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Thomas, Margaret; Binder, Susan; Friesen, Gerry; Evans, Ianto

5. CORPORATE AUTHORS (101)

Aprovecho

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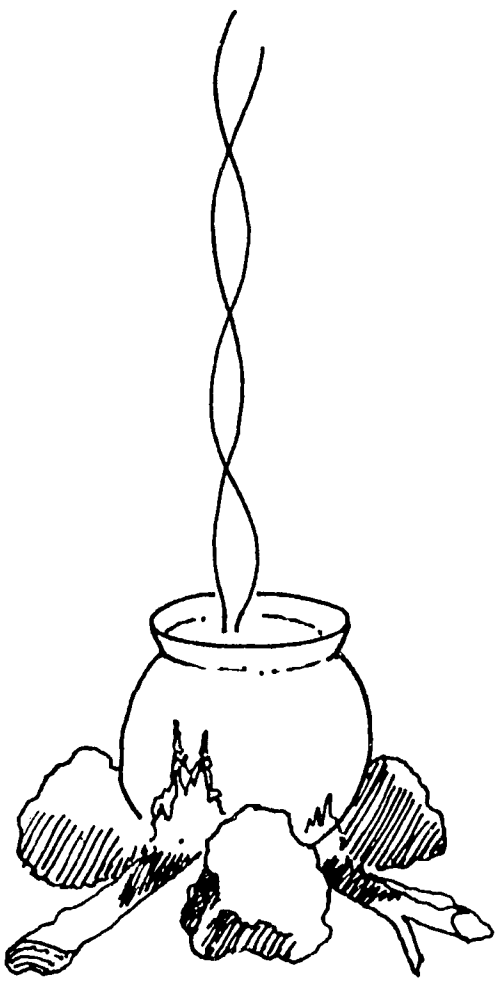
A Manual



produced for

The Africa Bureau
USAID

researched and written by

Aprovecho
442 Monroe
Eugene, Oregon, USA

Margaret Thomas
Susan Binder
Gerry Friesen
Tanto Evans

How to Use the Information in this Manual

The information contained here was assembled by Aprovecho specifically at the request of the Africa Bureau of USAID, to be used in assessing fuel savings in Africa. However, all over the world development planners, foresters, health officials and people concerned with deforestation are all looking carefully at the potential for more efficient cookstoves to reduce fuel needs.

Until now, the few references available on how to assess fuel use have concentrated on calculating "efficiencies", which can be defined in a confusion of different ways. Usually these measurements take place under laboratory conditions and present percentage figures which must then be compared with traditional cooking "efficiencies". The whole process is complicated and replete with opportunities for error and misunderstanding.

The methods described here simplify the process of collecting information at a household level, in village or city, without complicated apparatus or calculations. What is involved is simply comparing and evaluating the amount of fuel used.

The information can be used several ways:

1. To project an overall measurement of how much fuel could be saved if stoves were to be introduced, for a village or a whole region.

2. To calculate the reduced need for imported fuel (kerosene, for example) given a widespread program of improved stoves.

3. To examine the effect of specific design changes on fuel use. Beneficial changes can then be encouraged.

4. Foresters planning woodlots can better calculate the size of plantings needed to supply fuelwood.

5. To assess the cost/benefit of improved stove projects in terms of fuel saved.

Some very important information not directly relating to fuel use by stoves may come out of this study. This includes:

* methods that cooks use to conserve fuel which are independent of specific stove use. For example, changes in firebuilding techniques (using kerosene to get the fire started quickly), preheating water in the sun, changes in cooking styles (quick frying rather than long boiling, cooking with retained heat or switching to food which require less cooking time).

* use of non-traditional fuels in improved cookstoves. It is important to consider the implications of a switch in fuels. Is the new fuel something for which there is no other use in the area? For example, are people using coconut husks which previously were left to rot? Or will switching to a new fuel have serious consequences? Two examples: 1) Burning dung can create a severe problem of decreased soil fertility. 2) Cooking on charcoal accelerates the rate of deforestation, due to inefficiencies of charcoal production methods as well as the use of inefficient charcoal stoves.

Note: It is possible that this research will show that improved stoves are not saving a significant amount of fuel. This does not mean, however, that stoves may not be serving other useful purposes such as eliminating smoke from the kitchen and thereby having a beneficial effect on the cook's health. This may be a strong enough reason to continue a stove program even though its fuel saving aims are not being met.

READ THIS FIRST

For thousands of years open fire methods have been used to cook food. In recent years a firewood shortage has prompted changes from traditional cooking practices. One such change is the introduction of "improved" cookstoves. By talking with and observing both urban and rural cooks we can evaluate whether there are fuel savings resulting from the use of these stoves.

