Kitchen Performance Test (KPT)

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The Kitchen Performance Test (KPT) is the principal field-based procedure to demonstrate the effect of stove interventions on household fuel consumption. There are two main goals of the KPT: (1) to assess qualitative aspects of stove performance through household surveys and (2) to compare the impact of improved stove(s) on fuel consumption in the kitchens of real households. To meet these aims, the KPT includes quantitative surveys of fuel consumption and qualitative surveys of stove performance and acceptability. This type of testing, when conducted carefully, is the best way to understand the stove's impact on fuel use and on general household characteristics and behaviors because it occurs in the homes of stove users (Lillywhite, 1984; VITA, 1985). However, it is also the most difficult way to test stoves because it intrudes on people's daily activities. In addition, the measurements taken during the KPT are more uncertain because potential sources of error harder to control in comparison to laboratory-based tests. For this reason, the protocol for the KPT is quite different from the protocols for the Water Boiling Test (WBT) and the Controlled Cooking Test (CCT).

Overview: Household Surveys and Fuel Consumption Measurements

The Qualitative Survey

Surveys about how people feel about the stove should happen in two stages. Both stages of the survey are adopted from the work of Baldwin and VITA (1987, 1985), with slight changes. The goal of the first stage of the survey is to identify basic social and economic and cooking information of community families. This survey provides important information and it should occur before stoves are sold or distributed. The survey may also include households that do not adopt the stove.

In addition to providing information about families that are potential stove users, the survey will also identify households that are willing to participate in more in-depth fuel consumption tests as well as households that are willing to participate in the second stage of the qualitative survey.

We recognize that HEH groups promoting stoves may have a long history of interaction with the target community and may have already performed household surveys that capture this information. If this is the case, they may rely on survey data that has already been collected or conduct a shorter version of the survey provided here to fill in the gaps in data.

The second stage of the qualitative survey should be conducted about a month after the stove has been in use. This stage is meant to 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. The second qualitative survey should be limited to households that have adopted the stove, preferably in a paired manner so that the follow-up surveys are conducted on households that also participated in the initial survey. It may also be useful for stove promoters to conduct a follow-up survey that targets households that **do not** use the stove to better understand why some people choose not to use it, but such a survey is not included in this protocol.

Selecting Households to Participate in the Survey

The KPT is designed for implementation in communities where stove-related projects are underway. One important part of doing surveys is choosing families to participate. For projects that target a small number of households in a limited area, it may be possible to survey all of the families in the community. However, if stoves are to be provided to a larger number of households, or if the target communities are spread over a large area, then it will not be possible to survey all of the families and a fraction of the total number of families will have to be chosen. When only a fraction of the total number of families can be surveyed, the number of families chosen and the way that they are selected can affect the results of the survey, so it is important to choose families carefully. Ideally, families should be selected randomly to avoid bias. A selection is biased when families with certain characteristics are chosen (or *not* chosen) more than families that don't have those characteristics. A full discussion of survey sampling is outside the scope of this discussion (see separate HEH report, Considerations in Study Design), but some of the more important points will be mentioned. For example, a selection that only includes families that live along the main road, or a selection that leaves out families that belong to a certain parish would both be biased.

As a rule of thumb, if the number of families in the target population is known, about 10% of the total number of families should be covered by the initial survey. If the target population is large (e.g. more than 1000 families), then the number of households covered by the initial survey can be cut-off at about 100. If it is very small (e.g. less than 200 families), then the number of families covered by the initial survey between should be increased to at least 20. This is summarized in the table below:

Size of community (group of communities)	Number of households to be surveyed initially
Small (less than 300 households)	At least 30
Medium (300-1000)	~10%
Large (more than 1000 households)	100

The questions for the preliminary survey are included in Appendix 1 and the follow-up survey in Appendix 2.

The Quantitative Fuel Consumption Survey

The quantitative part of the KPT can be used for many different kinds of assessments:

1. To demonstrate differences in consumption of cooking fuels between households using traditional cooking technologies and households using improved stove technologies.

2. To assess medium or long term patterns of fuel consumption that result from stove interventions (for example, testers can periodically survey a sample of households using the new stove(s) in order to determine if changes in patterns of fuel consumption are sustained in the long term);

3. To test for seasonal variations in fuel consumption resulting from changes in climate, fuel availability, or local agro-economic cycles (independent of technological change);

4. To test for differences in fuel consumption among households using similar stoves but different types of fuel (e.g. fuelwood compared to crop residues);

5. To test for changes in fuel consumption resulting from changes not directly related to stove technology (for example: energy market or power sector reforms, income generating projects, public education campaigns, etc).

