Project No. **833**

Title

Rural Energy Development Project

TASK C

Date **October 2003**

Prepared for **EREDPC**

Rural Energy Development Project

Task C: Improved rural woodstoves

Colophon

Author: Piet Visser

BTG biomass technology group BV
c/o University of Twente
P.O.Box 217
7500 AE Enschede
The Netherlands
Tel. +31-53-4892897
Fax +31-53-4893116
www.btgworld.com
office@btgworld.com

TABLE OF CONTENTS

1 INTRODUCTION

In the framework of the "Rural Energy Development Project", three missions have taken place on task C: "Improved Rural Woodstove":
First mission from October 14 to November 9, 2002,
Second mission from February 12 to 24, 2003,
Third mission from October 13 to 31, 2003

Tasks for these missions, as formulated in the Inception Report, were:
- review past stove experiences and surveys
- develop several different improved stove models
- guide EREPDC staff to conduct laboratory tests and prototype field testing
- write TOR for the ceramic stove specialist
- organise field tests of a few units of micro-biogas
- write mission report concentrating on stove issues and testing procedures
- evaluate the field tests
- fine-tune stoves that are selected for larger-scale dissemination
- work with producers
- analyze the cost of cookingfor all stove alternatives
- draw up a large scale dissimination plan
- write a report with test results

Originally the second mission was scheduled for 4 weeks, but was reduced to two weeks, because of the non-availability of a ceramic s expert. Secondly the planned field tests had not been carried out. Consequently the TOR had to be adapted and following subjects have been addressed during the mission:
- analysis of water boiling-and kodcho baking tests results
- selection of stove model for field tests
- design and manufacture of mold for production of stoves for field tests
- operationalyse laboratory equipment

All the work was done in close collaboration with the "Household Energy Efficiency Improvement and Conservation Team" of the project, consisting of:

W/t Tsigereda Atnafu,	Team leader
Ato Iyob Tefara	Expert
Ato Telahun Andarge:	Expert
Ato Wossenu Areda:	Expert
Ato Tesfaye Abebe:	Expert

2 THE COOKING SYSTEM

A cookstove is part of a system, involving cooking habits, fuels used, pots and pans used, stoves used, social functions, stove production etc. Any new or improved stove must fit into this system in order to be disseminated successfully.
So the start of any stove development program must be an inventory of cooking habits, fuels used and stoves used.

In December 2001 and February 2002, the EREDPC carried out an assessment of the household energy end-use and cooking devices in the Amhara and SNNP regions[1)]. The results of this assessment will serve as the starting point of the work on rural cookstoves in the framework of the Rural Energy Development Project under the Energy II Programme.

To obtain a "life" impression of the rural household conditions, a field visit was made to a number of households around the city of Welkite, 160 km south-west from Addis Ababa.

In total 7 households were visited, of which 2 urban households in Welkite. The general picture that arises from the report as well as from the visits mentioned above, is described in the following paragraphs.
It is evident that the conditions in the region visited, are not representative for the whole of Ethiopia, only for the region concerned. But the approach to the problem is general and can (and must) be repeated in other areas where introduction and dissemination of improved cooking and baking stoves is considered.

2.1 Staple Food

Kodcho:
flat bread, made of a flour prepared from the leaves and roots of the "false banana" plant. Kodcho is prepared on a shallow metal plate (metal mtad) of about 45 cm diameter (58 cm diameter has been observed).
Kita:
flat bread, made of corn flour, sometimes mixed with sorghum flour. Kita is prepared on the same metal mtad as kodcho.
Injera:
flat bread, made of "teff" flour. Injera is prepared on a flat ceramic plate (mtad) of about 60 cm diameter and about 1.5 cm thickness)

Kodcho and kita are the most important breads prepared, depending whether the soil is better suited for the culture of the false banana's or sorghum and corn. In the case teff is cultivated, this is most often sold on the market. The preparation of injera is limited to special occasions.
Watt:

[1)] Pre-Appraisal on the Type of Household Energy End-Use Device Used in the Amhara and SNNP Regions, Household Energy Efficiency Improvement and Conservation Project, Ethiopian Rural Energy Development and Promotion Center of the Ministry of Rural Development, April 2002.

is the sauce that these breads are eaten with, most often made of cabbage, but also of beans, peas or lentils, depending on the season. Meat sauce only figures on the menu on special occasions (feasts etc.).The watt is prepared in a ceramic pot or in an aluminium pan.

The breads are prepared about 2 times per week; the sauces are prepared (or reheated) twice a day.

Coffee is prepared on a ceramic stove

2.2 Stoves

In the first three tukuls, two fireplaces called "gergets" were present. A gerget is a big stationary mud plate of up to 80 cm diameter, placed at the floor level. At the outside there is a rim of about 4 cm height and 6 cm width. In the centre of the gerget is a hole of about 10 cm diameter and about 10 cm deep. This holes serves to conserve the glowing embers of the fire for the next day.
The first gerget is placed in the centre of the tukul and serves mainly social functions (light, heat, etc.). The second gerget is placed more to the back of the tukul and is used for cooking. To support the mtad or pot or pan over the fire, the gerget is equipped with three "gounziye": loose ceramic cylinders, closed at the top but for a small hole to facilitate to pick them up. The central gerget (see Figure 1) has two sets of gounziye, big ones and smaller ones. The big ones are only for decoration, the smaller ones are used for cooking. Therefore the second gerget only has a set of the smaller gounziye. These are about 15 cm in diameter and also about 15 cm in height. The gounziye are placed far apart on the gerget to accommodate the mtad, and much closer to accommodate the pot or pan.

Figure 1: Gerget with gounziye, pot and pan

Next to the gerget there is a ceramic wood stove. This stove is used for the preparation of the sauce when the gerget is in use for the baking of the bread. The stove has a cylindrical base with a conical fire chamber. The bottom of the fire chamber is closed, i.e. there is no grate. The fire chamber has three supports for the pots or pans.
A set of 3 gounziye costs about 8 Birr, and the clay stove about 10 Birr.

2.3 Fuels

Principle fuel is wood, collected during four to five hours/day. Mainly small branches and twigs, but also bigger branches that are split, like the split logs that are sold on the urban markets. Next to wood, agricultural residues like corn stalks and cobs, sorghum stalks and the like are used as cooking fuel. Finally cow dung is dried and used, but only when no other fuel is available. People are aware that dung is better used as fertiliser. Generally people do not buy their fuel.

2.4 Utensils

All households have a metal mtad, a shallow metallic disk of 45 to 58 cm diameter, used to bake kodcho or kita (see Figure 2). In most cases there is also a ceramic mtad.
Watt is prepared in a clay pot or an aluminium pan. Diameters vary around 22 cm. Clay pots are preferred for the taste they give to the food, aluminium pans are appreciated because they are quicker and more durable, but the watt is less tasty (risk of burning). Aluminium pots are much more expensive: a clay pot costs about 8 Birr, aluminium pan about 30 Birr.

Figure 2: Gerget, traditional gounziye with metal mtad

2.5 General

Rural households own two to six cows. Dung is collected and mainly used as fertiliser, occasionally as fuel. This means basic conditions are fullfilled for micro-biogas installations.

3 STOVE TESTING

3.1 Stove Descriptions

Traditional gounziye

The traditional gounziye consist of three clay pots with a height and a diameter of about 15 cm. They are used as three stones to support the pan or the mtad. They are used with the open side on the floor and they have a hole in the top to facilitate picking them up (see Figure 2).

Improved ceramic gounziye, three sections

The improved ceramic gounziye consist of curved ceramic strips, together forming a full circle of 50 cm diameter. Height of the improved gounziye is 15 cm and their thickness is 10 cm at the bottom and 6 cm at the top. The improved gounziye are hollow. One of the three parts has an opening of 12 cm wide and 10 cm height, which serves as the door to feed fuelwood to the fire. Figure 3 shows the part with the door.

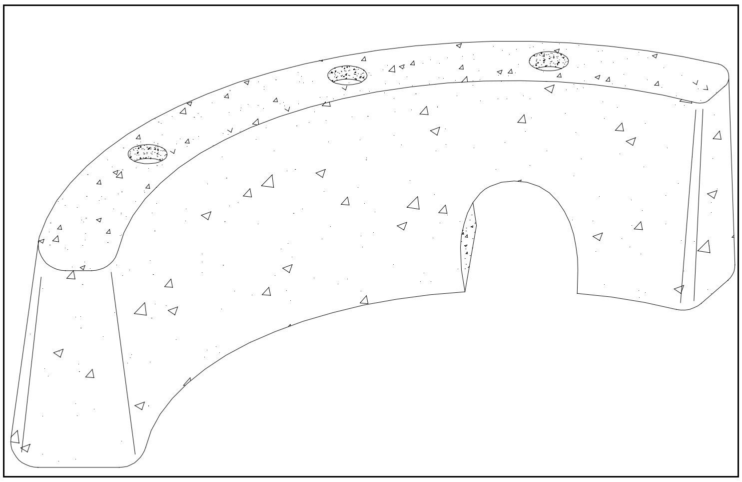


Figure 3: Improved gounziye

In their full circle form the improved gounziye serve to support the metal mtad. To support the much smaller pots and pans, the three elements can be placed in a triangular configuration (with the most of the parts sticking outside the triangle), as shown in Figure 4 and Figure 5

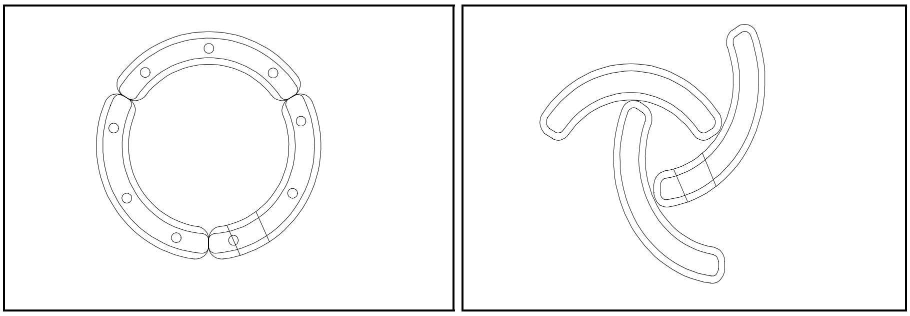


Figure 4: 3 sections gounziye in full circle and in configuration for pots and pans


Figure 5: Improved gounziye with pan

Figure 5 shows the 3 section improved gounziye with the aluminium pan.

Improved ceramic gounziye, three sections with low pan supports
This set of gounziye is the same as the 3 sections improved ceramic gounziye, but with pan supports at the inside of the gounziye at 10 cm from the bottom. The result is that the pan/pot is closer to the fire and that the pan/pot is partly shielded by the gounziye.

Improved ceramic gounziye, four sections
In the same way the full circle can be divided in three sections, it can be divided in four sections, resulting in four improved gounziye. The pieces of the 4-section gounziye are smaller, easier to handle and fit better to the gerget.
For all of the gounziye the full circle, measured on the inside, is 50 cm, and the wall height is 16 cm. The door is 16 cm wide by 11 cm high. The upper supports for the mtad, if present, are 1.5 cm high and the inside pan supports are 12 cm high.
In some of the later experiments, the height of the inside pan supports was reduced to 10 cm.
For bread baking (kodcho, kita, injera) all four sections are used, for watt cooking with a pot or pan only three sections are used. In that case the pan sits for a couple of centimeters in the gounziye, as shown in Figure 6


Figure 6: 4 Section gounziye with pan

4 Section gounziye without door

These gounziye are shown inFigure 7. Because the fuel door represents a weak spot, a set of gounziye was made without door. An opening to feed the fuel to the stove was created by leaving some space between two sections. These gounziye are equipped with top supports for the mtad and pan support on the inside wall.


Figure 7: 4 Section gounziye without door

4 Section gounziye with smoke outlet

These gounziye are shown in.Figure 8 These gounziye have a fuel door but no upper supports for the mtad. Instead there is one section with a smoke outlet. There are pan supports on the inside walls.


Figure 8: 4Section Gounziye with smoke outlet

4 Section Gounziye with door and supports for the mtad

These gounziye are shown in.Figure 9 These gounziye have a door, upper supports for the mtad and inside supports for the pan.


Figure 9: 4 Section Gounziye with support for mtad

Aluminium gounziye

The design of the aluminium gounziye is exactly the same as for the 3 section ceramic gounziye. Figure 10 shows the design drawing.