The evaluation of cookstoves is a process which begins with conversations between cooks and those conducting the evaluation. This is then followed by observations and simple measurements of the amounts of food and fuel used. If more information is needed simple quantitative measurements are made under controlled conditions.

This manual is a step-by-step description of the evaluation process. Included are:

* how to talk with cooks about cooking and fuel use.
* a listing of the kinds of information needed and sample questions.
* procedures for fuel use measurements.
* a list of equipment necessary.
* the range of probable results.
* a few cautions to be alert to.

The manual is divided into three sections. They are presented in the order in which the most information can be obtained for the least effort. Each section builds on the previous one. It is suggested that users start with the simplest techniques and pass on to later sections if more detailed information is required. The three methods of investigation described vary in what they can tell you, but used together they give a good overall picture of fuel consumption.

TALKING WITH COOKS ABOUT FUEL USE AND COOKING

Talking with cooks can tell you:

* whether fuel is being saved or not, and the approximate savings.
* the degree of awareness people have of the amount of fuel they are using.
* changes cooks have made in fuel type, amount used, fire building techniques, and other cooking and fuel consumption changes.
* the cooks' concerns about fuel.
* innovations in stove designs or methods of operating them.
* whether people perceive other benefits from cookstoves, such as freedom from smoke, convenience and safety, etc.

Talking with cooks cannot tell you:

* exact amounts of fuel used or saved.

SIMPLE HOUSEHOLD MEASUREMENTS

Simple household measurements can tell you:

* with some methods you can isolate fuel use due to cooking only.
* with other methods you can tell how much total fuel is used for cooking, heating, lighting, water heating, etc.
* through comparison tests these measurements can tell you how much fuel, if any, improved cookstoves are saving.

Simple household measurements cannot tell you:

* heat utilization efficiencies or burn rates.
* the effect of moisture content.
* the effect of individual innovation in stove design.

ISOLATED VARIABLE TESTS

Isolated variable tests can tell you:

* the amount of fuel a stove uses to cook a typical meal.
* the effect of changing a stove design or operating it differently.
* which adaptations should be discouraged because they use more fuel.

Isolated variable tests cannot tell you:

* the real reasons why cooks select either improved stoves or traditional means of cooking.

* amounts of fuel used or saved in actual use.

Fuel Use Measurements and Fuel Savings Calculations

There are two ways to calculate fuel savings, one for total fuel use (cooking, lighting, heating, etc.) and the other for cooking only. It is possible that the introduction of a stove may decrease fuel consumption for cooking but cause a slight increase in the amount used for another purpose, for example, heating (see Figure 1). Fuel needs for other uses may vary seasonally, especially for heating or a fire to sit around.

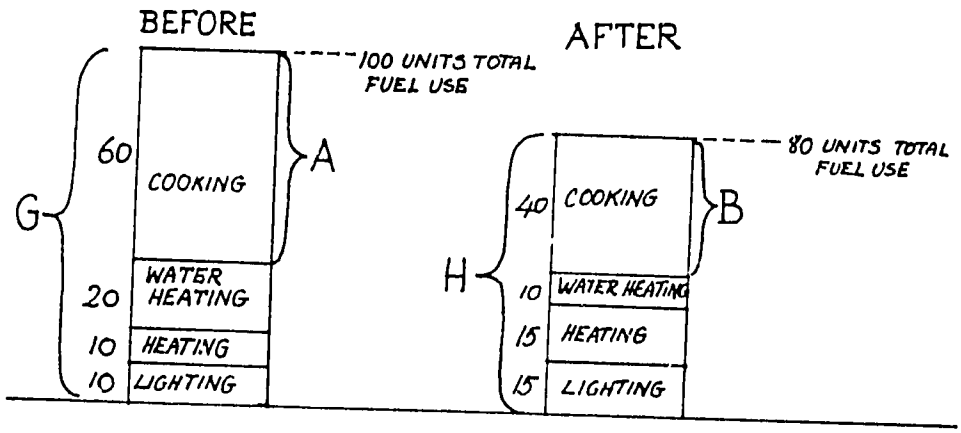


FIGURE 1 HOUSEHOLD USES OF FUEL

Total fuel savings will be calculated taking into account measures of all uses of fuel (H over G) whereas the fuel saved in cooking alone can be calculated from figures for cooking only (B over A).

Note: It cannot be assumed that an improved cookstove will save the same amount of fuel in places or under conditions other than where it is tested.

Choosing the Evaluator

Successful evaluation of cookstove performance is largely dependent on how well the evaluator can work with local people. Selecting the best evaluators may be the single most important part of the whole process.

The evaluators will be responsible for work in at least the first two methods described in this manual. They may also be involved in the third method, isolated variable tests.

Characteristics to look for in evaluators:

* Do they have genuine rapport with local people? Many educated people in poorer countries have little respect for the poorer people they work with.

