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BASIC GUIDE TO FUEL EFFICIENT STOVES AND EMISSION TESTING

Photo: Cassandra Nelson/Mercy Corps, 2009

BACKGROUND

Around the world two billion people still rely on highly inefficient three-stone fires for their cooking needs[1]. The global burning of biomass leads to deforestation and contributes up to 40% of the emissions of CO2 and other greenhouse gases[2]. Three-stone fires also emit high levels of black carbon (soot particles), which are now thought to play a large part in global warming[3]. In addition to these environmental concerns, the burning of biomass poses serious health hazards. Pollution levels in homes and huts from incomplete combustion can exceed levels measured in industrial cities – posing particular threats to women and children. These indoor pollution levels are firmly linked to acute respiratory infections (especially in children) and result in an estimated 4.3 million deaths a year. They are also linked to pulmonary disorders, complications in pregnancy and eye infections.

The simple act of food preparation is, therefore, arguably one of the most pressing health and environmental issues for developing countries. Addressing energy poverty through increasing the uptake of fuel efficient stoves (FES) has the dual benefits of directly improving the livelihoods of the poorest while playing a role in mitigating climate change. Not all stoves perform equally well; unless measures are taken to check the performance of the stove there is a risk of introducing an inefficient product, providing marginal benefits at best over the original cooking technology. This simple guide lists some of the considerations that projects need to think about when choosing a stove in addition to providing information on some of the tools than can be used to help judge performance.

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[1] Luoma, Jon R. *Environmental 360*. 8th March 2010.
[2] Kammen, Daniel M. *Hedon Magazine*. 1994, Issue 34.
[3] Vidal, John. *The Guardian*. 28th April 2009.

STOVE TYPES

There are numerous versions of FES around the world and over 100 organisations are involved in designing and making them. Depending upon the type of stove chosen, the reduction in wood use can range from 25-60%. The technologies vary – from the basic mud stove to factory manufactured metal stoves. Selecting the most appropriate design will depend upon a number of contextual factors including:

- **Wood-fuel use**[4] – some stoves are designed for charcoal and some for fuel wood. Although charcoal is much more efficient for cooking than fuel wood, the production process uses large quantities of wood and is highly polluting unless it is done under controlled conditions. Mercy Corps would therefore encourage the use of efficient wood burning stoves or the use of briquettes made from compressed agricultural waste in charcoal stoves.

- **Stove construction** – wood burning stoves are mostly made from mud, mud/metal or metal while charcoal stoves are usually constructed from metal because they involve higher burning temperatures. A few stoves have been specifically designed to use pelletised waste agricultural material.

- **Stove efficiency** – stoves vary significantly in performance so it is crucial to look at the materials being used and the construction methods. The efficiency of simple mud stoves can be easily enhanced with the incorporation of straw or hay into the mud mix. The addition of a metal "skirt" also improves combustion and stove performance. The quality of metal stoves is dependent upon the design of the stove and the metal used. Bioenergy designs (http://stoves.bioenergylists.org) is one the most comprehensive sources of information on basic construction methods and ways to improve thermal properties. Boiling Point, a practitioner's journal produced by Hedon (www.hedon.info/boilingpoint), is also a very useful resource. Factory manufactured stoves (either from an in-country source or overseas) will usually be the most efficient overall but transport of these to remoter areas may be costly and difficult. However, if carbon credits are being pursued then consistency of performance of factory manufactured stoves may be helpful.

- **Stove lifespan** – the lifespan of the stove depends on a number of factors including the construction material (mud or metal), the quality of the materials, and how well maintained the stove is. Obviously stoves with a longer lifespan are preferable and the hope would be that the fuel and cost savings from using a FES would encourage households to replace their stove when it does reach the end of its lifespan.

- **Stove maintenance** – cracked or broken stoves will not perform efficiently and may lead to discontinued use. For this reason it may be most appropriate to use mud, or simple mud/metal stoves, which can be easily maintained and repaired in rural areas. Stove users in urban and peri-urban areas will also need access to a repair or spare part facility.