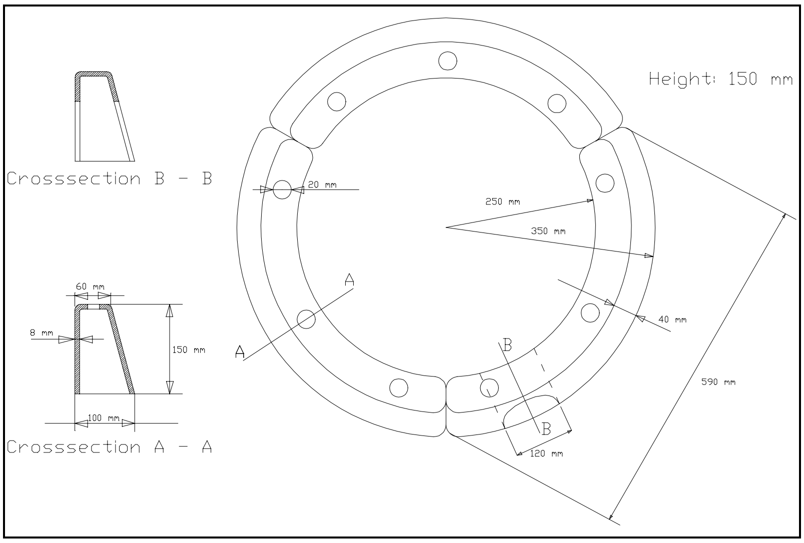


Figure 10: Design drawing aluminium gounziye

Traditional woodstove

The traditional woodstove can be seen in Figure 11. It consists of a nearly cylindrical base with a conical combustion chamber. There is no grate and three supports serve to hold the pan or pot above the fire.

Figure 11: Gerget with traditional woodstoves

Improved woodstove

No special improved woodstove has been developed, because the improved gounziye also fulfil this function. Household should be equipped with two sets of improved gounziye, allowing a large flexibility in the use of the improved gounziye for cooking as well as for bread baking.

3.2 Utensils

Aluminium pans

Deep-drawn sheet aluminium pans have been used with a diameter of 220 mm and a height of 100 mm. Pans were filled with 2500 g of water as initial amount

Ceramic pots

In the tests ceramic pots have been used with an outside diameter of 220 mm and an effective height of 200 mm. These pots are identical to the spherical pots used in the rural areas except for the top part; the pots used have a kind of neck, making them higher than the rural pots. The ceramic pots are filled with an initial amount of 3000 g of water.
These pots had to be used, because the rural pots as used around Welkite, were not available in Addis.

Metal mtads

Two nearly identical steelsheet metads have been used for the bread baking tests. One had an outside diameter of 5850 mm, the other 5450 mm. The steelsheet is recuperated from old oildrums. These mtads are not flat, but have a shallow form, with a depth of about 40 mm in the centre.

Aluminium mtad

An aluminium mtad was made using a clay mtad as mould. Only modification was the reduced thickness of the mtad. While the ceramic mtad has a thickness of 15 to 20 mm, the cast aluminium mtad has a thickness of about 10 to 15 mm. The weight of the original clay mtad is around 5.5 kg, the cast aluminium mtad weighs 7 kg. The aluminium mtad was made by the Federal Micro and Small Enterprises Development Agency (FMSEDA) in Addis Ababa.

Aluminium pots

Cast aluminium pots have been ordered from Mali to be tested after arrival, but unfortunately these pots have never arrived and, consequently, they have not been used.in the tests. These pots are spherical cast aluminium pots with a diameter of about 26 cm and a height of about 24 cm. Wall thickness is about 4 mm.

3.3 Testing Procedure

Two types of test have been used, the water boiling tests and bread (kodcho) baking tests.

3.3.1 Waterboiling Tests

In the water boiling tests a pan of water is brought to the boil and kept boiling for 30 minutes, followed by a simmering period of 60 minutes. The goal of the test is to establish the most important stove characteristics. These are:

- the maximum power of the stove, Pmax (kW)
- the efficiency at maximum power, Emax (%)
- the minimum power of the stove, Pmin (kW)
- the efficiency at minimum power, Emin (%)

So the test consists of a high power and a low power phase. At high power all fuel controls are fully opened. At low power, the fuel controls are closed to such an extent that the water temperature just is maintained at 100 C.
Readings of the relevant weights, temperatures and time are taken at the beginning of the test, at the beginning of the low power phase and at the end of the test. Each test is

repeated three times and the results are averaged. The data gathered in the test is processed in a spreadsheet, to calculate power and efficiency for the high power and the low power phase of the test.

3.3.2 Kodcho Baking Tests

During the baking tests the bread is baked on the metal mtad. The amount of dough is recorded as well as the weight of the baked bread, the weight of the fuel used and the elapsed time. Three kodcho's have been baked per test.
Results are expressed in the form of a specific fuel consumption, grams of fuelwood used per gram of baked bread: SFC (g/g) and in the form of specific energy consumption, SEC (kJ/g). The latter figure is useful when fuel consumption figures for different fuels must be compared.

3.3.3 Fuel Consumption Calculations

The fuel consumption calculation is based on the assumption that during the preparation of a meal, the stove operates according to a defined power regime, starting with a period of high power followed by a period of low power or simmering.
The high power is needed to bring the content of the pan to boiling point and the duration of the high power period depends on the kind and quantity of food. The necessary heat input to the pan can be determined from the quantity of the food and water in the pan and the specific heats of the ingredients. Then the duration of the high power period can be calculated using the Pmax and Emax determined in the water boiling tests.
The low power or simmering period only depends on the kind of food. Food needs to be kept at boiling point for some time in order to become edible. The only function of the stove during this period is to maintain boiling temperature or, in other words, to compensate the heat losses from the pan. Because these heat losses are small, Pmin only needs to be small. A high Pmin results in unnecessary fuel consumption and unnecessary evaporation of water. Of course the effect of Pmin on the fuel consumption is stronger as the simmering times are longer.
The fuel consumption that results from the calculations is a measure for the minimum fuel consumption that a cook can achieve. In practice fuel consumption will be higher. But the calculation results offer a good basis for stove comparison, because the results are independent of the external influences that effect the controlled cooking tests.
Fuel consumption is expressed in grams of wood and in energy. The latter enables comparison between different fuels.

3.4 Test Equipment

The fuel consumption calculation is based on the assumption that during the preparation of a meal, the stove operates according to a defined power regime, starting with a period of high power followed by a period of low power or simmering.
The high power is needed to bring the content of the pan to boiling point and the duration of the high power period depends on the kind and quantity of food. The necessary heat input to the pan can be determined from the quantity of the food and water in the pan and the specific heats of the ingredients. Then the duration of the high power period can be calculated using the Pmax and Emax determined in the water boiling tests.
The low power or simmering period only depends on the kind of food. Food needs to be kept at boiling point for some time in order to become edible. The only function of the

stove during this period is to maintain boiling temperature or, in other words, to compensate the heat losses from the pan. Because these heat losses are small, Pmin only needs to be small. A high Pmin results in unnecessary fuel consumption and unnecessary evaporation of water. Of course the effect of Pmin on the fuel consumption is stronger as the simmering times are longer.

The fuel consumption that results from the calculations is a measure for the minimum fuel consumption that a cook can achieve. In practice fuel consumption will be higher. But the calculation results offer a good basis for stove comparison, because the results are independent of the external influences that effect the controlled cooking tests.

Fuel consumption is expressed in grams of wood and in energy. The latter enables comparison between different fuels.

3.5 Test Results

3.5.1 Waterboiling Tests

The results of the waterboiling tests are shown inTable 1.

Table 1: Results of waterboiling tests

Stove type	Pmax (kW)	Emax (%)	Pmin (kW)	Emin (%)
Trad. gounziye,.clay pot	5.8	11	3.4	14
Trad. gounziye, al. pan	5.0	15	1.8	13
3- Section gounziye, supports for mtad, 10 cm pan supports., clay pot	3.4	18	2.5	22
3- Section gounziye, supports for mtad, 10 cm pan supports. al. pan	2.0	30	1.4	26
4- Section gounziye, without door, supp. for mtad, 12 cm pan supp., al.pan	3.5	20	1.9	22
4- Section gounziye with smoke outlet, 12 cm pan supp., al.pan	2.6	25	1.8	24
4- Section gounziye, supports for mtad, 12 cm pan supports. al. pan	2.8	25	1.6	28
4- Section gounziye, supports for mtad, 10 cm pan supports. al. pan	2.3	27	1.3	29

In all tests the improved gounziye perform much better than the traditional gounziye. The 4- section gounziye with out door and the 4- section with the smoke outlet show performances that are somewhat inferior to the other gounziye (lower Emax and higher Pmin). The 12 cm pan supports are not at the optimal height, the gounziye with 10 cm pan supports perform better. The performance of the 4- section gounziye with door and 10 cm pan supports is nearly equal to the performance of the 3 section gounziye with the same specifications, as was to be expected, with a Pmax of 2 to 2.3 kW, Emax.of 30 to 27%, Pmin of 1.4 to 1.3 kW and Emin of 26 to 29 %. The fact that the performance of the 4- section gounziye is consequently slightly lower than the 3-section gounziye can be explained by the bigger door of the 4-section gounziye. This was done on request of the cook, but for the gounziye to be dissiminated, the door size should be reduced to the original dimensions of 12 * 10 cm with rounded of corners.

3.5.2 Kodcho and Kita Baking Tests

The results of the kodcho baking tests are shown in Table 2.
No baking tests have been done on the 4- section gounziye without door, because of the relatively poor results in the waterboiling tests.
Table 2 presents the results in terms of specific fuel consumption, expressed as grams of fuelwood consumed per gram of baked kodcho. On the traditional gounziye two kodcho baking tests have been done, on the 3- section gounziye only one and on the 4- section gounziye four kodcho baking tests. The results of the tests show a rather wide spread and to facilitate the analysis, the different columns of Table 2 presents the results in different ways. In the first column the minimum consumption of all the tests is given. In column two the average of two tests is noted and in the third column the average of four tests. In the last column the average of the best three tests is given, leaving out the test with the highest fuel consumption.
Next to the specific fuel consumption Table 2 presents the fuel savings in percents compared to the traditional gounziye. Here the average value of the two kodcho baking tests on the traditional gounziye of 0.159 g/g is taken as the reference value.

Table 2: Results of kodcho baking tests

	Specific fuel consumption and fuel savings							
	min		Avg. 2 tests		Avg. 4 tests		Avg. 3 tests	
Stove type	(g/g)	(%)	(g/g)	(%)	(g/g)	(%)	(g/g)	(%)
Traditional gounziye	0.144		0.159	0				
3- Section gounziye, with support for mtad	0.127	20						
4- Section gounziye with smoke outle	0.115	28			0.149	6	0.135	15
4- Section gounziye, with door and support for mtad	0.134	16			0.142	11	0.139	13

As said previously, the spread in the results makes it difficult to draw an unambiguous conclusion. On the average the conclusion that the improved gounziye can save 20% of fuel is justified, while 25% is possible.
In the use of the gounziye with smoke outlet the smoke emissions were significantly higher than with the gounziye with upper supports for the mtad. With the upper supports the aeration of the fire is better and more uniform. Therefore the final model of improved gounziye should have upper supports and no smoke outlet.

The spread in the results is due to the user of the stove (the cook) and not to the design as such, and with controlled cooking tests this effect is much more influential as with waterboling test. This once more stresses the point that in dissemination campaigns of improved stoves the formation of the users of the improved stoves is of the utmost importance.

3.5.3 Fuel Consumption Calculations

Fuel consumption calculations have been done on two levels. First the fuel consumption has been calculated for the preparation of shiro watt and meat watt. Secondly the weekly fuel consumption for an average family is estimated, combining the results of the watt preparation calculations and the kodcho baking tests.