* Do they live in the area or are they familiar with it? Someone who lives there has fewer barriers to overcome.

* Are they friendly and open to new experiences, ideas and other people?

* Are they willing to learn from others, especially those who may be from rural areas or different income groups?

Other qualities that will help:

* Older people are often given more respect than younger ones.

* The cooks, who are nearly always women, will often be more comfortable talking with other women, rather than to men.

* Someone who knows the local language will be most useful. Quite often women do not get the opportunity to learn other languages; therefore it will be necessary for the evaluator to possess at least a working knowledge of the local language.

In many places it may be advisable to use a man/woman team to carry out the evaluation. In this team the woman would make contacts with local women and talk with the cooks. The man would meet with the local community leaders and seek to gain support of the community for the evaluation.

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There are good reasons to talk with cooks about fuel savings and to watch how they cook in their homes. First of all, most cooks know whether they are changing their patterns of fuel use or cooking techniques. Secondly, these times together give the evaluators the opportunity to watch the cook working and look out for subtleties and innovations in fire building and maintenance. Finally, this is the best way to learn about attitudes toward new cookstoves. Does the stove affect a woman's status? Does it make the kitchen air cleaner? Are the children safer from burns? Is it now possible to keep domestic animals or rodents out of the cook pot?

To get statistically reliable results talk with cooks from at least 30 different households. Choose the households at random from among those where improved cookstoves are used. From among these 30 households it should be possible to find people willing to participate in the more detailed measurements as outlined in Section II.

Tips for talking with Cooks

* When introducing yourself make your purpose clear and tell the cook how the information she gives will be used.
* Be friendly and interested but respect the cook's definitions of space; for example, she may indicate that you should stay to one side of the kitchen when she is cooking.
* Although the discussion will be centered on traditional hearths and improved cookstoves, do not ignore other interests and concerns the cook feels. The conversation should be directed by your questions, but not limited by them.

* Be sure you know your questions very well. Use the questions as part of a conversation; do not read them word for word from a list. This improves the flow of the conversation and puts both you and the cook at ease.

* Express your ignorance of cooking practices. For instance, ask the cook to show you how she cooks a typical meal. Note how much fuel she uses and whether it correlates with what she says she uses.

* Use your hands. If you and the cook are talking about a bundle of wood, ask her to show you how big it is with her hands. Use your hands when asking: Is it this big, or this big? If the cook tells you she used the cookstove earlier in the day, feel it to see if it is warm. If not, are there warm ashes where her traditional cooking fire is? She may be saying she uses the stove even though she doesn't, so as not to disappoint you.

* Cross check your information. This will ensure that you have reliable information. Ask questions in different ways; ask contradictory questions; watch everything closely and compare with what is said. Use two methods if you can. Talk not only with the cook but also to the person who gathers or buys fuel. Talk with other people in the household, both male and female, children and adults.

* Keep clear and accurate notes. First, ask each cook if it is OK to take notes. If it is OK, take copious notes and as soon as the interview is over review them and fill in blank spaces. If you are not permitted to take notes, make the interview sessions short and more frequent, writing up the information from memory immediately after you finish talking with the cook.

During these talks you will be asking questions in many different ways. One of the easiest ways to begin is to ask the cook to describe something: Could you show me how you build a fire in your stove? What kinds of fuel do you burn in your stove? Descriptive questions can also be very specific: How big are the sticks you burn? How many do you burn to make breakfast? The cook may answer these descriptive questions with words, or she may show you the answer through her actions.

Another technique is to ask the cook to make a comparison: How does cooking with dung differ from using wood? How are they the same?

The cook may use words in new ways, or words that are new to you. It is more important to understand what the cook means than to just hear and record what she says. It is helpful to the cook if you use her own words when phrasing the questions. In order to understand her words you may have to ask what she means: You said you only used wood in your stove but you just put bundles of straw in with that wood. Are those straw bundles also considered wood?

Information Needed

* Size of household (number of people eating there regularly).
* Who does the cooking? Is there more than one cook in the family?
* Is the cooking done indoors or out?
* How many cooking hearths are used? Note types of hearths, traditional stoves or improved stoves. Make a scale drawing if the stove is not standard.
* What type of chimney does the stove have? Height of chimney.
* Types and average amounts of foods cooked and whether they vary with the season.
* Number of pots used. Materials, depth and diameters of pots. Are lids used with the pots?
* The type and amount of fuel used. Include fuel sizes, diameter and length.
* Fire and smoke observations.
* Is the stove purchased as a unit? If not, by whom and how is the stove or hearth constructed? By the cook, the man of the family, an artisan?
* Who is responsible for the maintenance and repair of the stove?

Sample Questions for the Cook

* How long have you been using your stove (use local name of improved stove)?