- **Cultural issues** – it may be preferable to adopt a lower performance stove if cultural preferences indicate that it is more likely to be used. However, cultural preferences can change – particularly if the project raises awareness of environment issues or highlights the economic benefits of using a FES.

- **Employment creation** – factory manufactured stoves will not help with local job creation – particularly if the stoves are imported from another country. If this is one of the aims, the project might want to promote simple mud stoves or a combination of mud and metal that can draw on, or increase, local metal working skills.

- **Stove location** – cooking preferences, and whether the stove is also used for indoor heating, will determine whether households prefer to use a portable or fixed stove. Fire risk and child supervision may also be factors.

[4] Woodfuel is used to denote all fuels derived from woody biomass including charcoal, as opposed to fuel wood, which is understood to mean wood in its original form.

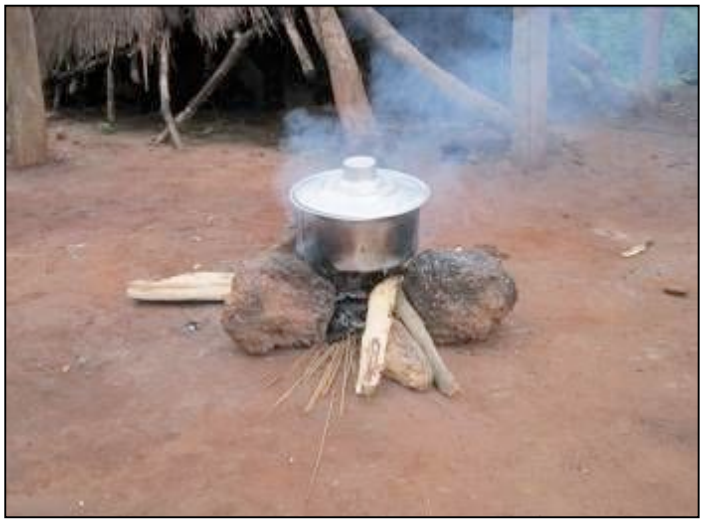

Photo: Three-Stone Fire (Elisha Moore-Delate/Mercy Corps)

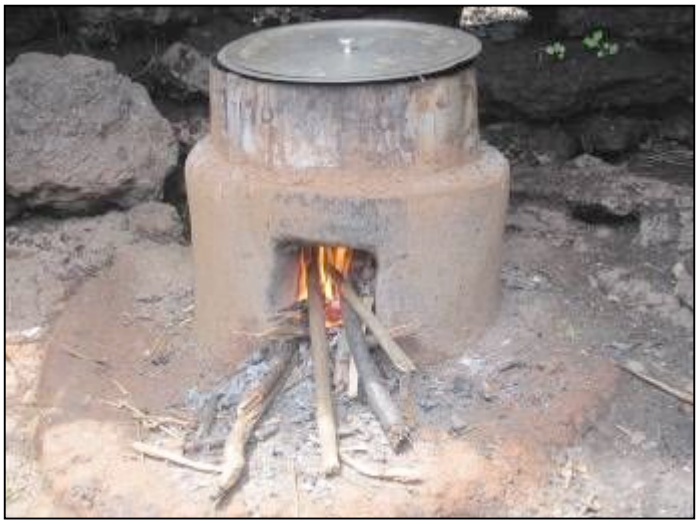

Photo: Mercy Corps DRC FES (Elisha Moore-Delate/Mercy Corps)

IMPROVED COOKING METHODS

The cooking methods used by householders are almost as important as the type of stove chosen and most projects will need to provide some training to improve cooking methods. A number of simple techniques will ensure the optimum performance of the stove:

- Keep any gap between the cooking pot and the stove (the annulus) as small as possible and preferably not more than 2cms;
- Ensure that pot lids are kept on during cooking;
- Encourage the use of dry wood wherever possible;
- Pre-soak appropriate foods such as pulses and beans;
- Encourage use of a pot with as large a base as the FES will reasonably accommodate to maximise the heat transfer area;
- Do not overload the stove with wood and avoid wood protruding from the fuel inlet by using smaller pieces.