3.5.3.1 Watt preparation calculations.

The results of the watt preparation fuel consumption calculations are presented in Table 3

Table 3: Results of watt preparation calculations

Stove	Consumption		Savings versus	
	Fuel (g)	Energy (MJ)	Trad.+clay (%)	Trad.+Al (%)
Trad. gounziye,.clay pot	3162	25296	0	- 46
Trad. gounziye, al. pan	2159	17271	32	0
3- Section gounziye, supports for mtad, 10 cm pan supports., clay pot	2085	16681	34	3
3- Section gounziye, supports for mtad, 10 cm pan supports. al. pan	1195	9560	62	45
4- Section gounziye, without door, supp. for mtad, 12 cm pan supp., al.pan	1784	14274	44	17
4- Section gounziye with smoke outlet, 12 cm pan supp., al.pan	1507	12052	52	30
4- Section gounziye, supports for mtad, 12 cm pan supports. al. pan	1467	11740	54	32
4- Section gounziye, supports for mtad, 10 cm pan supports. al. pan	1216	9727	62	44

3.5.3.2 Family fuel consumption

Using the above reported results, the weekly fuel consumption for an average family is estimated. For these calculations the following assumptions have been used:

- average family size: 5.1 persons (1995 census)
- watt cooking 2 times per day
- shiro watt cooking 1 time per week
- meat watt cooking 13 times per week
- kodcho baking 3 times per week, 3 kodcho per session
- weight of one kodcho: 2000 g
- fuelwood price: 0.35 Birr/kg

The results will be presented in three sets.
In the first set the traditional gounziye are the reference base, using the traditional clay pot for watt cooking. Comparison is made to the improved gounziye using an aluminium pan. Results are presented in Table 4.
In the second set the traditional gounziye again are the reference base, but this time the aluminium pan is used for watt cooking. Comparison is made to the improved gounziye also using an aluminium pan. These results are presented in Table 5.
In the third set of results the traditional gounziye are the reference base, using the traditional clay pot for watt cooking. Comparison is made to the improved gounziye using the clay pot. Results are presented in Table 6.

In each set the results are presented as percentages of fuel savings, using the outcome of the single kodcho baking test on the 3- section gounziye and the average of 4 kodcho baking tests, the average of the three best kodcho baking test and the best kodcho baking test on the 4- section gounziye. The fuel consumptions for the preparation of the watt are the same for the respective stoves in all cases.

Table 4: First set of fuel consumption comparisons

First set, comparison to Traditional gounziye using the clay pot for watt preparation and watt preparation on improved gounziye with aluminium pan										
Results based on average of four kodcho baking tests for 4- section, one kodcho baking test for 3 section										
	Results tests and calculations			Weekly consumption				Weekly savings		
Stove	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Total (g)	(g)	(%)	(Birr)
Traditional gounziye clay pot	1783	1397	318	1783	17926	955	20664	0	**0**	0.0
Traditional gounziye alu pan	1179	980	318	1179	12739	955	14873	5791	**28**	2.0
3 Section 10 cm	679	516	254	679	6712	761	8152	12512	**61**	4.4
4 Section smoke outlet 12 cm	860	647	298	860	8409	895	10165	10500	**51**	3.7
4 Section supports 12 cm	826	642	285	826	8342	854	10022	10643	**52**	3.7
4 Section 10cm	680	536	285	680	6973	854	8506	12158	**59**	4.3
Results based on average 3 kodcho baking tests for 4 section, 1 kodcho baking test for 3 section										
	Results tests and calculations			Weekly consumption				Weekly savings		
Stove	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Total (g)	(g)	(%)	(Birr)
Traditional gounziye clay pot	1783	1397	318	1783	17926	955	20664	0	**0**	0.0
Traditional gounziye alu pan	1179	980	318	1179	12739	955	14873	5791	**28**	2.0
3 Section 10 cm	679	516	254	679	6712	761	8152	12512	**61**	4.4
4 Section smoke outlet 12 cm	860	647	270	860	8409	810	10079	10586	**51**	3.7
4 Section supports 12 cm	826	642	278	826	8342	835	10002	10662	**52**	3.7
4 Section 10cm	680	536	278	680	6973	835	8487	12178	**59**	4.3
Results based on best kodcho baking tests for 4 section, 1 kodcho baking test for 3 section										
	Results tests and calculations			Weekly consumption				Weekly savings		
Stove	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Total (g)	(g)	(%)	(Birr)
Traditional gounziye clay pot	1783	1397	318	1783	17926	955	20664	0	**0**	0.0
Traditional gounziye alu pan	1179	980	318	1179	12739	955	14873	2050	**28**	2.0
3 Section 10 cm	679	516	254	679	6712	761	8152	4555	**61**	4.4
4 Section smoke outlet 12 cm	860	647	230	860	8409	691	9960	3960	**52**	3.7
4 Section supports 12 cm	826	642	268	826	8342	805	9973	3882	**52**	3.7
4 Section 10cm	680	536	268	680	6973	805	8457	4418	**59**	4.3

Table 5: Second set of fuel consumption comparisons

Second set, comparison to Traditional gounziye using the aluminium pan for watt preparation and watt preparation on improved gounziye with aluminum pan										
Results based on average of four kodcho baking tests for 4- section, one kodcho baking test for 3-section										
	Results tests and calculations			Weekly consumption				Weekly savings		
Stove	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Total (g)	(g)	(%)	(Birr)
Traditional gounziye	1179	980	318	1179	12739	955	14873	0	**0%**	0.0
3 Section 10 cm	679	516	254	679	6712	761	8152	6721	**45**	2.4
4 Section smoke outlet 12 cm	860	647	298	860	8409	895	10165	4709	**32**	1.6
4 Section supports 12 cm	826	642	285	826	8342	854	10022	4852	**33**	1.7
4 Section 10cm	680	536	285	680	6973	854	8506	6367	**43**	2.2
Results based on average of three kodcho baking tests for 4- section, one kodcho baking tests for 3 – section										
	Results tests and calculations			Weekly consumption				Weekly savings		
Stove	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Total (g)	(g)	(%)	(Birr)
Traditional gounziye	1179	980	318	1179	12739	955	14873	0	**0**	0.0
3 Section 10 cm	679	516	254	679	6712	761	8152	6712	**45**	2.4
4 Section smoke outlet 12 cm	860	647	270	860	8409	810	10079	4795	**32**	1.7
4 Section supports 12 cm	826	642	278	826	8342	835	10002	4871	**33**	1.7
4 Section 10cm	680	536	278	680	6973	835	8487	6387	**43**	2.2
Results based on best kodcho baking test for 4- section, one kodcho baking test for 3- section										
	Results tests and calculations			Weekly consumption				Weekly avings		
Stove	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Total (g)	(g)	(%)	(Birr)
Traditional gounziye	1179	980	318	1179	12739	955	14873	0	**0**	0.0
3 Section 10 cm	679	516	254	679	6712	761	8152	6712	**45**	2.4
4 Section smoke outlet 12 cm	860	647	230	860	8409	691	9960	4914	**33**	1.7
4 Section supports 12 cm	826	642	268	826	8342	805	9973	4901	**33**	1.7
4 Section 10cm	680	536	268	680	6973	805	8457	6416	**43**	2.2

Table 6: Third set of fuel comsumption comparisons

Third set, comparison to Traditional gounziye using the clay pot for watt preparation and watt preparation on improved gounziye with clay pot											
Results based on one kodcho baking tests on 3- section improved gounziye with improvised support for the mtad											
	Results tests and calculations			Weekly consumption				Weekly savings			
Stove	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Meat watt (g)	Shiro watt (g)	Kodcho (g)	Total (g)	(g)	(%)	(Birr)
Traditional gounziye clay pot	1783	1379	318	1783	17926	955	20664	0	**0**	0.0
Imp. 3 section gounziye clay pot	1194	892	254	1194	11590	761	13545	7120	**34**	2.5

3.6 Conclusions

The results show umambiguously the saving potential of the Improved Gounziye, and also the saving potential of the use of aluminium pans. Only the shift from the traditional clay pots to aluminium pots can bring about fuel savings of over 25%. If at the same time Improved Gounziye are introduced, the savings can go up to over 50%.
In case the family has already made the change to the use of aluminium pans, the introduction of Improved Gounziye can help saving about 30 to 40% of fuel.
If the family is traditional and wants to keep on using the traditional clay pots, the introduction of the Improved Gounziye can also produce savings of over 30%.

In concrete terms of Birr saved, the savings vary from 4 Birr per week in case the shift to aluminium pans is made to around 2 Birr per week in case the traditional pots are continued to be used.

Here once more the saving potential of aluminium pots and/or pans must be underlined. The traditional clay pots are a disaster from an energy efficiency point of view.
The argument of the cooks against the use of aluminium pans is that with aluminum pans you cannot get the right taste for the watt. This may be true. The ceramic absorbs spices and flavours that may add to the taste of the sauce. Also the preparation of the sauce in the clay pot takes longer, which may help to develop more thet taste of the spices used. Finally the heat distribution to the food by a clay pot will be different and more even compared to the aluminium pan, where the heat input comes direct through the pan bottom.
The "taste" argument is wel known as was also heard in other African countries during household surveys. Yet in almost all of these countries -and in any case in all of the Sahel countries and Western Africa- households have since long made the shift to aluminium pots. In this case cast aluminium pots with a spherical shape that resemble the traditional ceramic pot, but offer all the advantages of the superiour thermal behaviour of aluminium. Because the wall thickness of cast aluminium is 3 to 4 mm, instead of the 0.8 to 1 mm of the sheet aluminium pans, their characteristic as cooking pot resembles more that of the ceramic pot than that of the sheet aluminium pan. There seems no reason why

the shift to cast aluminium, as it has taken place in many other countries, could not be realized in Ethiopia.

3.7 Results of Household Tests

To assess the reactions of rural households to the new Improved Gounziye, a household survey was conducted. Also the woodfuel consumption of the Improved Gounziye compared to the traditional Gounziye was monitored in a kitchen performance test. This work was executed by the stove team and the results from their report are summerized here[2)]

3.7.1 Household survey

The household survey was conducted in three Woredas (Cheha, Gummer, Abeshege), selected from the Gurage zone around Welkite, the same area where the original field visit, described in chapter 2, had taken place. In each Woreda a number of 100 households have been surveyed, totalling to 300 households.

The questionnaire was designed to collect information on the type of stove fuel used, the socio-economic condition and the cooking habits. From the data collected it appears that most of the households surveyed:

- use three stone open fire (gounziye) as their main cooking divice
- regularly bake kodcho
- use wood and BLT as their main and secondary fuel types
- prepare coffee like two to three times per day
- understand the problems of a three stone open fire
- need a cooking device that could reduce smoke and that is save

3.7.2 Kitchen performance and acceptability assessment

The kitchen performance and acceptability assessment was conducted on forty households, fifteen of them as a control group and twenty five as a test group. The test have been done during 25 days.

The Improved Gounziye showed a 25% fuel saving compared to the traditional ones and received good acceptance by the by almost all of the households. Comments given by the households concern the following points:

- enlarge the fuel opening
- add handles on each section for easier manipulation
- increase height of stove and pot support
- increase the strenght of the stove
- add outside support to increase stability when big pots are placed on it
- increase its aestetic appeal

All stove users have bought their improved stove at 3 Birr at the end of the test period (except for the stoves that were broken). On the average the households indicated they are willing to pay 10 to 15 birr for the Improved Gounziye when their comments are taken into account.

[2)] "Final Report on Improved Gounziye for the year 2003", by Eyob Tefara, Tilahun Andargie, Wossenu Areda and Tsigereda Atnafu, july 2003.

3.8 Economic analysis (money, time savings)

3.8.1 Money

The benefits of rural improved stoves are less straightforward than those of urban improved stoves. In urban areas, household purchase their fuels and the use of an improved stove immediately yields monetary savings. In fact, the incremental costs for purchasing an improved stove rather than a traditional stove can be compared to these financial benefits, and usually a very short payback time is found (on the order of 1-4 weeks). Additional benefits are normally more difficult to quantify and value: time savings, better controllability of the stove, perception of having a modern stove, etc.

Improved rural stoves replace traditional stoves that have often not been purchased but were self-made by the households. A financial payback time is difficult to estimate under these circumstances. The household tests that were performed showed a favorable feedback on the improved stove models developed by BTG, the 3 segment and the 4-segment improved Gounziye. After some 4 months, participating households were still using the improved stoves and indicated a willingness to pay as much as Birr 15 for such stoves, if certain modifications were realized. This in itself is a good indication that rural households are willing to invest in living condition improvements. The resulting benefits are, besides lower fuel consumption, a better controllable fire, food that might be cooked earlier, and more hygienic conditions in the kitchen.

The willingness to pay can be used as a proxy for the economic benefits. But also a classic cost-benefit analysis expressed in monetary terms has been carried out for the estimated weekly consumption, as was presented in Table 4 to Table 6. In concrete terms of Birr saved, the savings vary from 4 Birr per week in case the shift to aluminium pans is made to around 2 Birr per week in case the traditional pots are continued to be used. If the Improved Gounziye will be marketed for 15 Birr per set and the cost of the traditional Gounziye are 10 Birr, than the pay-back time varies from one to two and a half week.