* How do you cook on this stove? Will you please show me?

* Do you still use your (name of traditional hearth or stove)? How often and for what foods, or occasions?

* Do you make the fire differently in your improved stove than in your traditional hearth or stove? How is the fire different? Can you show me? Do you tend or maintain it differently?

* Do you use the same kind of fuel as before? Do you use different kinds of fuel now? What kinds? Do you use the same sizes of firewood? Bigger? Smaller?

* Does your new stove use more or less fuel than your traditional method of cooking? How much do you use now? How much before?

* Do you collect your own wood? If not, who does? How often must it be collected? Every day, every other day, twice a week? How much each time? How far do you go? Where do you get it?

* Do you buy wood? How much does it cost you each time? How often do you buy it now? How often before you had this stove?

* How long does a (use standard measurement for the area: cartload, bundle, number of sticks, certain amount's worth) of wood last in cooking on your new stove? How long did the same amount last with the traditional method of cooking?

* Do you use other methods for conserving wood? Please show me.

* If you could change your stove in some way to make it work better for you, what would you change?

For doing isolated variable tests only, construct a typical local cooking profile. This profile includes:

* a description of a typical day's use of the cookstove.
* the amount of food being cooked at each meal.
* the kinds of pots used for each typical meal and whether lids are used.
* a description of any other fuel use (heating, lighting, water heating, etc.).
* the average amount of fuel which is used for each task.
* a standard cooking timeline showing the progression of how food is cooked, for how long and over what heat, for morning, noon and evening meals.

Sample timeline:

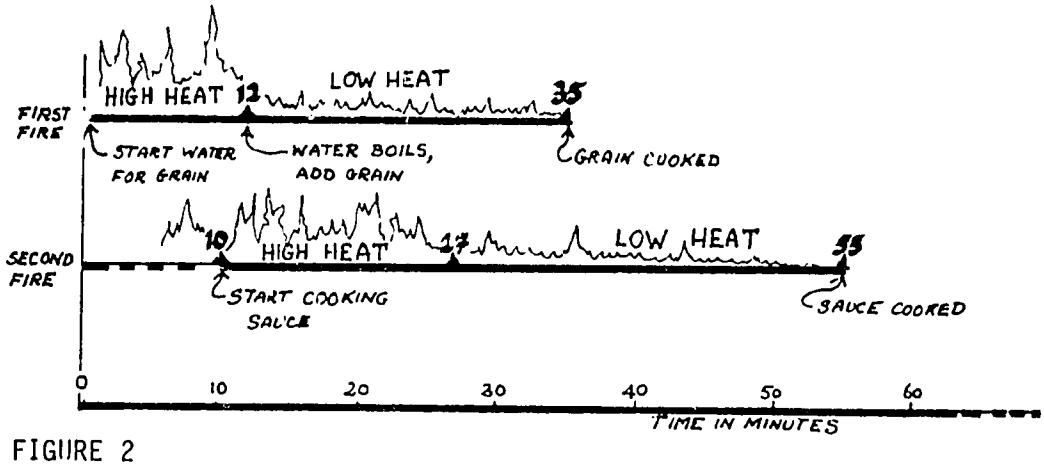

FIGURE 2

Do a number of sample timelines for typical meals with several different cooks until you feel you have a good average. They should define events which occur during cooking: lighting the fire, rice coming to a boil and simmering, sauce boiling, etc.

Note: It is important to stay in contact with people who have been especially helpful. Let them know the results of this evaluation and pass on to them any fuel-saving tips you may have learned in the process. Comment on things they have taught you.

SIMPLE HOUSEHOLD MEASUREMENTS

Several different methods can be used to determine fuel saved by improved stoves. Each method gives a statistically significant measure of fuel used. Differences in fuel use due to the cook's performance, amount of food cooked, moisture content in the fuel, and stove construction can be minimized through averaging.

Each community which uses improved cookstoves is unique. Here are four methods that can be locally adapted to measure the amount of fuel saved:

* SINGLE MEAL MEASUREMENTS
* COST COMPARISONS
* WOODSTACK MEASUREMENTS
* MODIFIED KAYA TEST

WHAT SIMPLE HOUSEHOLD MEASUREMENTS CAN TELL YOU:

* with some methods you can isolate fuel use due to cooking only.
* with other methods you can tell how much fuel is used for cooking, heating, lighting, water heating, etc., combined.
* through comparison tests these measurements can tell you how much fuel (if any) improved cookstoves are saving.

In measuring fuel consumption it is necessary only to record the dry weight of the wood consumed, not its species or volume. The major difference between woods is their densities or weights, but pound for pound most woods have similar energy content (about 4800 kJ per kg at 15% moisture content). Note, however, that the energy content of other fuels (charcoal, peat, dung) is different.