This protocol focuses on the first type of assessment – testing for the difference in fuel consumption between households using the traditional type of stove and households using the improved stove(s). However, stove promoters are encouraged to use variations of the protocol to test other aspects of their projects in order to fully understand how the project can impact their target communities.

The Kitchen Performance Test (KPT) allows testers to compare the rate of daily fuelwood consumption per person of two stoves as they are used in the normal household environment over an extended period of time. The KPT is a prolonged test conducted with the **willing cooperation** of individual families.

In order to compare two or more types of stoves, the testing can be done in two ways. It can be done by conducting daily measurements as families use the traditional stove for a period of time (e.g. 3–7 days) followed by daily measurements of the same families using the improved stove for the same period of time. This type of test makes a comparison of the family's fuel use with the old stove and with the improved stove. This is a *paired-sample study with no control*.

Alternatively, the KPT can be done by comparing fuel consumption in two or more groups of families for a period of 3–7 days, with one group using the traditional stove and the other group(s) using the improved stove(s). This is a *cross-sectional study*, in which a two groups of households, one using the old stove, and one using the new stove, are compared at the same time.

We recommend doing the *paired-sample study*, where the same households are measured using the old stove and then the new stove(s). This test measures the fuel consumption in each family as they make the transition from a traditional to an improved stove, and it allows for repeated testing to capture seasonal variation and changes in stove performance as the stove ages (as described in point 2 above). It also permits stove testers to use a smaller sample size than the cross-sectional method for a desired level of statistical significance. However, there are advantages and disadvantages to both approaches and circumstances differ between projects in different locations, so the testing method that stove-testers decide to use must be adapted to suit the conditions among the population of stove-users (**see the related document "Considerations in Study Design"** for a more detailed discussion).

For example, it may be difficult to test old stoves and new stoves in the same household (use a *paired-sample* design) because of the local circumstances. Testers may wish to measure fuel consumption in families that have already started using the new stove. If this is the case, then a comparison group of families that still use the old stove will be needed to do a proper test. Time may also be a constraint. Testing the same families using both the old stove and the new stove will probably take more time than testing two groups simultaneously. To allow for these contingencies, we provide information about both approaches to field-testing.

In either case, testers must be careful to choose the families in a way that minimizes the variability in factors that influence fuel consumption. These factors include household income, local farming practices and gender roles in the household, as well as environmental factors like wood scarcity and climate. For example, if a cross-sectional approach is taken, socio-economic or environmental conditions among the two groups of families may vary in a way that influences household fuel consumption. This can either increase or decrease the effect that the stove itself has on fuel consumption.

This are also potential biases in a paired-sample testing. For example, weather conditions or local economic conditions may change in the period between the two surveys in ways that affect fuel consumption. Temperature changes between rainy and dry seasons can change the demand for space-heating and pre-harvest and post-harvest seasons can affect either household income or food consumption, which also affects fuel use. Project monitors should identify and minimize these sources of bias in the KPT (for example, differences in season in the paired-sample measurements). Otherwise, the results of the KPT may be misleading.

Selection of communities and households for the KPT

Communities: One way to minimize potential sources of bias is through the careful selection of the communities where the tests are to be carried out. If the stove project is only targeting a single community, or a group of communities located close to one another, then the choice of community is simple. However, if the project is targeting a large area then the choice of communities to conduct the test becomes more complicated.

In addition, if stove-testers decide to use a cross-sectional approach, they will need to choose separate groups of families using the new stove and the old stove. If possible, they should choose both groups from within the same community. However, this will not be possible if every household in the target community is already using the improved stove. Then they must choose families to act as the comparison group from a community that is similar in socioeconomic status, livelihood options, and climatic or environmental conditions.

When taking a paired-sample approach, the two surveys should be conducted during the same season so that differences in weather conditions are minimal and do not affect fuel consumption. Also, try to be aware of significant changes in any other factors that may influence fuel consumption: for example, if the test of the first type of stove occurs during a pre-harvest "lean season" when food and money are scarce and the test of the second type of stove occurs soon after a harvest period when food and money are plentiful. Changing conditions like these can affect fuel consumption even if weather conditions are the same.