3.8.2 Time

Next to the results of savings in terms of fuel and money, the test and calculations also produce results in terms of time savings. These savings represent mainly a comfort argument, because the savings are realised during the period when the content of the pot is coming to the boil, a period of time the cook normally has to be present near her stove to notice time of boiling. The simmering time as explained above, is a characteristic of the food and will not change with the stove.

Time savings with the improved Gounziye are only realized when the stove is used for cooking. For the baking of Kodcho, the advantage of the improved stove lies only in teh reduced fuelconsumption, because the baking time of the Kodcho are consistently 8 min per Kodcho. This is the time a Kdocho needs to get cooked and, like the simmering time for other foods, can not be reduced by the use of another stove[3)].

[3)] Under the assumption that the stove delivers the minimal power necessary to heat the kodcho to baking temperature.

The results show that with an improved Gounziye when used with an aluminium pan, boiling times can be reduced by 10% to 20%. The total time for watt preparation can be reduced by around 10%.

3.9 Prospects for large-scale adoption

Two sets of experiences on the Improved Gounziye exist now that allow to evaluate the prospects for their large scale dissimination. Both have been presented and discussed in the previous chapters, namely the the waterboiling tests and the consumer surveys.
The waterboiling tests have unambiguously shown the woodfuel saving potential of the Improved Gounziye, which can be of the order of 50% when at the same time the switch is made to the use of aluminium pans in stead of the traditional clay pots, and 25% when the households continue to use their traditional pots. These savings offer real good prospects for large scale dissimination, because the savings are substantial and will be noticed and appreciated by the users, wether they collect or buy their fuel. On top of these fuel savings, the Improved Gounziye save time.
The same level of fuel saving was recorded during the kitchen performance tests: 25% less fuel consumption only by the introduction of the Improved Gounziye. This confirms the results of the tests and calculations, and thus the potential for large scale dissimination.
Next to the confirmation of the fuel saving potential, the reactions of the participants of the kitchen performance tests concerning the Improved Gounziye are positive. All have bought their Improved Gounziye and indicated their readyness to buy a new set of Improved Gounziye at a price which is higher than that of the traditional gounziye (15 Birr in stead of 10 Birr). Obviously, for a succesfull dissimination, the remarks made by the users during the kitchen performance test must be taken into consideration. This is done in the Final model of the Improved Gounziye, as it is presented in this report, together with a number of other improvements as well (hollow in stead of massive etc.).

Finanlly, to embark on a succesfull dissimination program, the production side of the Improved Gounziye must be well organized, to assure a constant supply to the market of high quality Improved Gounziye. The best option to achieve this goal is to delegate the production to comercially operated dedicated production centers, equipped with moulds, presses and a fixed kiln for the firing of the products.

And last but not least, dissimination needs to be supported by a large scale formation and promotion campaign that is repeated (eventually on a less intensive scale as the first time) regularly.

The total number of rural and peri-urban households in Ethiopia can be estimated at 9.5 million. If we assume 50% will be reached by the dissimination program and of the housholds reached 30% will make the change to the Improved Gounziye, about 1.4 million (= 15%) households will posess and use an Improved Gounziye at the end of the dissimination program.

4 MANUFACTURE OF IMPROVED GOUNZIYE

4.1 Introduction

In the first days of the third mission a short field trip was made the Welkite aerea, where also potters were visited. From these visits the following picture arises.
The traditional Gounziye (the three clay pots), as are used now in thew rural aereas, are produced and marketed in a purely artisanal way. Clay and sand are collected, sometimes from far away, and brought to the potters workplace. There the preparation of the clay and the shaping of the products are done by hand. Firing is done in a small pit kiln, using some thin firewood and mainly dry grass as fuel. The products are transported to the market by potter herself and sold.
Pottery is a purely feminine business and the social status of the potters is low. Their husbands sometimes are also craftsmen (woodworkers, blacksmiths), sometimes farmers. In many cases potters do not own their own house, but rent one. Several potters work at one location and sometimes fire their products together, but in general there is no structural cooperation. Hardly any tools are used.
Potters tend to specialize in a certain product, also as a function of the available clay. At one site the potters made Gounziye, at another only coffee pots and at a third only bowls.
From the amount of products fired a weekly income of 25 Birr could be estimated. The price for the traditional Gounziye varies from 5 Birr for the small ones to 10 and 15 Birr for the bigger ones.

The potters visited have been involved in the production of the inproved Gounziye for the survey. Comments of the potters concerning the Improved Gounziye were:

- uses too much clay (the Gounziye made were solid)
- difficult to get out of the mould
- heavy and difficult to dry
- difficult to manipulate during firing, no handles

In general the opinion was that the production of the Improved Gounziye demands a lot of work, compared to the traditional ones.

4.2 Ceramic Improved Gounziye

The desing of the Improved Gounziye is based on the assumption of mass production with the use of moulds and tools in a small scale, but still semi-industrial way. The form of the Improved Gounziye, although not very complicated, is too complex to be made by hand.To achieve the potential fuel savings, the model should be produced in a constant high quality with fixed dimensions under low tolerances.

For the production of the Improved Gounziye for the survey moulds have been made for the outside shape. As a result the Gounziye used in the survey were massive and thus heavy. But from the first prototypes the intention was to make the Improved Gounziye hollow (the waterboiling tests have been done with hollow Gounziye) and this feature should be maintained. Given the remarks from the users and potters during the survey, these outside moulds have been redesigned. Main changes incorporated are:

- increased height from 15 to 16 cm
- widening of the base from 8 to 9 cm.

To assure the Improved Gounziye will be made hollow, a second mould has been designed for the inside shape. In the dimensions of the moulds a shrinkage percentage of 10% of the caly has been taken into account.
To speed up production and to facilitate the positioning of the inside mould to the outside mould, the moulds are equipped with guiding rods and a press has been designed and made. Figure 12 shows the assembly of press and moulds. For easy of handling the moulds are not fixed to the press, but can easily be taken of.

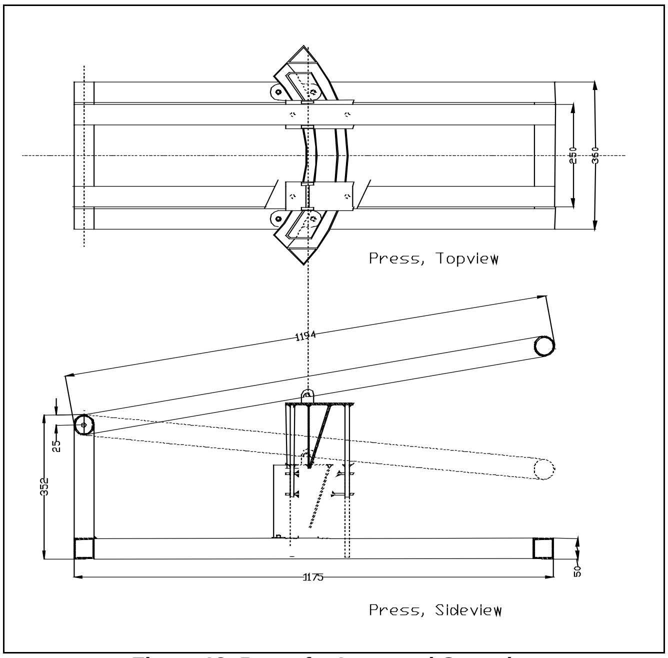


Figure 12: Press for Improved Gounziye

The other remarks, made by potters and users, that result in adaptations of the Improved Gounziye, are not incorporated into the moulds, but will have to be implemented after demolding. It concerns the following adaptations:

- fuel door of 15 by 10 cm (instead of 12 by 10 cm)
- top supports of 15 mm (instead of 10 mm).
- inside pan supports of 11 cm (instead of 10 cm)
- handles

For this molds and patterns will have to be made.
Figure 13 shows how the new Improved Gounziye will look. Figure 13 shows the part with the fuel opening, the other three parts have -of course- no doors

Figure 14 shows the New Improved Gounziye in a triangular arrangement as for cooking of watt. The picture also shows that the handles, introduced in this model, do not obstruct the triangular arrangement.

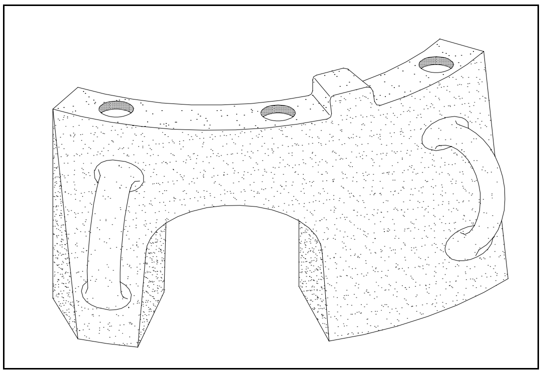


Figure 13: New Improved Gounziye

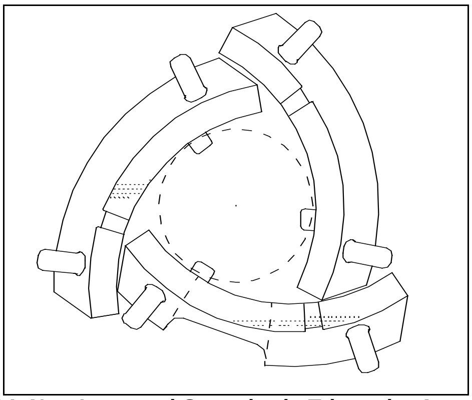


Figure 14: New Improved Gounziye in Triangular Arrangement

4.2.1 Estetic aspects

An outcome of the cunsumer test that has not been discussed sofar concerns the estetics of the Improved Gounziye. The traditional Gounziye as well as the traditional woodstoves are decorated with patterns that are made up of lines of transversely put dashes, simmilar to:

- //////////////////////////////// or
- <<<<<<<<<<<<<<<<< or
- xxxxxxxxxxxxxxxxxx or

These patterns are made by hand and their making is time consuming. To allow the producers to decorate the Improved Gounziye, but in a short time, one possibility is to use pattern wheels. These can be metal or wooden wheels, with a diameter of about 4 cm and a width of the desired pattern, say 8mm, on which side the pattern is carved. Thus when the wheel is rolled over the (wet) clay, the pattern is imprinted on the clay. With the wheel lines of patterns can be drawn over the surface of the Improved Gounziye according to the tradional pattern lines or any new plan suited for the improved Gounziye. Figure 15 gives an idea how such a pattern wheel could be made.

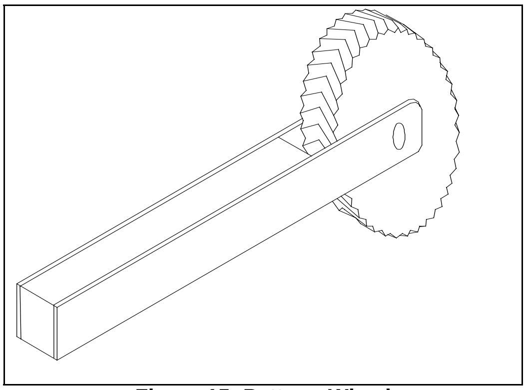


Figure 15: Pattern Wheel

4.3 Production tests

At the end of the mission the press with the mould was not ready, so no production tests could be done.

4.3.1 Selection of Clay

The selection of the clays to be used for the production as well as the composition of the clays, e.g. the kind and amounts of additives (sand, groc, sawdust), will be decided by the ceramic specialist, Dr. Ahmed Hood. Here we refer to his report on clay and clay testing.

4.3.2 Selection of Potters

To be be decided by the ceramic specialist, Dr. Ahmed Hood. Here we refer to his report on clay and clay testing.

4.3.3 Description of tests

To be be decided by the ceramic specialist, Dr. Ahmed Hood. Here we refer to his report on clay and clay testing.

4.3.4 Results of tests

To be be decided by the ceramic specialist, Dr. Ahmed Hood. Here we refer to his report on clay and clay testing.

4.4 Production costs

To be be decided by the ceramic specialist, Dr. Ahmed Hood. Here we refer to his report on clay and clay testing.

4.4.1 Production with traditional potters

In first instant the idea was to have the local potters produce the Improved Gounziye. The new product could replace the traditional Gounziye and they are the source for the knowledge of clay and firing. At the same time the Improved Gounziye could be marketed through the same channels as the traditional ones.