Single Meal Measurements

This is a simple way of gaining a general idea of the fuel savings from improved cookstoves. In these measurements, the fuel for cooking the main meal of the day is weighed and recorded. Measurements made on a large number of both traditional and improved stoves will give a fair idea of relative fuel savings.

Requirements:

* a portable scale that measures to within 10 grams.
* an evaluator fluent in the local language.

Procedure:

Find in the community 10 or more improved stove users and an equal number of traditional hearth or stove users who will allow you to make fuel measurements. Observe each cook in action. Measure the amount of food in pots either by weight or by graduated marks on pot walls. Make measurements of the amount of fuel each cook uses by weighing the fuel before and after the main meal is cooked. Compare the fuel used in the traditional stove to that used in the improved stove. (See Fuel Savings Calculations, page 18.)

Things to be careful of:

* be sure the cook is not cooking something special because of your presence.
* large variations in the size of the households. Choose families of similar average size.
* small samples which do not represent the population. Larger samples will give more reliable results.
* be sure that additional fuel is not added to the pile, or that a mixture of fuels is not being used (wood with dung or charcoal for instance).
* make sure the cook uses only one stove for each meal.
* remember that this method will tell you little about fuel used for secondary meals unless you test them separately.

Cost Comparisons

A comparison can be made between the cost of fuel for traditional and improved stoves. Cost comparisons are most applicable in the major cities or anywhere fuel is usually purchased, rather than collected. Fuel costs will necessarily include all fuel uses, not just cooking. This enables one to assess the total fuel savings, not merely the relative savings over traditional cooking methods (see Fuel Savings Calculations, page 18.) Results will be more accurate if prices for fuel are stable and if fuel is sold by weight, not volume.

Requirements:

* no special equipment needed.
* an evaluator fluent in the local language.

Procedure:

Conduct a survey in the area to determine which households have improved cookstoves. Randomly choose at least 10 of these households to be the sample population. Ask them to record their fuel purchases for a three month period. Compare these purchases with a randomly chosen sample of households of comparable size which use traditional stoves.

Things to be careful of:

* changes in fuel prices.
* a change in the amount of fuel in storage. Measure this and record it at the beginning and end of survey period.
* other fuel being used which is not bought or recorded.
* changes in the types of fuels being used when improved cookstoves are introduced.
* make sure cost comparisons are over the same period; costs may fluctuate seasonally.

Woodstack Measurements

In areas where wood is collected seasonally or bought in large quantities, woodstack measurements can be used to determine fuel savings. These measurements will indicate the total amount of wood used for cooking, heating and lighting and will provide a comparison of savings in overall fuel use after acquiring improved cookstoves.

Requirements:

* a portable scale which is capable of measuring to the nearest 10 grams.

* an evaluator who is fluent in the local language.

Procedure:

Randomly choose at least 10 families with improved cookstoves of a particular design and a similar number of families without stoves or with traditional stoves. Ask them all to be part of the evaluation and explain its purposes. Weigh the wood in the woodstack after gaining assurance from the cooks that there is more than enough fuel for cooking, heating and lighting during the coming week. Give careful instructions to use only the wood from the stack. Do this on the same day at all 20 houses.

Return periodically throughout the week to check for questions and low fuel supplies. Exactly one week after the start of the test weigh the remaining woodstack. The measurements should be done several times during the year since different fuels and foods might be used.

Alternative method:

Choose an area where cookstoves are being introduced. Randomly choose A) 10 households without improved stoves, B) 10 with improved stoves, and C) 10 which would like improved stoves. Test A and B simultaneously with C before C get their new stoves. Then test C again after stoves have been built and the cooks are used to using them. The Fuel Savings Factor between A and B should be the same as for C, before, and C, after. If it is very different, you must question your methods.

An interesting check is to arrange with B to cook without their improved stoves, in traditional manner, and record their fuel use. This may tell you whether the action of acquiring an improved stove creates sufficient awareness of fuel economy to actually create a saving. Run all tests for one week.

Things to be careful of:

* unweighed additions to the woodstack during the week.

* other types of fuel which might be used.

* in some areas the daily fuel supply will partially come from the woodstack and partially be collected off the ground nearby and placed directly on the fire.

* differences in moisture content. Check that all fuel for a given house is either straight off the tree or is well dried; partially dry wood with varying moisture contents can affect the fuel use considerably. Comparisons can only be made between houses using all dry or all green wood.

Modified Kaya Test

The Kaya test directly compares the amount of fuel used in traditional versus improved cookstoves. It is best suited to areas where stoves have recently been introduced and/or where there is only a small sample of improved cookstoves available for testing.