MEASURING STOVE EFFICIENCY

Companies producing manufactured stoves will likely be able to provide figures for stove fuel efficiency but these should be verified in a field context and comparisons made between the various stove types to ensure that the project is choosing the most efficient stove and is able to deliver the impact that it is claiming. If the project is proposing to use locally produced stoves, the fuel efficiency of the various options should be calculated before a decision is made on which stove to promote. Two tests are widely used for determining relative efficiency. The first of these is the **Water Boiling Test** (WBT), which is a simple test to measure the amount of fuel needed to bring a known quantity of water to boiling point – the more efficient the stove the shorter the time required, with less fuel consumed. The **Controlled Cooking Test** (CCT) is then used to simulate a normal cooking regime. Testing for both the WBT and CCT is straightforward but does require accurate scales to weigh the amounts of wood used in each test and thermometers to ensure consistency in determining the boiling point. See Annex 1 for a description of how to conduct these tests.

KITCHEN PERFORMANCE

Just measuring the efficiency of stoves is not enough – we need to be able to demonstrate that use of the stoves is having the desired impact. The **Kitchen Performance Test** (KPT) allows us to do this in two ways: the first assesses the qualitative aspects of stove performance through household surveys, while the second compares the impact of the FES on fuel consumption in the kitchens of project households. See Annex 3 for a description of how to conduct a KPT.

AWARENESS RAISING

The information from the stove performance tests and the kitchen performance tests is important for demonstrating project impact but is also vitally important for ensuring that householders understand the reasons behind the project and the benefits that will accrue to them (reduced deforestation, reduced time collecting fuel wood, improved health and improved livelihoods through a reduction in the amount of household income spent on fuel). Access to this information will encourage the householder to replace their stove with a new one when the existing one reaches the end of its lifespan.

SAMPLING

If the project is selecting stoves based on comparative fuel efficiencies of different stove types, then random sampling does not need to be carried out. However, if the reductions in wood use between the traditional three-stone fire and the FES are being used to generate carbon credits, it is important that random sampling is used for all the tests. The minimum requirements for this are provided below:

Group size	Minimum sample size
< 300	30
300 to 1000	10% of group size
> 1000	100

Please see the guide, "Ten Steps to Setting up Carbon Credits" for more information:
https://mcdl.mercycorps.org/gsdl/docs/10StepstoSettingupCarbonCredits.pdf

Information on other resources and stove design, construction and monitoring is available from the Climate Change Unit. Contact: Dory McIntosh – Energy and Climate Manager (dmcintosh@uk.mercycorps.org)

ANNEX 1

Water Boiling and Controlled Cooking Tests

The Water Boiling Test (WBT)

There are a number of ways to conduct the WBT. Mercy Corps uses the simple test outlined below:

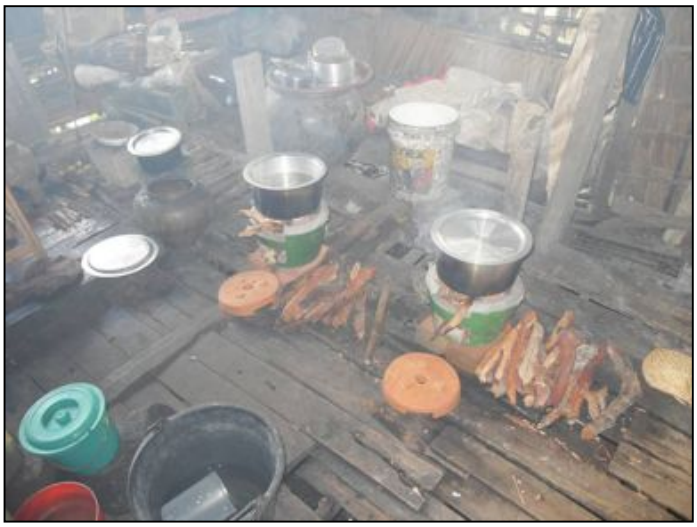

Photo: Water Boiling Test (James Stewart/Mercy Corps)