After the visit to the potters and the experience of the production of the Improved Gounziye for the kitchen performance test by three different groups of potters this idea was revised.

It appeared that the traditional potters are not really interested in the production of the Improved Gounziye. In the first place because each have their own traditional product in which they specialize, like coffee pots or the special saucers for kitfo. Only one of the groups was involved in making the traditional Gounziye.
Secondly the rate of organization of the potters is low to non-existent. They work individually and only occasionally do the firing together. Their rate of production is low and dependent of a number of external circumstances (rain, family conditions etc.).
Thirdly the potters do not own their own land, so there no place available to install a production site where a press and molds can be put and a firing kiln can be placed.
All together, the traditional potters are not an ideal group in combination with the goel of the project, namely a massive dissimination of improved stoves, realized by semi-industrial large scale stove production accompanied by intensive information and promotion campaings.

4.4.2 Dedicated private production facilities

The alternative for production of the Improved Gounziye by the traditional potters would be dedicated private production facilities.
Here an entrepreneur, interested in the subject and motivated to start a new, small but promising enterprise, would be the key factor. With assistance of the EREDPC he would set up the production facility, engage some personnel and do the marketing. Assistance of EREDPC would consist of technical input (moulds, press, kiln, training in ceramics) and the set-up and realization of the information and promotion campaign.
In this case the site can be choosen moreor less freely, but the following factors shouold be taken into consideration:

- close to the primary materials like clay, sand and water
- close to a source for the necessary fuel (collection or commercial)
- close to an (asphalted) road
- close to market places
- not to close to (semi)-urban settlements, so the smoke of the firing kiln will not cause nuisance to the neighbours.

4.5 Quality control

Quality control is essential to assure the woodfuel savings forecasted. The performance of the Improved Gounziye depend on their correct dimensions and the waterboiling tests as well as the fuel consumption calculations have shown that small diversions of these dimensions can already have a dramatic influence on the performance. On top of that, the final Improved Gounziye model is optimized in the tests so any deviation from the dimensions given in this report will surely mean a decrease in performance and an increase in woodconsumption

4.6 Need for Rural Energy Fund

The rural energy fund should comprise an appropriate financing mechanism to support local initiatives. This can include co-financing for preliminary studies and/or realizing investments. A “menu of options” should be established that lists the generic activities that *a priori* will be eligible for financial support from the rural energy fund. For each type of action from this menu of eligible activities, the levels of co-financing/subsidies should be determined according to the strategic priorities fixed at regional and state levels. For instance, higher levels of support should be dedicated to: (i) Woredas where the current wood fuel balance (based on WBISPP data) show a deficit or a trend towards deficit; or (ii) actions aiming at improving the management of communal woodlands or lands in Woredas where they are in jeopardy and/or can play a significant role as source of wood products.

Examples of options that should be included on the menu are: setting up a stove production facility; setting up a briquetting facility; creation of a professional charcoalers association; opening a retail outlet for improved stoves; launching a promotional campaign for improved stoves and setting up a distribution network; assisting villages to set up natural resource management systems; assisting villages to organize woodfuel transformation; demonstrations of on-farm planting, etc.

4.7 Prospects for large-scale production

The prospects for large-scale dissemination of the improved Gouziye depend on three conditions:

- Do rural households appreciate this stove sufficiently that they are willing to purchase it?
- Can it be produced in sufficiently large quantities.
- The type of support mechanisms to be put in place to increase awareness and possibly provide financial assistance.

The household tests confirmed the laboratory tests: the improved Gouziye is a good stove from an energy point of view. The household tests also confirmed that sample households appreciated the performance of the stove, and were even willing to pay money for it. The sample households was just a fraction of the total households, even in the Region surveyed. Thus, this evidence is statistically by no means sufficient to base a dissemination strategy up on. However, since most households use roughly similar cooking equipment and employ similar cooking techniques, it would be possible to propose dissemination trials in different Regions. It is very likely that households in those regions will behave similarly.

Clay is found throughout Ethiopia, and so are potters. Pottery has been a staple of Ethiopian culture, and clay pots have been in use for ages. With it comes a certain inherited expertise on preparing clay and making clay products. The potters that the EREDPC team worked with were in general capable to produce the improved Gouziye without major problems. Some groups of potters posed difficulties that were not related to the stove model but to the way they are currently organized.

In general there are two ways to produce the improved Gouziye on a large scale:

- Use the network of traditional potters. In this case, they will need to earn more from the production of stoves than from whatever they are producing now. Initially, a training program will need to be launched among potters who are willing to collaborate. Over time, a quality assurance program will need to be implemented to realize a consistent and constant quality of the stoves. It may not be impossible that it would be beneficial if the potters were grouped in associations of stove making potters.

- Create a profession of stove maker in rural areas. This would be production facilities that supply weekly urban markets with improved wood stoves. Most households regularly visit weekly markets where they buy many supplies. Stoves could be one of those products. Awareness should be raised to promote the idea that using an improved rural stove is beneficial to the user. A training program and an investment program geared to assist entrepreneurs to set up stove production facilities will be needed.

There are about 10 m rural households; assuming that all use firewood, dung, and/or BLT for cooking, the minimum number of stoves is 10m; quite a few households use two or more stoves on a regular basis. If the life of the improved stove were 2 years, some 5m are needed per year to satisfy the market. A traditional potter can make approximately 5-8 stoves per day; a stove production facility should be able to make over 100 stoves per day. This implies that to supply this market, some 4000 traditional potters are needed or 200 stove production facilities. In reality, there are likely to be both traditional potters and stove production plants simultaneously in operation. These numbers do not look unrealistic, and it can be expected that large-scale dissemination is feasible.

The third condition is the type of support mechanisms put in place. Three different mechanisms are identified:

- An awareness campaign; this should be organized at the national level first, but should then be realized also at the regional, woreda and FA levels. This campaign needs to be maintained for a sustained period, or until a majority of rural households are convinced about the usefulness of using improved stoves.
- A training and extension program is needed to identify traditional potters and firms willing to create stove production plants, and to assist them in producing improved stoves of acceptable quality. A quality assurance program also needs to be launched.

A financing mechanism is needed to assist producers to create stove production capacity; the rural energy fund would be a good candidate to supply this assistance. Stove promotion activities could possibly also be financed from the rural energy fund.

5 BIOGAS

5.1 introduction

The actual situation on biogas in Ethiopia has been assessed by a quick review of the literature on the subject in the library of the EREDPC. Most of the publications date from the 1980's. One of the more recent publication is an evaluation done by Fisseha Tegegne in 1991[4].

The most of the biogas installations have been constructed in Ethiopia in the 1980's and were of the Chinese fixed dome type constructed out of bricks or the Indian floating dome type made out of steel. Main conclusion of the report is that biogas has not been too successful and that more than 55% of the installations was not operational at the time the report was written. More recent literature on biogas concerns project proposals and studies, e.g. of the EESRC (now EREDPC) and Addis Ababa University.

No information was been found on the micro-biogas installations as proposed for this project.

Towards the end of the second mission a former director of the EREDPC (then EESRC), Ato Omar Mohammad Getta, informed us of an experiment with a micro-biogas installation by ILCA, in Addis Ababa, around 1986.

A visit was paid to ILCA and in the library the article written as a result of the experiment was retrieved[5)]. The author of the article, Senait Seyoum, was no longer employed by ILCA, but works now as a consultant. She was contacted by telephone, but unfortunately it was on the eve of a two-week mission to Mongolia. She agreed EREDPC would contact her on her return to Ethiopia to discuss the possibilities for pilot micro-biogas installations.

An email has been sent to Ms. Seyoum to explain the background of the project and her co-ordinates (email and telephone number) have been passed on to the EREDPC.

The subject of micro-biogas will further be taken care of by the "bio-gas team" of EDEDPC, with assistance from the Household Energy Efficiency Improvement and Conservation Team concerning the bio-gas burner.

5.2 Description of micro-biogas system

The polyethylene tubular biodigester technology is a cheap and simple way to produce gas for small-scale farmers. It is appealing to rural people because of the low cost of the installation and therefore of the gas, and the improvement in the environment that the installation allows. It can be applied in rural or urban areas, both in low and hilly lands.

A micro-biogas installation consists of a large plastic bag, of about 1 m diameter and 10 m lenght, which is closed at the ends, where an inlet or feed tube and an outlet tube are connected. This plastic bag is placed in a horizontal trench the ground. The inlet and outlet tubes are of hard plastic (standard PVC pipe) of a sufficient large diameter, e.g. 6cm. The exit tube should extend to the bottom of the digester. On top of the bag the gas

[4)] Fisseha Tegegne: "Biogas in Ethiopia", EEA, Ministry of Mines and Energy
[5)] Senait Seyoum: "The economics of a biogas digestor". ILCA Bulletin 30, April 1988.

outlet is placed, which can be connected to a gas holder, normally also aplastic bag. As gasline a normal garden hose can be used, but also PVC or metal pipesmay be used.
The digester daily needs to be supplied with fresh biomass (dung, crop residues) and water. Dung must be mixed with the same amount of water before it is loaded in the digester. At the same time, the same amount will flow out of the digester at the other side.

5.3 Test program

A total number of 11 plastic digester bags have been delivered to the EREDPC. Further installation at selected sites and biogas experiments will be carried out by the biogas unit of the EREDPC. At the moment this report was written, no further data was available.

5.4 Feedback from users

The available micro-digesters will be tested by 5 to 10 households (negotiations and selection are on-going). Also the Biofarm at Addis Ababa agreed to install and test one of the mocro-digesters. At the moment this report was written, no further data was available.

5.5 Economic analysis

The micro biogas system comprises of a plastic bag that is used as the digester and the pipes and valves, and end-user equipment. It is estimated that the bag needs replacement every 3 years, the pipes etc. every 10 years, and the en-use equipment every 7 years (lamp, stove). The bag is estimated to cost Birr 300; the pipes etc. Birr 210, and the lamp or stove Birr 85.

Since initial indications are that people will use a lamp with their digester system (and not a stove), there are financial savings from a reduction of kerosene consumption. It was estimated that rural households use 1-2 liter of kerosene per week, with a value of Birr 5-7 per week. This represents an internal rate of return of 45% and a payback time of a little less than 2 years. This is an investment worth making. In addition, the farmer will considerably improve his living conditions. In fact, this may be the only real improvement he is able to make in the near future. Access to electricity will require a magnitude of difference in investment levels. Nevertheless, a financing mechanism such as provided under the rural energy fund will accelerate the uptake of micro biogas digesters.

Table 7: Economic Data of Using Biogas

Biogas	$	Birr	life/yr													
digestor	35	298	3													
pipes	25	213	10													
lamp	10	85	7													
	70	595														
kerosene consumption	2	liter/week														
kersoene price	3	Birr/lt rural														
kerosene consumption	0.71	US$/wk														
	year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
equipment costs	595				298			85	298			213	298			85
operational costs																
benefits	0	312	312	312	312	312	312	312	312	312	312	312	312	312	312	312
net benefits	-595	312	312	312	15	312	312	227	15	312	312	100	15	312	312	227
irr	45%															

5.6 Prospects for large-scale dissemination

Because the results of the test with the micro-biogas units, as planned by the EREDPC, are not available at the moment this report is written, little can be said concretely about the prospects for large scale dissimination. This will depent largely on the reaction of the users concerning the usefull results (gas for cooking and lighting) of the biogas reactor versus the amount of work and investment involved.

If we suppose the reaction is positive, the prospects for large scale dissimination are important. A rough estimate gives a number of rural households suited for the use of a micro-biogas reactor of 2.3 million households (25%of the total of 9.5 million rural households). If only 10% of these households finally will own a micro-biogas reactor, still a total number of 230.000 reactors will function at the end of the dissimination program.

6 COMPLEMENTARY ACTIVITIES

6.1 Formation and Promotional campaign

6.1.1 Formation

To get the best results from the Improved Gounziye, they must be used in an optimal way. Given the observations made during the field trip and the remarks from the users during the survey and the kitchen performance test, this optimal way is not obvious to the users. Therefore information to the user is very important and a formation campaign should have high priority. Items that the information campaign should cover are:

- explanation about the general reasons behind the design.
- why the Improved Gounziye form a closed circle.
- why the door is not bigger
- why a smaller amount of wood is sufficient
- why it has the height of 16 cm.
- what is the function of the upper supports
- what is the function of the inner supports
- how to make the arrangement for cooking with pots and pans
- to use the inside supports with the aluminium pans
- to support the clay pots on the top of the Improved Gounziye
- explain the relation between the correct use of the Improved Gounziye and the fuel savings, fire management

The way the formation of the customers will be realized should be direct and informal.