The tests are conducted over a two week period during which time the cooks are asked to alternately use traditional and improved cookstoves every other day, according to the following schedule:

Day 1: Traditional hearth or stove
Day 2: Improved stove
Day 3: Traditional hearth or stove, etc.

Requirements:

* a portable scale that measures to the nearest 10 grams.
* test evaluators fluent in the local language.
* a minimum of five improved cookstove users who are well accustomed to using their stoves and are willing to participate in the test. With fewer than five, statistical accuracy falls rapidly. The cookstoves should all be similar.

Procedure:

1. Conduct a survey in the area to find improved cookstoves of similar design which can be used for testing.
2. Talk with the users, and determine if they would be willing to be part of a two week test in which they would use both the traditional and the improved stoves.
3. After agreement is reached on their involvement in the test, set aside a sufficient amount of wood to be used for cooking the next day's meals. Record its weight.
4. Ask the cook to use only this fuel in cooking the next day's meals on the traditional stove.
5. Return the following day and weigh the wood that remains. Then weigh out enough wood for use the next day and ask the cook to use it with the improved stove.
6. Continue this testing according to the cooking schedule.

Note: A substantial portion of this test was outlined by Dutt in "Field Evaluation of Wood Stoves", February, 1981.

The household will need to be visited once each day. During these visits the wood should be weighed and the cooks reminded of which stove to use for the following day's meals. Information on the weight of wood used, the number of people who ate each meal, the amount of food cooked, significant happenings during the day, and which stove was used should all be recorded. Any additional helpful observations such as fuel characteristics, fire operation, or unusual weather conditions should also be made.

Things to be careful of:

* be sure the cook uses only that wood which was weighed.
* in order to assure normal amount of usage, the wood should be acquired by the users in the usual manner.

Note: This test can measure either total fuel savings or savings due to cookstove use alone. If the measured fuel is used for cooking, heating, lighting, etc., then the total fuel savings are being measured. If the measured fuel is used only for cooking, then it is measuring the fuel savings due to cookstove use only.

What to do with the Simple Household Measurements

The purpose of the simple household measurements is to determine if improved cookstoves are saving fuel. This can be done by comparing measurements of the amount of fuel used by traditional stoves to that amount used by improved stoves.

In the tests, measurements are made under similar conditions and a representative sample is used to obtain an average. The average for each type of stove can be calculated according to the following equation:

$$\text{Average Amount of Fuel Used by Traditional or Improved Stove} = \frac{\left(\begin{matrix}\text{Fuel}\\ \text{used in}\\ \text{Test \#1}\end{matrix}\right) + \left(\begin{matrix}\text{Fuel}\\ \text{used in}\\ \text{Test \#2}\end{matrix}\right) + \left(\begin{matrix}\text{Fuel}\\ \text{used in}\\ \text{Test \#3}\end{matrix}\right) + \ldots\ldots}{\text{Total Number of Tests}}$$

The average from the two stoves can be simply compared by looking at the differences between them. A more complicated but useful way of comparison is through a fuel savings factor:

$$\text{Fuel Savings Factor} = 1 - \left(\frac{\begin{matrix}\text{Average amount of fuel}\\ \text{used by the Improved Cookstoves}\end{matrix}}{\begin{matrix}\text{Average amount of fuel}\\ \text{used by the Traditional Stoves}\end{matrix}}\right)$$

It is important to note that:

* The fuel savings factor can be calculated in two ways. Total fuel savings is different from that for cooking alone. Total fuel savings are being calculated when measurements are made of total fuel use. Fuel savings from cooking alone are being calculated when only the fuel for cooking is measured. (See Figure 1.)

* Larger samples give more reliable results. The number of people we have suggested should be considered to be a minimum sample size. If the results seem inconsistent, use a larger sample size. A more detailed statistical analysis, though not required, might be helpful. (See Appendix A.)

From experience of improved stoves already tested in Africa, you should expect fuel savings of between 20 and 50 percent. Higher or lower figures might lead you to examine your evaluation methods. If you find no error in your methods, the stoves are either exceptionally efficient or unusually inefficient. Find out why.

ISOLATED VARIABLE TESTS

Fuel savings due to changes in stove design or operating conditions can be determined by using isolated variable tests. These tests provide a quantitative measure of the amount of fuel used to cook a typical meal. The information gained from them can tell how much a single design modification changes the amount of fuel used. Because many household conditions will not be replicable these tests should be used only for stove design improvements, not for the projection of how much fuel can be saved in the field.

Isolated variable testing speeds the evolutionary process of stove design by testing and evaluating new stove ideas. These design ideas, most of which should come from the local people, will help develop a stove uniquely adapted to local cooking and fuel conditions.

WHAT ISOLATED VARIABLE TESTS CAN TELL YOU:

* the amount of fuel a stove uses to cook a typical meal.
* the effect of changing a stove design or operating it differently.
* which adaptations should be discouraged because they use more fuel.

