bottom. After a while this becomes so thick that it begins to insulate the pot from the heat. This is caused by the flame actually touching the bottom of the pot.
- There should be several follow-up visits to assess the incorporation of this information and practice into daily use of the stoves.
 - To more accurately quantify the fuel saving potential of these improved stoves Controlled Cooking Tests and Kitchen Performance Tests should be undertaken. A summary of these tests can be found above and in the Aprovecho Power Point presentation called "Stove Performance Testing" given in Vientiane. Yet more details can be found at <http://www.aprovecho.org/lab/pubs/testing>.

Annex 1: Suggested improvement for the combustion chamber

Current situation



Recommended Taller Combustion Chamber







Annex 2: Suggested fuel shelf for improved combustion

Fuel Shelf For Helvetas Stove