- at the moment the Improved Gounziye is sold, the vendor should give an explicit explanation
- with each (set[6)] of) Improved Gounziy a leaflet should be handed out, showing al the important issues of its use in clear pictures
- at the places where the Improvred Gounziye are sold, an exibit should be set-up that shows the Improved Gounziye in its different configurations with the different pots, pans and mtads. To make such an exibit less difficult to handle, it could be made up out of models on small scale, say ¼th .of the actual size.
- during the begin period of the introduction of the Improved Gounziye, the families that have bought Improved Gounziye should be monitored and given additional explanation in case this seems necessary.

Althoughthe Improved Gounziye are based on ideas that were inspired by the traditional Gounziye, they are nevertheless a big change compared to the traditional ones and their correct use is not obvious, at least not to everyone. Thus to assure this correct use and the fuel savings that come with it, the message of its correct use should be repeated regularly and over alonger period until it has become part of daily life.

[6)] The first Improved Gounziye should be sold as a set, but later on the clients should be able to buy the Improved Gounziye by piece, just to replace a broken one. Because of the semi-industrial manufacture under close tolerances this is possible and helps on the longer term, to reduce the costs of the Improved Gounziye.

6.1.2 Promotion

Next to the formation campaign, which is more directly aimed at the customers, the promotional campaign is meant to bring the Improved Gounziye into the focus of the attention of the large group of potential customers. It should therefore bring the advantages and the background of the Improved Goiunziye forward in more general terms. The publicitary channels that should be used are:

- television. Regular spots on National Television,
- national and local radio. Regular spots
- national and regional newspapers. Advertisements and articles.

In this way the existance of the Improved Gounziye will become known not only to the rural population -the principal target group-, but also to the urban and peri-urban population. This will not only once more start the discussion about woodfuels and the problems connected and thus raise the awareness, but also show that solutions are available that help to alliviate the problem.

6.2 Aluminum pots

All tests and calculations have shown that the use of aluminium pans instead of the tradional clay pots can save 30% of fuel when these pans are used with the tradional Gounziye, and over 50% when used with the Improved Gounziye.

This saving potential is enormous and should not be neglected. In paragraph 3.6 already the differences between clay and aluminium pots and pans are discussed. The arguments of the users in favour of teh clay pots are valid, but only to a limited extend and there is no reason why the introduction of cast aluminium pots in Ethipia couold not be succesfull, where it has been succesfull in almost every other African country, including the neighbour country Sudan, where the cooking habits are comparable.

First logical step appears to be the import of a number of these cast aluminium pots from a neighbouring country and have these tested by a group of families, preferably families that use an Improved Gounziye and that have an open mind to the introduction of new items in the kitchen. It is advisable to first run waterboiloing test on these pots to establish their real fuel saving potential.

In case the results are positive, both in terms of energy savings and cooking use, a start could be made with the set-up of local production of these pots. Therefore the feasability should be established (availability of scrap aluminium, fuel, costs) and the existing experience in the neighbouring countries should be used.

6.3 Use of lids

The use of lids form a longstanding issue of discussion among the household energy specialists. In fact the differences in heat loss with or without lid are small and occur mainly during the heating up of the water.

When the water is boiling, all the net heat input to the pan is converted into steam and this steam will come out because we have a pressureless system.

During heating up the difference is in the heatloss from the water surface compared to the heatloss from the surface of the lid. Normally the heatlosses from an open water surface are higher and these can be aggravated by wind or draught that take the water vapour from the pan, thus disturbing the equilibrium and forcing the formation of more water vapour thus reducing the water temperature. This mechanism of steam removed by wind or draught of course can also occur during the boiling phase.

So in general it is better to cook with lids on the pan. Than in any case unnecessary heatlosses are prevented

6.4 Fire management

Fire management is important to realize the fuel savings of the Improved Gounziye as established in the waterboiling tests and fuel consumption calculations. Also good fire management is relatively simple and can be summarize in only a couple of basic rules:

- only use dry firewood
- only use twigs or split logs (no leaves!!)
- only use a limited amount of sticks (this limit is determined by the fuel door)
- always keep the flames under the pan
- reduce the fire as much as possible during simmering
- kill the fire with sand as soon as the cooking is finished

6.5 Chimney and hood

During the field visits and visits to kitchens one of the most penetrating observations has been the amount of smoke in the kitchens. The kitschens often are small with low roofs and already a small amount of smoke will fill the kitchen completely. This is not the place to elaborate on the serious negative health effects of smoke, but literature about the subject is abundant.

The Improved Gounziye produce less smoke than the traditional ones, but are not smokeless, and in a small kitchen their smoke emissions will also fill the kitchen to -in fact- unacceptable levels.

This problem can be largely ovecome by the installation of a hood combined with a short chimney, and although the dissimination of hoods and chimneys is not subject of this project, it is an item that is closely related and couild be easily incorporated into the formation and publicity campaigns.

6.6 Economic analysis

An economic analysis has already been presented in paragraph 3.8. There was concluded that:

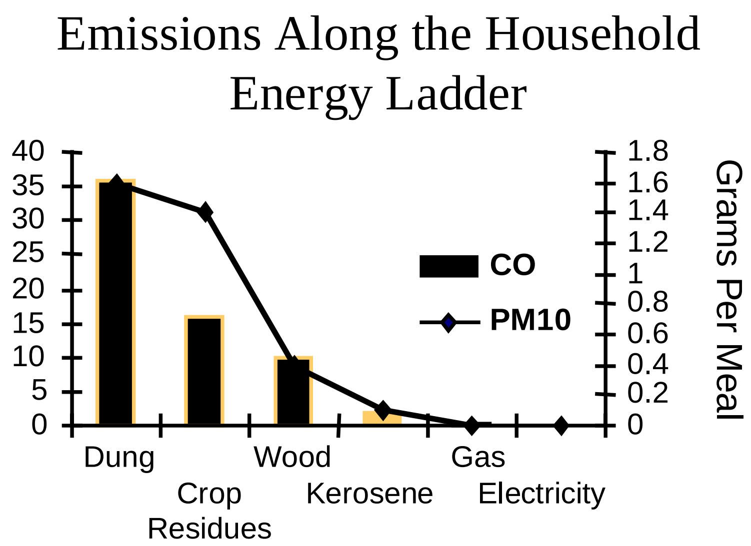
In concrete terms of Birr saved, the introduction of Improved Gounziye will result in savings that vary from 4 Birr per week in case the shift to aluminium pans is made to around 2 Birr per week in case the traditional pots are continued to be used. If the Improved Gounziye will be marketed for 15 Birr per set and the cost of the traditional Gounziye are 10 Birr, than the pay-back time varies from one to two and a half week.

7 ENVIRONMENTAL CONSIDERATIONS

7.1 Smoke & health

Indoor Air Pollution (IAP) as result of the use of traditional energy sources is considered a major risk factor contributing to poor health. The health burden from IAP is greater in high altitude rural areas and amongst poor families who tend to use cheap low quality fuels in traditional stoves without proper ventilation. Women and young children are at greatest risk because they spend more time indoor, where the highest incidence of particulate exposure occurs.

Biomass is cheap and readily available, but quite polluting and poses serious health hazards due to acute and chronic exposure to particulates (PM10), nitrous oxides (NOX), carbon monoxide (CO), aldehydes and para amino hydrocarbons (PAH). IAP levels in developing countries are typically many times higher than developed world standards for ambient air quality. Concentration levels vary with the time of day, season and place of measurement, especially for particulates that are inhaled (<PM10) and for CO levels.



While acute exposure to smoke may result in carbon monoxide poisoning and/or death, most of the effects occur as a result of long-term exposure. Evidence shows that chronic exposure to indoor air pollutants increases the risk of respiratory illnesses, including acute lower respiratory infections (ALRI) in children and chronic obstructive pulmonary disease (COPD) in adults.

The three factors that mostly influence IAP are: ventilation conditions of the house, the fuel – stove combination, and behavior. With unventilated kitchens, as is often the case in rural Ethiopia, IAP levels increase. Chimneys and hoods, opening opposing widows and doors may assist in evacuating smoke and particulates. Modern fuels, and modern stoves burn more cleanly and efficiently, and result in lower IAP levels. The improved Gouziye shows good burning characteristics, and when used with a chimney in the roof should considerably reduce IAP levels. The third factor is the human factor, that to a great extent determines how severe the exposure to IAP is; knowledge, experience and practice of using cooking equipment and fuels.

7.2 Fuel & deforestation

Woodfuels do not contribute as much to deforestation as agricultural expansion does. Most of the wood resource degradation is due to the fact that new land is cleared from trees and transformed into agricultural land. This in itself is an economic activity that has its merits. The low agricultural productivity and related low usage of fertilizers necessitate the continuous expansion of new agricultural lands.

Woodfuel use in rural areas does hardly contribute to deforestation. Most rural households have agricultural residues and dung easily available, which they will use whenever they can. Wood is often collected and it is rare that whole trees are cut for rural energy use. Sometimes people will trim trees, but cutting of whole trees is not done. It is different for urban energy use. Since markets are functioning to a certain extent, some people will cut trees and transform this into firewood and charcoal for sale to urban areas. This is more detrimental to the resource base.

The fact that ownership rights of the trees, or the land on which the trees stand are unclear, does also not contribute to sustainable use of resources. This in itself may be the greatest motivation for deforestation: since the tree belongs to no-one, why not cut it?.

7.3 Environmental monitoring

Environmental monitoring emcompasses two main fields, Indoor Air Pollution (IAP) and Outdoor Air Pollution (OAP).
Indoor Air Pollution is concerned with the effects of the stove emissions on the health of the cooks and the other persons present in the space where the cooking takes place. Next to the cooks, these are often children and old people. IAP depends not only on the stove and fuel, but also to a large extend on the situation in the kitchen: how big is it, hjow is it ventilated, is there a chimney etc. Monitoring IAP is a rather complicated job, involving monitoring of gases and particulates using samplers worn by the cooks, and an elaborate analysis of the samples afterwards.
Outdoor Air Pollution is mainly concerned with the emission of CO_2, the gas that contributes to the global warming problem. In this case a good estimate of the reduction in CO_2 emissions can be derived from the reduction in the consumption of fuel wood. If the reduction in fuelwood consumption is well monitored, the reduction in the emissions of CO_2 can be easily quantified by simple mathematics.

8 INSTITUTIONAL ARRANGEMENT

Figure 16 shows how an institutional network for stove dissimination could be set up. In this set-up, EREDPC will be the main coordinating body, which coordinates and delegates to the Wmerd's. The Wmerd's contact local entrepreneurs and households, execute the program on the regional level and are as such crucial in the realization of the dissimination program. Next to the Wmerd's, the EREDPC contacts NGO's, donor organizations etc, to look for additional funds and coordinate simmilar activities -planned or already under execution-, of these organizations. This is also very important because the execution of two (or more) improved stove dissimination programs at the same time will greatly confuse the consumers and probably frustrate both programs at the same time.

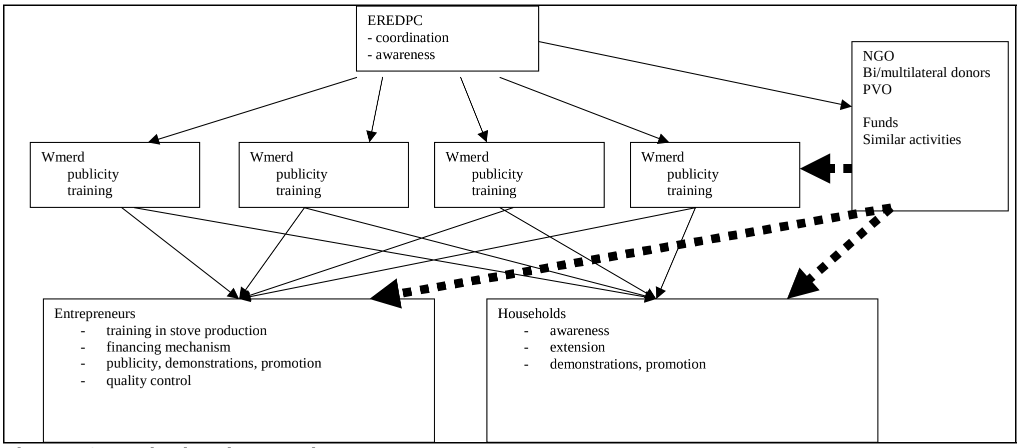


Figure 16: Institutional Network

The following subjest, relevant to large scale dissimination, have already been discussed in the different previous chapters of this report. Here a short summary will be given.