The purpose of testing stoves under controlled conditions is to develop a design which conserves fuel or has some other desirable quality which will improve the likelihood of the cookstove being used in the area. To make the test as relevant as possible to local conditions it is important to:

* use cooks who are experienced in cooking local foods.
* maintain environmental conditions which are similar to those in households; for instance, don't test outdoors if cooking is done inside, or don't test with pot lids on if people seldom use them.

Only one variable can be tested at a time. All other differences should be minimized. Special attention should be given to standardizing these things:

* The Cook: her cooking behavior, the sequence of cooking operations, and how she stokes the fire.
* The Fuel: its species, size, and moisture content.
* The Cooking Pots: their shape, materials and size.
* The Stove Construction: its materials and design.
* Weather: especially the effect of wind.

The Organization

Testing improved stoves should take place in regional test centers. These test centers should be located in the areas where the stoves are used, and where they are readily accessible to the general public. They should be close enough to the communities to insure that altitude, weather, and other environmental factors will be similar to local conditions. The food and fuel used should come from the same sources that a typical household in the community would use. Be sure the supply of fuel can be maintained for the duration of the test.

Local people should be employed and consulted as much as possible in the construction and testing of stoves. As the community becomes involved in the program the people will identify with the stoves and offer design ideas.

Cooking tests should be conducted by two or three women from the community who are experienced in the cooking of local foods. Having several cooks participate in the tests will eliminate differences in

cooking styles and provide a more consistent measure of when the food is cooked. As a group, they will be stronger than a lone woman in offering suggestions in stove design and testing procedures.

How to do an Isolated Variable Test

The isolated variable test should closely approximate cooking as practiced by people in the local community. The amount of fuel needed to cook a standard meal is measured on a modified versus an unmodified stove. Use standard cooking timelines (see page 10). Several identical main meals and secondary meals are cooked in sequence on each stove. A comparison can then be made of the average amount of fuel needed for cooking.

Stoves which are tested should be identical to those used locally. Building materials, design faults, defects in construction, and any other idiosyncracies of local stoves should be copied carefully. The modified and unmodified stoves should differ only with respect to the one variable being tested. In order to assure similarity of results, tests should be conducted according to the following schedule:

Test #1: Test modified stove. Gain familiarity with its operation. Do not use results in the analysis.

Tests #2,4,6: Test traditional or unmodified stove. Use cooking sequence for the main meal.

Tests #3,5,7: Test modified stove. Use cooking sequence for the main meal.

Tests #8,10: Test traditional or unmodified stove. Use cooking sequence for the secondary meal.

Tests #9,11: Test modified stove. Use cooking sequence for the secondary meal.

Requirements:

* an area protected from rain and wind.
* a scale which measures to the nearest 1 gram.
* building materials and equipment for stove construction.
* several cooks who are experienced in cooking local foods.

Procedure:

Weigh fuel at the beginning of the test. Start fire using the method which is used in the area. Record the starting time. As events happen record the time they occur. Cook the meal according to the timeline to approximate local cooking. When the cooks decide that the food is cooked weigh the fuel that remains. Throughout the test write down comments about the ease of operation, smoke, and amount of fire tending.

Cautions and Comments:

* All testing should be done on a cold stove.
* Checks should be made to see if the cooks are burning an excess amount of fuel. Correlate the amount of fuel being used by the cooks with that which is used in typical cooking in the community.
* Additional tests should be run if large variations occur in the data.
* Use lids on pots only if they are regularly used in the area.

Simple Statistical Analysis

You can determine if the fuel consumed by traditional and improved stoves is significantly different by comparing confidence intervals. A confidence interval is a projection from the fuel use measurements of the range within which the average for the total sample will fall. This interval is directly dependent upon the degree of confidence you choose, the number of measurements made, and the amount of variability in the measurements.

Steps in Solving for the Confidence Interval

1) Calculate the Average, x, for the sample.

$$x = \frac{\left(\text{Measurement } \#1\right) + \left(\text{Measurement } \#2\right) + \left(\text{Measurement } \#3\right) + \ldots\ldots\ldots}{\text{Total number of measurements made, } n}$$

2) Calculate the Standard Deviation, s.d.

$$\text{s.d.} = \sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n - 1}}$$

a) The caculation of the standard deviation is most easily done by using a table.

Column 1 Measurements from a single series of tests, x	Column 2 x^2
(Measurement #1) + (Measurement #2) + (Measurement #3) + . . .	(Measurement #1)^2 + (Measurement #2)^2 + (Measurement #3)^2 + . . .
Total sum of all measurements	Total sum of all measurements squared

b) Now, substitute into the equation:

$$\text{Standard Deviation} = \sqrt{\frac{\left(\text{Total from Column \#2}\right) - \frac{\left(\text{Total from Column \#1}\right)^2}{\text{Total number of measurements}}}{\left(\text{Total number of measurements}\right) - 1}}$$

3) Determine the t-distribution factor, μ, from the table.

a) Choose the amount of confidence you wish to have in the result. We suggest using a 95% level of confidence.

b) Look in the table and find the distribution factor, μ.