1. Ensure that the cook-stove to be tested is on level ground and in a safe location
2. Accurately weigh 4kg air-dried fuel wood and place near to hand
3. Begin a hot fire with minimum smoke (do not over-load fuel wood)
4. Measure 3 litres cold water into the pot
5. Record the water temperature
6. Place pot with lid over established flame
7. Record the WBT starting time
8. Manage the fire for good flame, good heat, fast boil, minimum smoke until water boils
9. Record the WBT finish time
10. Remove the lid from the pot
11. Record the water temperature
12. Record the weight of the remaining wood, including any that is unburned in the cook-stove (without extinguishing the fire!)

Projects can also choose to use the widely adopted, but slightly more detailed, **Shell/Berkeley methodology** (http://ehs.sph.berkeley.edu/hem/page.asp?id=42) that tests stove performance from a cold start test and a hot start. The same quantities of wood and water can be used as in the Mercy Corps methodology.

1. *Cold-start high-power test:* The tester begins with the stove at room temperature and uses a pre-weighed bundle of wood or other fuel to boil a measured quantity of water in a standard pot. The tester then replaces the boiled water with a fresh pot of cold water to perform the hot start.

2. *Hot-start high-power test:* This follows immediately after the first test while stove is still hot. The tester uses a pre-weighed bundle of fuel to boil a measured quantity of water in a standard pot. Repeating the test with a hot stove helps to identify differences in performance between a stove when it is cold and when it is hot.

The Controlled Cooking Test

The purpose of the controlled cooking test is to test stove performance while simulating actual cooking conditions. Again there are different ways to do this, each with advantages and disadvantages. Some tests recommend cooking a typical meal in a realistic kitchen setting. However, uniformity can be lost if there are variations in quantities/ingredients and the decision on when something is "cooked" can be highly subjective. For this reason Mercy Corps has been using a simplified (but very accurate) method which involves simmering water for a set amount of time. The simmering represents the cooking period (even if nothing is cooked) while the set time removes any subjectivity.

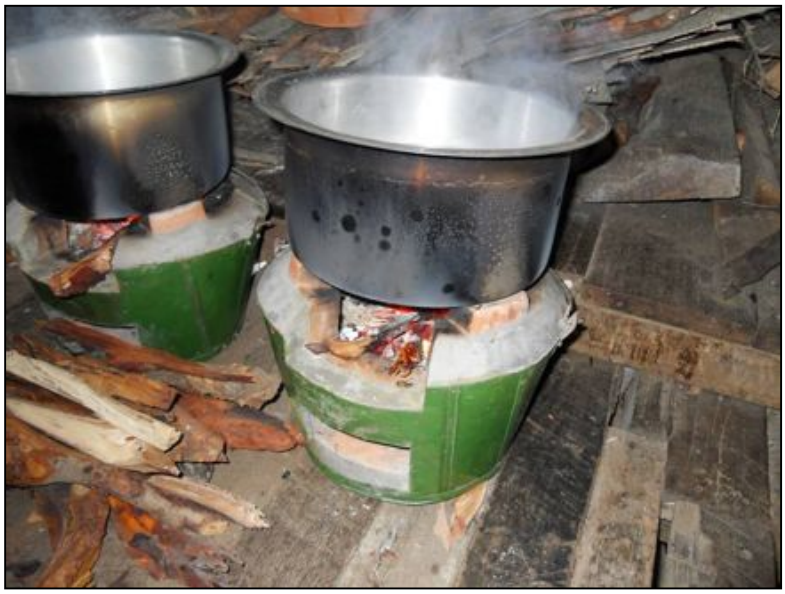

Photo: Controlled Cooking Test (James Stewart/Mercy Corps)