8.1 How to organize Large-scale dissemination

Dedicated production centers should be created in semi-urban settlements in the rural areas. These centers should be managed in a commercial way by a private entrepreneur and be equipped with molds, presses and kilns. Technical support to these enterprises should be given by EREDPC, through the Wmerd's, in the form of technical specifications (and eventually supply) of the equipment (moulds and presses, kilns), clay preparation instructions based on local available materials and business management techniques.

EREDPC should also support dissimination by the realisation and execution of the formation and dissimination campaigns aimed at the (future) customers.

8.2 Institutional responsibilities

Product development and materials testing:	EREDPC
Production tools development and tools production:	EREDPC and Entrepreneur
Site selection:	Wmerd and Entrepreneur
Production and quality control:	Entrepreneur
Marketing	Entrepreneur
Development formation and publicity campaign:	EREDPC and Entrepreneur

Execution formation campaign:	Entrepreneur
Execution promotion campaign:	EREDPC / Wmerd

8.2.1 Publicity campaign

Will in fact consist of a formation campaign and a publicity campaign.
The formation campaign is aimed directly at the buyers of Improved Gounziye and will focus on instructions how to use the Improved Gounziye and explanations why it should be used in this way. The formation campaign will include fire mangement instructions.
The publicity campaign aims at giving general information about the Improved Gounziye to the public, to enlarge the awareness about the existence of the Improved Gounziye and the connected problems within the target group but also to the population in general. .See paragraph 6.1 for details.

8.2.2 Production aspects

This subject will be covered by the ceramic expert, Dr Ahmed Hood. Here we refer to his report. Items covered under this heading will, amongst others, be:

- clay types and mixtures with different additives (sand, groc, sawdust, etc)
- clay preparation
- use of moulds and presses
- drying and finishing of the Improved Gounziye
- firing, use of kiln, stacking of products, use of fuel
- quality control

8.2.3 Quality control

Quality will be assured by the means of production used (moulds, presses and kilns), the quality of the clay used and the quality awareness of the entrepreneur. See paragraph 4.5
Quality control is an important aspect of the production cycle. The fuel saving capacity of the Improved Gounziye depends to a large extend on the correct dimensions of the Improved Gounziye, so care should be taken that the entrepreneur does not change any aspect of the design on his own accord. Any change should only be incorporated after testing and approval of EREDPC.
On the other hand, the quality aspect will be emphasized in the publicity campaign, and customers will be encouraged only to buy Improved Gounziye of good quality. It is therefore also in the interest of the entrepreneur to produce Improved Gounziye of impeccable quality.

8.2.4 Environmental monitoring

Should be done on two different levels: Indoor Air Pollution (IAP) and Outdoor Air Pollution (OAP). IAP focusses on the direct inhalation of hazardous stove emissions by the cook and other people present near the cooking spot or in the kitchen, in general housewives, children and elderly people. Literature is abundant on this subject, inhalation levels can be very high and the negative health effects are severe.
OAP focusses on the emissions of Green House Gases (GHG), in the case of woodstoves CO_2 .See paragraph: 7.3 for further details.

8.2.5 Coordination

As allready proposed above and indicated in Figure 16, general coordination of all activities lies with EREDPC.

9 CONCLUSIONS AND RECOMMENDATIONS

Based on a review of cooking practices and prevailing rural cooking equipment, different models of improved stoves were identified. The Improved Gounziye, as developed under this project, adapts to the rural cooking practices and allows different types of food to be prepared without changing stoves (as is now often the case). The Improved Gounziye stove can be adjusted to prepare coffee or wot in small cooking pots and kotcho or injera on large mitads. This is done by extending the three stones from the traditional gounziye into larger slabs of clay that shield the heat and keep this between the gerget and the cooking pot. The Improved Gounziye is made up from 3 or 4 of such slabs that can easily be produced by traditional potters. Since they are made of clay, the production costs can be kept to a minimum and chances are that rural households will adopt the stove on a large scale.

The Improved Gounziye offers important possibilities to reduce fuel consumption in the rural areas and savings up to 30% at the household level are possible. Initial reactions in the Welkite area from pottery specialists about production and from households about the performance of the stove were positive. Not only are fuel savings relatively important (important enough to notice), some improvements to the air quality were observed also. These fuel savings will reduce time for collection of the fuel and the person who benefits most will vary from household to household; often these tasks are reserved for the young or the elderly. Better air quality will benefit those who stay in the household when cooking takes place, thus mainly the housewives and the young children.

Savings were confirmed by the kitchen performance test executed by the EREDPC, where some 40 households obtained average savings of 25% after the introduction of the Improved Gounziye. In these kitchen performance test the users also gave a number of critical remarks that have been used to design the final model of the Improved Gounziye.

Higher savings of up to 50% are possible if aluminium pots are also introduced - in addition to the Improved Gounziye - to replace traditional clay pots that are now being used. Several countries in the Sahel have successfully introduced such aluminium cooking pots; in Ethiopia only aluminium pots for urban cooking are available, which are of lower quality adapted to electric or kerosene cooking. For rural cooking more sturdy and thick walled pots and pans are required to make up for the higher power outputs of rural stoves.

A low-cost mould and a press have been designed to facilitate the production of the Improved Gounziye and to assure a constant quality. At the end of the mission this equipment was not yet ready and no production tests could be done. Several of these would be placed with pottery groups and private firms to test the production aspects.

In principle, on the order of 4000 individual potters (possibly organized in traditional groups) or 200 more professionally oriented production private facilities are needed to satisfy the anticipated market for these stoves. It was estimated that some 5 millions stoves per year are needed to satisfy the total potential demand. For large-scale dissemination, we anticipate that some 20% of the potential demand will be reached, or about 2 million households with an improved Gounziye stoves.

Regarding biogas, there is a renewed interest world-wide in this technology, particularly the low-cost models. It is one of the few technologies that potentially could break the traditional energy barrier in rural areas. BTG brought a few sample in the country but at the time the last BTG mission was in the field, the digesters had not been placed in participating farms. It is expected however, that these digesters will save very little wood as the intended use as expressed by interested households is lighting rather than cooking. Thus, biogas would replace consumption of kerosene and increase the availability of fertilizer, both of which have clear economic benefits.

Annexes:

A. STOVE PRODUCTION MANUAL

This subject wil be covered in the report of the ceramics specialist, Dr Ahmed Hood. For further information we refer to his report.

B. STOVE TESTING MANUAL

1. Introduction.

This annext will describe a number of ways to test wood cookstoves. The testing procedures are in accordance with the International Standards for the Testing of Woodburning Cookstoves [7]). Similar documents exist for gas/kerosene stoves, for charcoal stoves and for briquette stoves.

To test cookstoves, some minimal equipment and facilities are essential, some others are optional. These are summed up in chapter 2.

The chapters hereafter give descriptions of the test methods. The methods described are:

I. Extensive efficiency tests.
Water is brought to the boil and kept boiling for 30 minutes, followed by a simmering period of 60 minutes.
In these test the power and the efficiency of the stove are determined every 5 minutes (or any other interval), as wel as the CO/CO2 ratio. In this way graphs can be made showing the changes of the most important stove parameters with time.

II. Simple efficiency tests.
Water is brought to the boil and kept boiling for 30 minutes, followed by a simmering period of 60 minutes.
In these tests the maximum power, the minimum power and the according efficiencies are determined.

III. Fuel consumption tests.
Water is brought to the boil, followed by a simmering period of 90 minutes. In this way a cooking session is simulated.
In these tests the quantity of fuel, needed to perform this task, is determined.

IV. Controlled cooking tests.
A standard meal is prepared by an experienced cook.
In these tests the quantity of fuel, needed to perform this task, is determined.

For one type of stove, any test must be repeated at least three times. The results are then averaged. The data obtained with I. can be used together with the results of II. for the calculation of maximum and minimum power, and according efficiencies.

The **spreadsheets** to collect data during the test as wel as the spreadsheets to process this data, are provided to EREDPC.

---

[7]). "Testing the Efficiency of Woodburning Cookstoves: International Standards", (ISBN 0-86619-229-8); Volunteers In Technical Assistance, 1815 N.Lynn Street, Suite 200, Arlington, Virginia 22209, USA.

The **fuel** used must be uniform, i.e. the sizes of the individual pieces of fuel must be more or less the same: do not use small pieces (except for kindling), and do split big lumps of wood. Secondly, the moisture content, on dry basis, must be 10 +/- 5 %. In the spreadsheet for data processing, the **combustion value** is set at 17 MJ/kg, for wood with 10 % moisture. The ash content of wood is normally around 0.5% and not taken into account. If the moisture content or ash content of the wood used is different, or the combustion value is otherwise different, corrections must be made.

The **pans** used must be the same for all stoves, and preferably the pan most commonly used for cooking in the families. Pans must be used with lids. The **initial amount** of water must be 2/3 of the pan's full capacity, rounded of to the nearest 500 g.

The **initial charge** of fuel must fill the combustion chamber to a reasonable level. If pan supports are provided on the stove, the fuel must not touch the bottom of the pan. Initial charges must be more or less the same for all the stoves tested. The **additional charge** must be 1 stick at a time.

To determine the weight of the **burned fuel** and the **evaporated water**, the following procedure is followed. First the **stove plus fuel plus pan** are put on the balance and the weight is noted down, then the pan is lifted from the stove and the weight of the **stove plus fuel** is noted down. Eventually, then the unburned fuel is removed from the stove and the weight of the **stove plus remaining charcoal** is noted down. In the calculations of powers, efficiencies and specific consumptions this remaining charcoal is taken into account. To check on the total amount of fuel burt, a reasonable **stock of fuel** is set apart for each test and weighed. At the end of the test this stock is weighed again.

For **ceramic stoves** the weightloss due to the initial moisture content of the ceramic is accounted for. It is assumed that this moisture evaporates during the first 45 minutes of the experiment, following a quadratic curve.

2. Equipment.

Equipment to test cookstoves is the following:

Absolutely necessary:

- electronic balance, minimal range 0-30 kg, accuracy 1 g.
- digital thermometer, minimal range 0-120 ^{o}C, accuracy 1 ^{o}C.
- digital stopwatch
- (access to) an IBM compatable computer with spreadsheet program
- test room:- well ventilated
  - runing water (from a tap)
  - electricity
  - minimal 3.5 * 5.5 m
  - funiture.
- technician (tester).
- utensils, like buckets etc.

To be able to run more tests simultanuously:

- one or two more thermometers.
- one or two more stopwatches.

For more extensive testing:

- oven to dry fuelwood, briquettes and charcoal. This should be a thermostatic controlled oven with an accuracy of 5 ^{o}C at an operational temperature of 110 ^{o}C.
- gasanalysis equipment, to measure CO, CO2 and O2. This equipment must be able to monitor high CO concentrations (min. 0.5 %) over an extended period of time (1 hour), and support higher CO concentrations.
- digital thermometer, ranging up to 1300 ^{o}C, with two or three channels, accuracy 1 ^{o}C.

3. Extensive efficiency tests.

3.1. Description.

In this type of test a pan of water is brought to the boil and kept boiling for 30 minutes, followed by a simmering period of 60 minutes. The goal of the test is to monitor the most important stove characteristics over time. These are:

- the power of the stove
- the efficiency of the stove
- the CO/CO2 ratio of the combustion gasses.

So the test consists of a high power and a low power phase. At high power all air controls are fully opened and wood is added when necessary to maintain this high power. At low power, the air controls are closed to such an extent that the water just stays at a temperature of 100 ^{o}C. Wood is only added if this is necesary to maintain the water temperature at 100 ^{o}C.

Readings of the relevant weights, temperatures and gas compositions are taken at the beginning of the test and subsequently every 5 minutes. (Or any other interval).

The data gathered in the test is processed in a spreadsheet, to calculate power and efficiency and CO/CO2 ratio for each 5 minutes period, as well as the averaged values of these parameters for the high power and the low power phase of the test. The data is also used to plot graphs to show the development of power, efficiency and CO/CO2 ratio with time.

For this test the stove is best permanently installed on the balance. Only a very experienced tester can run two tests simultanuously.

3.2. Testing.

The following is a point to point desciption of the actual testing procedure.
The data is to be noted down on the test sheet for extensive efficiency tests.