	Total Number of Measurements							
	2	3	4	5	6	7	8	9
Level of 90%	6.314	2.920	2.353	2.132	2.015	1.943	1.895	1.860
Confidence 95%	12.71	4.303	3.182	2.776	2.571	2.447	2.365	2.306
Desired 99%	63.66	9.925	5.841	4.604	4.032	3.707	3.499	3.355
	Total Number of Measurements							
	10	12	14	16	18	20	25	30
Level of 90%	1.833	1.796	1.771	1.753	1.740	1.729	1.706	1.696
Confidence 95%	2.262	2.201	2.160	2.131	2.110	2.093	2.056	2.040
Desired 99%	3.250	3.106	3.012	2.947	2.898	2.861	2.779	2.744

4) Calculate the Confidence Interval

$$\bar{x} - \frac{(\mu)(\text{s.d.})}{\sqrt{n}} < \bar{x} < \bar{x} + \frac{(\mu)(\text{s.d.})}{\sqrt{n}}$$

Things to be careful of:

* The range of the confidence interval varies in proportion to the number of measurements. To decrease its size, take more measurements.

* Be sure that the measurements all are measuring the same thing. Do not use any measurements in the calculations which do not follow the established test procedure.

Note: Statistical precision is not the most important goal of this type of investigation. Provided stoves are saving fuel, it may be more important to spread stoves to the hundreds of millions of households which could benefit from their use than to direct all our efforts into precise measurements of exactly how much fuel a particular stove saves.

Cookstove News, a quarterly, published by Aprovecho, 442 Monroe Street, Eugene, Oregon 97402, U.S.A.

This journal reports on international cookstove projects, developments in fuelwood saving technologies and related topics, including testing procedures. Contributions are welcome.

Dutt, Gautam S., "Field Evaluation of Wood Stoves" (with special reference to Africa), Volunteers in Technical Assistance, 3706 Rhode Island Avenue, Mt. Ranier, Maryland 20822, U.S.A., February 1981.

This paper outlines how stove design features can be optimized with fuel use data from representative households.

Evans, Ianto and Michael Boutette, Lorena Stoves, Volunteers in Asia, Box 4543, Stanford, California 94305, U.S.A., September 1981.

A 90 page construction manual for stoves using the lorena sand/clay system. It also covers some testing procedures.

Geller, Howard S., "Cooking in the Ungra Area: Fuel Efficiency, Energy Losses, and Opportunities for Reducing Firewood Consumption", a report to the Center for Application of Science and Technology to Rural Areas, Indian Institute of Science, Bangalore, 560 012, India.

Examines the cooking efficiency of a traditional rural Indian cookstove. Cooking simulation tests were conducted for quantitative analysis of heat losses.

Helping People in Poor Countries Develop Fuel-Saving Cookstoves, GATE, c/o GTZ, Postfach 5180, D-6236 Eschborn 1, Federal Republic of Germany, 1980. (Free to development workers.)

This manual covers all aspects of developing a program for fuel-saving cookstoves. It emphasizes the importance of local participation in every phase of program design and execution.

Joseph, Stephen and Yvonne Shanahan, "Designing a Test Procedure for Domestic Woodburning Stoves", Report No. 3.1, Intermediate Technology Development Group, 9 King Street, London, WC2E 8HN, England, November 1980.

A 37 page report which outlines information required to assess stove suitability in the field and details both field and laboratory tests to evaluate design performance.

Lou Ma, Roberto, Evaluación de la Eficiencia y Utilidad de Pequeñas Cocinas a Leña para el Area Rural, Centro de Ingenieria, Ciudad Universitaria, Zona 12, Guatemala, January 1981.

A report (available in Spanish) on the relative thermal efficiencies of improved cookstoves including the HERL Chula, the Ghana stove and the Lorena.

User Response Sheet

We at Aprovecho would like to know how useful this manual has been to you for evaluating the fuel consumption of improved cookstoves. Please let us know which methods you used and what your results were with each method.

TALKING WITH COOKS ABOUT FUEL USE AND COOKING:

SINGLE MEAL MEASUREMENTS:

WOODSTACK MEASUREMENTS:

COST COMPARISONS:

MODIFIED KAYA TEST:

ISOLATED VARIABLE TESTS:

If you have other suggestions or criticisms, please let us know.

Aprovecho, 442 Monroe Street, Eugene, Oregon 97402 USA