This simple method is outlined below:

1. Start the CCT straight after the WBT has been completed
2. Manage the fire with minimum smoke for a slow, rolling boil for 60 minutes with lid removed
3. Record the CCT finish time
4. Record the weight of the pot with the remaining water
5. Discard the remaining water safely or offer to householder for cooking
6. Record the weight of the empty pot
7. Record the weight of wood remaining in reserve, including any that is unburned in the cook-stove
8. Remove the cook-stove to a safe position
9. Confirm all necessary entries have been made on the Stove Test Record Sheet, including details/signatures of those involved (See Annex 2)
10. If necessary, further analysis of the test results, including fuel wood saving and carbon emission reduction against baseline, can be obtained by interpreting the records of the original baseline three-stone fire and FES tests.

Again, projects can choose to use the Shell/Berkeley methodology (http://ehs.sph.berkeley.edu/hem/page.asp?id=42). This is more detailed and would allow Mercy Corps projects to be directly compared with others around the world. However, since it requires the cooking of a normal meal by the household it does involve a subjective decision on when the meal is "done".

ANNEX 2

Stove Test Record Sheet

Item No	Question	Response		
1	Date of test			
2	Name of test supervisor			
3	ID No of test supervisor			
4	Location of stove in HH			
5	Name of test operator			
6	Occupation of test operator			
7	Type of cook-stove – ***"tick"***	***3-stone***	***FES***	
8	Identify FES – ***"tick"***	***Model 1***	***Model 2***	***Model 3***
9	Signature of test operator			
10	Signature of test supervisor			
For office use only >>>>>>>		Record Serial No:		

Process Measurements

TABLE 1 – Water Boiling Test

TEST	Water temp start (deg C)	Water temp finish (deg C)	Water temp rise (deg C)	Time start	Time finish	Time taken (min)	Vol. water start (litres)	Vol. water finish (litres)	Water evap. (litres)
WBT							3	3	Nil

TABLE 2 – Controlled Cooking Test

TEST	Time start	Time finish	Time taken (min)	Vol. water start (litres)	Weight of pot with water (kg)	Weight of pot empty (kg)	Weight of water remaining (kg)
CCT			60	3			

TABLE 3 – Fuel Wood Consumption

TEST	Weight of fuel wood at start (kg)	Weight of fuel wood at finish (kg)	Weight of fuel wood consumed for test (kg)
WBT			
CCT			

ANNEX 3

The Kitchen Performance Test

The Qualitative Survey

There are two stages to the qualitative survey. The first stage identifies basic socio-economic information about the household, including members of household, income levels, and fuel sources, in addition to gathering information on normal cooking practices. Because of the type of information that this survey gathers, it should be undertaken before stoves are sold or distributed. The second stage of the qualitative survey should be conducted a month after the stove has been in use and will identify both strengths and weaknesses in the stove's performance as well as identify any changes in the economic or demographic status of the household. It might be useful to carry out a simultaneous survey in households that did not adopt the improved stove to better understand why some adopt it and others do not.

The test should be conducted in the communities where the stove project is underway and participating families chosen on a random basis to avoid bias. If there are wide variations in the characteristics of the target populations (socio-economic, fuel use or environment) then clusters of sampling will need to be undertaken to take this into account.

Quantitative Test on Fuel Consumption
The test on fuel consumption can be done in one of two ways:

1. *Paired-sample study*: households measure fuel wood consumption while using the traditional stove for a period of time, preferably 3–7 days. This is followed by daily measurements carried out by the same households using the improved stove for the same period of time. This type of test allows a direct comparison of the family's fuel use with the three-stone fire and with the improved stove in a real setting.

2. *Cross-sectional study*: fuel consumption in two or more groups of families is compared for a period of 3–7 days, with one group using the traditional stove and the other group(s) using the improved stove(s).

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