- prepare the fuel stock. Note down the weight.
- prepare the balance, stopwatch, thermometer and gas-analyser.
- weigh the empty pan (with lid!). Note down the weight.
- fill the pan with the initial amount of water. Note down the initial temperature of the water.
- weigh the empty stove. Note down the weight.
- fill the stove with the initial amount of wood.
- light the stove. When the the stove is burning, then
- - open all air controls of the stove
- - start the stopwatch and note down the time.
- - put the stove plus fuel on the balance
- - install probe for the gas analysis
- - note down the weight of the stove plus fuel
- - put the pan on the stove
- - note down weight of stove plus fuel plus pan
- - note down CO and CO2 values.

- after 5 minutes
- - note down CO and CO2 values.
- - note down the weight of the stove plus fuel plus pan
- - lift the pan from the stove
- - note down the weight of the stove plus fuel
- put the pan back on the stove
- measure and note down the water temperature
- repeat this procedure every 5 minutes **during the whole test.**
- maintain the high power and add wood if necessary. Note down the weight of the added wood. Repeat this procedure if neccessary.
- when the water has reached boiling point, continue for another 30 minutes.
- at the end of this 30 minutes period:
  - note down CO and CO2 values
  - close the air controls of the stove
  - note down the weight of the stove plus fuel plus pan
  - lift the pan from the stove and place it beside the stove
  - note down the weight of the stove plus fuel
  - remove unburned wood from the stove
  - note down weight of stove plus remaining charcoal
  - put the used wood back in the stove
- put the pan back on the stove to start the low power phase of the test.
  - note down weight of the fuel stock.
- continue for another 60 minutes.
- continue with the 5 minutes measurements.
- manipulate the air controls to have the lowest possible power which keeps the water boiling.
- for this phase the charging procedure is different. Now wood is added only if without recharging it is impossible to keep the water boiling. Note down the weight of the added wood. Repeat this procedure if neccesary.
- at the end of this 60 minutes period:
  - note down CO and CO2 values
  - note down the weight of the stove plus fuel plus pan
  - lift the pan from the stove and place it beside the stove
  - note down the weight of the stove plus fuel
  - remove unburned wood from the stove
  - note down weight of stove plus remaining charcoal
  - note down weight of the fuel stock.
- for ceramic stoves only. At he end of the test:
- empty the stove
- weigh the empty stove
- note down the weight of the stove.

3.3. Data processing.

The data can be processed in the prepared spreadsheet.

Transfer the data from the test sheet to the corresponding cells of the spreadsheet. It then will calculate the power, efficiency and CO/CO2 ratios and generate the graphs.

4. Simple efficiency tests.

4.1. Description.

In this type of test a pan of water is brought to the boil and kept boiling for 30 minutes, followed by a simmering period of 60 minutes. The goal of the test is to establish the most important stove characteristics. These are:

- the maximum power of the stove, Pmax
- the efficiency at maximum power, Emax
- the minimum power of the stove, Pmin
- the efficiency at minimum power, Emin

So the test consists of a high power and a low power phase. At high power all air controls are fully opened and wood is added when necessary to maintain this high power. At low power, the air controls are closed to such an extent that the water just stays at a temperature of 100 ^{o}C. Wood is only added if this is necessary to maintain the water temperature at 100 ^{o}C.

Readings of the relevant weights, temperatures and time are taken at the beginning of the test, at the beginning of the low power phase and at the end of the test.

The data gathered in the test is processed in a spreadsheet, to calculate power and efficiency for the high power and the low power phase of the test.

For this type of test it is not necessary to install the stove permanently on the balance. It is possible for an experienced tester to perform 4 to 6 tests simultanuously.

4.2. Testing.

The following is a point to point desciption of the actual testing procedure.

The data is to be noted down on the test sheet for simple efficiency tests.

- prepare the fuel stock. Note down the weight.
- prepare the balance, stopwatch and thermometer.
- weigh the empty pan (with lid!). Note down the weight.
- fill the pan with the initial amount of water. Note down the initial temperature of the water.
- weigh the empty stove. Note down the weight.
- fill the stove with the initial amount of wood.
- light the stove. When the the stove is burning, then
- - open all air controls of the stove
- - start the stopwatch and note down the time
- - put the stove plus fuel on the balance
- - note down the weight of the stove plus fuel
- - put the pan on the stove
- - note down weight of stove plus fuel plus pan
- maintain the high power and add wood if necessary. Note down the weight of the added wood. Repeat this procedure if neccessary.
- when the water has reached boiling point, continue for another 30 minutes. Note down the time.
- at the end of this 30 minutes period, note down the time and:
- - close all air controls of the stove

- - put the stove plus fuel plus pan on the balance
- - note down the weight of the stove plus fuel plus pan
- - lift the pan from the stove and put it beside the stove
- - note down weight of stove plus fuel
- - remove unburned wood from the stove
- - note down the weight of the stove plus remaining charcoal
- - put the wood back in the stove
- put the pan back on the stove to start the low power phase of the test.
- - note down the weight of the fuel stock
- continue for another 60 minutes.
- manipulate the air controls to have the lowest possible power which keeps the water boiling.
- for this phase the charging procedure is different. Now wood is added only if without recharging it is impossible to keep the water boiling. Note down the weight of the added wood. Repeat this procedure if neccesary.
- at the end of this 60 minutes period, note down the time and:
- - put the stove plus fuel plus pan on the balance
- - note down the weight of the stove plus fuel plus pan
- - lift the pan from the stove and put it beside the stove
- - note down weight of stove plus fuel
- - remove unburned wood from the stove
- note down the weight of the stove plus remaining charcoal.
- - note down the weight of the fuel stock
- for ceramic stoves only. At he end of the test:
- - empty the stove
- - weigh the empty stove
- - note down the weight of the stove.

4.3. Data processing.

The data can be processed in the prepared spreadsheet. Transfer the data from the test sheet to the corresponding cells of the spreadsheet. It then will calculate the power and efficiency for the high and the low power phase of the test.

5. Fuel consumption tests.

5.1. Description.

In this type of test a pan of water is brought to the boil, followed by a simmering period of 90 minutes. The goal of the test is to determine the fuel consumption of the stove to perform this task. This fuel consumption is expressed as Specific Fuel Consumption, SFC, and as Specific Energy Consumption, SEC.
So the test consists of a high power and a low power phase. At high power all air controls are fully opened and wood is added when necessary to maintain this high power. At low power, the air controls are closed to such an extent that the water just stays at a temperature of 100 ^oC. Wood is only added if this is necessary to maintain the water temperature at 100 ^oC.
Readings of the relevant weights, temperatures and time are taken at the beginning of the test, at the beginning of the low power phase and at the end of the test.
The data gathered in the test is processed in a spreadsheet, to calculate Specific Fuel Consumption and Specific Energy Consumption. The SFC can be used to compare wood stoves, while the SEC can be used to compare stoves with different kinds of fuel. (If tested using the same testing procedure).

For this type of test it is not necessary to install the stove permanently on the balance. It is possible for an experienced tester to perform 4 to 6 tests simultanuously.

5.2. Testing.

The following is a point to point desciption of the actual testing procedure.
The data is to be noted down on the test sheet for fuel consumption tests.

- prepare the fuel stock and note down the weight.
- prepare the balance, stopwatch and thermometer.
- weigh the empty pan (with lid!). Note down the weight.
- fill the pan with the initial amount of water. Note down the initial temperature of the water.
- weigh the empty stove. Note down the weight.
- fill the stove with the initial amount of wood.
- - light the stove. When the the stove is burning, then
- - open all air controls of the stove
- - put the stove plus fuel on the balance
- - start the stopwatch and note down the time
- - note down the weight of the stove plus fuel
- - put the pan on the stove
- - note down weight of stove plus fuel plus pan
- maintain the high power and add wood if necessary. Weigh the extra charges and note down the weight.
- when the water has reached boiling point, then
- - note down the time
- close all air controls of the stove to start the low power phase of the test.
- continue for another 90 minutes.
- manipulate the air controls to have the lowest possible power which keeps the water boiling.

- for this phase the charging procedure is different. Now wood is added only if without recharging it is impossible to keep the water boiling. Note down the weight of the added wood. Repeat this procedure if neccesary.
- at the end of this 90 minutes period, note down the time and:
- - put the stove plus fuel plus pan on the balance
- - note down the weight of the stove plus fuel plus pan
- - lift the pan from the stove and put it beside the stove
- - note down weight of stove plus fuel
- - remove unburned wood from the stove
- - note down the weight of the stove plus remaining charcoal
- - note down the weight of the fuel stock
- for ceramic stoves only. At he end of the test:
- - empty the stove
- - weigh the empty stove
- - note down the weight of the stove.

5.3. Data processing.

The data can be processed in the prepared spreadsheet. Transfer the data from the test sheet to the corresponding cells of the spreadsheet. It then will calculate the Specific Fuel Consumption and the Specific Energy Consumption.

6. Controlled cooking tests.

6.1. Description.

In this type of test a standard meal is prepared. The goal of the test is to determine the fuel consumption of the stove to perform this task. This fuel consumption is expressed as Specific Fuel Consumption, SFC, and as Specific Energy Consumption, SEC.
This meal should be representative for an average daily meal prepared by an average family. The quantities of ingredients should be approximately the same for each test. The cooking should be done by an experienced cook, who should try to use as less fuel as possible. It is the cook who decides when to charge the stove and how much to add.
Readings of the relevant weights and time are taken at the beginning of the test, at the beginning of the preparation of a new dish and at the end of the test.
The data gathered in the test is processed in a spreadsheet, to calculate Specific Fuel Consumption and Specific Energy Consumption. The SFC can be used to compare wood stoves, while the SEC can be used to compare stoves with different kinds of fuel. (If tested using the same test procedure).

For this type of test it is not necessary to install the stove permanently on the balance. It is possible for an experienced tester to perform 2 to 4 tests simultanuously.

6.2. Testing.

A point to point desciption of the actual testing procedure.
The data is to be noted down on the test sheet for controlled cooking tests.

- prepare the fuel stock and note down the weight.
- prepare the balance and the stopwatch.
- weigh the ingredients. Note down the weight.
- weigh the empty pans to be used. Note down weight.
- weigh the empty stove. Note down the weight.
- fill the stove with the initial amount of wood.
- prepare the water to be used for the cooking. Weigh it and note down the weight.
- light the stove. When the the stove is burning, then
- - open all air controls of the stove
- - put the stove on the balance
- - start the stopwatch and note down the time
- - note down the weight of the stove plus fuel
- - start the cooking
- when the first dish is ready, then
- - note down the weight of the pan with the food
- - note down the weight of stove plus fuel
- - remove unburned wood from the stove
- - note down the weight of the stove plus remaining charcoal
- - note down the time
- - note down the weight of the remaining water
- - note down the weight of the fuel stock
- repeat this procedure for every dish.

- for ceramic stoves only. At he end of the test:
- - empty the stove
- - weigh the empty stove
- - note down the weight of the stove

6.3. Data processing.

The data can be processed in the prepared spreadsheet. Transfer the data from the test sheet to the corresponding cells of the spreadsheet. It then will calculate the Specific Fuel Consumption and the Specific Energy Consumption.

Note: This spreadsheet was prepared for a meal comprizing of rice or beans with a sauce. But it can easily be adapted to other meals comprizing of other, different dishes.

C. ENVIRONMENTAL MONITORING

It will be very difficult to carry out environmental monitoring *in situ*, and this is therefore not recommended. The number of household where measurements would need to be taken in order to obtain a meaningful reading is too high to be practical. In addition, the measurements would upset family life as the kitchen would need to be equipped and measurements would need to take place over extended periods of time, which in itself influences the reading one is supposed to take.

It is therefore recommended to simulate household kitchens in a laboratory environment. Special kitchen space may be created where traditional houses are replicated. All tests are to take place in such laboratory facilities. Replicas for each of the main types of kitchen prevailing in rural Ethiopia should be constructed. In these rooms necessary measuring equipment can be installed on a permanent basis.

This way will allow for easy comparison between "before" and "after" situations where by i.e. the improved Gounziye is compared to the performance of the 3 stones and gerget, or the influence of a hood and chimney, a lid, etc.

The type of equipment that should be installed is: scales to measure the weight of the fuel; another scale would ideally be built into the floor so that the stove sits on top of it and can be used to make continuous measurements while cooking; and emission equipment, mainly to detect and measure CO, PIC, and smoke levels. See further information in the stove testing manual.