Clustering: If environmental or economic conditions vary considerably across the region where stoves are being promoted, testers should "cluster" the communities being tested. Clustering communities simply means categorizing them according to characteristics or conditions that the stove-testers think may influence fuel consumption. For example, communities may be categorized in one or more of the following groups:

- ⇒ Highland communities and lowland communities.
- ⇒ Communities in arid climates and communities in moist climates.
- ⇒ Communities in fuel-scarce and fuel-abundant areas.
- ⇒ Communities where families use a mix of wood together with other types of fuels and communities where families only use wood.
- ⇒ Wealthy and poor communities[1]

In both the *paired-sample* and the *cross-sectional* approach, after a community or communities are selected for the KPT, individual households must also be selected. If communities are very small and highly localized, stove-testers may test fuel consumption in all of the families that receive stoves. However, 100% coverage is rarely possible. If there are a large number of households in the community or the households are highly dispersed geographically, then it will only be possible to test a

[1] Of course, there are always variations of wealth *within* communities, but in certain regions, the difference *between* communities may dominate the difference *within* communities. For example, if one community practices cash crop cultivation and is located near a main road while another community is far from the main road and practices only subsistence farming, the differences in wealth between communities are likely to be significant.

fraction of the total number of households. If there are distinctly different populations of households, for example highland and lowland communities, within the project area, separate studies will be needed.

Households: As with communities, the choice of families can also bias the outcome of the tests. **The best way to avoid bias is to choose families randomly from a list that includes all of the participating families.** This ensures that all families have equal probability of being selected for the survey.[2] If the project is disseminating a large number of stoves or is targeting many different communities, then random selection for the KPT is strongly recommended. However it may not always be possible due to other constraints: some households may be unwilling to participate, or they may be too remote to reach on a daily basis (daily measurements are recommended for the KPT). If these, or other constraints exist, then households should still be chosen in a way that minimizes potential sources of bias.

However, it is important to realize that if households are not selected with equal probability, it will not be possible to generalize the results of the KPT. In other words, if the promoters of the stove want to make claims about the ***actual fuel savings*** *of their stove(s) among the entire population that is affected by their activities, then they should base their KPT on a random sample of families in those communities. Any general claims about the fuel savings resulting from stove projects not based on random sampling are not statistically valid.*[3]

Random sampling over a large area, however, often leads to difficult transport and scheduling logistics because households can be far apart. Thus, larger projects should use cluster sampling (communities or villages are first randomly chosen from the entire area and then households are randomly chosen from within the chosen communities). If the communities are much different in size, however, then a weighted sampling procedure should be used (See "Considerations in Study Design").

Deciding on a sample size for the fuel consumption surveys

The number of families that should be included in the KPT is also related to statistical factors. The test is designed to compare the average daily fuel consumption per person using the improved stove and the traditional stove. As explained above, this can either be done using a paired sample test, where a single group of families is evaluated as they use the old stove and then reevaluated after they switch to the new stove, or it can be done using a cross-sectional test, where different groups of

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[2] Random selection sounds complicated, but it doesn't have to be. Many simple calculators have a random number function. So do many data management software programs (e.g. Excel). Starting with a list of all families that received stoves, assign each family a random number and then rank the families according to their random number and choose families according to their random ranking.

[3] The results of non-random samples can still be valuable indicators of stove performance, but they should not be generalized across entire communities or larger populations.

households are evaluated – one group using the old stove and one group using the new group.

In the first case, average fuel consumption per capita in each family before and after switching stoves is compared. In the second case, the average per capita fuel consumption of the group of families using the improved stove to the average per capita fuel consumption of the group of families using the traditional stove is compared.

When trying to identify improvements in average fuel consumption in either the paired-sample or the cross-sectional tests, there are several important factors that affect the validity of the comparison. These are:

- ⇒ The variability of the data.[4]
- ⇒ The difference in the two averages.
- ⇒ The number of tests that are conducted for each type of stove.

The variability in data is particularly important in the KPT. The tests are done in real households and are many things that the testers can't control. This adds to the variability in the test results so that the results of the KPT are likely to have much more scatter than the WBT where testers can control most variables. Data from 13 South Indian households collected by Geller and Dutt (FAO, 1983) shows a coefficient of variation (CV) in per capita fuel consumption of over 40%, where the CV in the WBT is typically about 10%.[5] Similar results have been found recently in tests in Guatemala (Kuwabara, 2003).

In addition to the variability or scatter of the data, the detectable difference in average fuel consumption is another important consideration. This is the minimum difference that the stove testers want to be able to detect with their KPT. Many improved stove programs claim reductions in fuel consumption of 50% or more, but a test that is designed to show 50% fuel savings may not be able to demonstrate a 40% reduction in fuel consumption with the same statistical rigor. In addition, it's much harder to prove a reduction in fuel consumption of only 20%, even though it may

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[4] The correct statistical term is variance. For a given set of data, variance is the square of the standard deviation (σ) and indicates the degree of scatter around the mean or average value.

$$\text{variance} = (\text{standard deviation OR } \sigma)^2 = \frac{n\sum x^2 - \left(\sum x\right)^2}{n(n-1)}$$

[5] Variation in data is typically measured the coefficient of variation (CV), which is the ratio of the standard deviation to the mean (see the discussion of Data Analysis in the section on the WBT). The Data reported in reports on stove-testing shows that WBT and CCT tests usually have a CV between 5 and 10%. However, data collected from the KPT can have a CV of 40% or more (Baldwin, 1986; FAO, 1983).

result in significant fuel savings over the lifetime of the stove. We recommend that KPTs be designed to show a 30% fuel savings.

The tables in Appendix 3 show the recommended number of tests to demonstrate a range of detectable differences in average fuel consumption per person at a 95% level of confidence for both paired-sample and cross-sectional testing methods.

If possible, stove-testers should base sample size on data from their own area. However, if no data are available we recommend they assume the CV will be roughly 40%, based on past experiences with household fuel consumption studies. In addition, we recommend that the testers choose 30% as a reasonable fuel reduction to try to detect, although they may want to choose larger or smaller values.

Appendix 3 shows that a paired-sample test detecting a 30% reduction in fuel use will require testing at least 14 households first using the old stove and then the new stove. A cross-sectional test will require testing 56 households (28 in each group). In practice, of course, it is a good idea to leave a margin for error, dropouts, or failed tests, so we recommend choosing 20 for paired sample and 70 for cross-sectional tests respectively.

As discussed above, if stove projects are attempting to reach a wide range of households spread over a large geographical area, we advise that they cluster their groups of families. In this case, each cluster should be treated as a different sampling group and 20 households for paired-sample testing or 70 households for cross-sectional testing.[6] The box below gives a specific example of each testing method.

If no local data are available at the start, one possible approach would be to begin the study and then, after completing tests in about 10 households, calculate the CV. Then, assume that the CV for the entire sample is modeled by the CV of the initial sub-sample base the remaining sample size on this locally determined CV.

[6] If different clusters are grouped together for analysis, multiple factors influencing per capita fuel consumption will be combined. It is possible to use more advanced statistical techniques to determine how factors other than the type of stove used by the household contribute to variability in fuel consumption. These techniques are beyond the scope of this paper, but see any elementary statistical text for an explanation.

Box 1: Hypothetical examples of cross-sectional and paired-sample sampling for the KPT

Case 1 – a cross-sectional study: An NGO in Guatemala wants to help a small stove producer to get donor support to promote stoves in Community A. However, the donor requires evidence that the stove reduces fuel consumption before they will release funding. 80 households in nearby Community B were given the same model of improved stove with the support of a different donor. These households have been using the stove for over a year and report anecdotally that the new stove helped them to cut their fuel consumption in half. The NGO decides to compare a sample of improved-stove households in Community B with households using traditional stoves in Community A. The NGO decides that they'd like to be able to report fuel reductions of 30% with 95% confidence, so they choose to test 28 households in each community (see Appendix 3). The communities are close to one another and the NGO has sufficient personnel, so they decide to conduct the surveys at the same time. They spend several weeks making the necessary arrangements and conducting preliminary qualitative surveys about household demographics and kitchen practices on larger samples of households in each community. They then select 28 households at random from each community, obtain permission to proceed with their fuel consumption tests, and conduct daily visits to the participating households for eight days measuring the previous days' fuel consumption, in order to obtain one week of measurements.

Case 2 – a paired-sample study: A Kenyan NGO has designed an improved stove with a chimney that they wish to promote. The NGO has already completed their initial tests, which show that their stove requires 40% less wood to boil 5 liters of water in laboratory conditions. However, they realize that this may not occur in real field conditions. Moreover, they would like their results to be statistically significant for fuel savings as low as 20%, but they lack some resources and realize that they will not be able to test enough households to obtain results that are valid with 95% confidence (31 households according to Appendix 3). As a compromise, they choose to survey 18 households before and after they switch to the improved stove, knowing that these households will be more than sufficient to detect 30% reductions in fuel consumption with 95% confidence if the CV is 40% and will detect 20% reductions at the 95% confidence level if the CV is somewhat lower (30%).

Accounting for multiple stoves and fuels during the KPT

The KPT was originally designed to measure fuel consumption in households that use a single woodburning stove for all of their cooking needs. While this still occurs in some areas, it is becoming more common for households to use more than one combination of stoves and fuels (Masera et al., 2005).[7] It is possible that a new stove will affect consumption of all fuels. Thus, the KPT has been redesigned to accommodate a range of possible stove-fuel combinations that may be used in real conditions in addition to the improved stove.[8]

Through the KPT, stove testers will measure daily fuel consumption in order to calculate the average per capita quantity of each fuel consumed in the household as well as the total quantity of energy consumed. In order to compare total fuel consumption in either the cross-sectional or the paired sample test design, stove testers must weigh the quantity of fuel that is consumed each day and convert this quantity into an *energy equivalent* quantity by multiplying the mass of each fuel consumed by the calorific value of that fuel. See Appendix 4 for a discussion of the calorific value of various types of fuel.

Example: As an example, we'll use a hypothetical project in an Indian community where it is common for dung to be used in combination with wood. To conduct a paired-sample KPT, 20 households are selected and the mass of both wood and dung consumed in each household is measured each day for 3 days (the minimum recommended test period) while households use the traditional stove. Measurements are repeated 1-2 months later after the same households have switched to the improved model. Results of one households KPT are reported in Table 1 below.

The entire KPT will yield 20 similar data sets. These data sets are used to calculate the average daily per capita fuel consumption with and without the improved stove. In addition, the variability in each data set will be used to determine whether the observed differences are significant or not. Data for all 20 households is shown in Table 2, with an accompanying statistical analysis.

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[7] This can range from a household that uses a single solid fuel stove to burn crop residues and/or dung in addition to wood as is common in India, to a household that owns a woodstove and an LPG burner as is common in rural Mexico, or a family that uses a 3-stone wood fire and a kerosene wick stove as is common in Kenya.

[8] Stove testers might wish to test their stove in real household conditions, but without the use of other stoves and fuels. In some areas, this might be the "natural" situation. However, in other areas, where people are accustomed to using more than one stove-fuel combination, this might be an artificial situation. Nevertheless valuable information could result from a systematic comparison of the traditional stove and the improved stove in a real household setting. Such a test, with imposed conditions on households, would be considered a "Controlled" KPT (C-KPT), and is a hybrid between the CCT and the KPT described here. The C-KPT could be conducted following this protocol - simply restrict families to using one stove and fuel and fill the data and calculation sheets accordingly. Contact the author for more information about this variation of the KPT.

The analysis in Table 2 shows that average per capita consumption of wood and dung have both decreased after the households switched to the improved stove. Of course, average per capita energy consumption has also decreased. However, the statistical analysis shows that, while the observed decreases in wood and overall energy consumption are statistically significant, the decrease in dung consumption is not.[9]

This analysis can be generalized to most household fuels that are likely to be encountered in communities targeted for improved stove projects. Stove testers simply need to account for the quantity of fuel consumed each day and the calorific value of the fuel. This will be explained in more detail in the KPT procedure below.

[9] In this example, the t-test comparing average dung consumption before and after adoption of the improved stove is 0.07, which is greater than 0.05 - the conventional level at which results are considered "significant". This means that there is greater than a 5% (or 1-in-20) chance that more dung is actually consumed by households using the improved stove, and that the observed difference is simply the result of random chance.

Table 1: Example data from a 3-day KPT in one Indian household using fuelwood and dung

BEFORE Intervention

Daily Results		Wood consumption				Dung consumption				Energy	
	No. of adult equiv	Wet wood used in the past 24 hrs	Wet wood used per capita in past 24 hrs	Dry wood used in the past 24 hrs	Dry wood used per capita in past 24 hrs	Wet dung used in the past 24 hrs	Wet dung used per capita in past 24 hrs	Dry dung used in the past 24 hrs	Dry dung used per capita in past 24 hrs	Total energy	Per capita energy
Day 1	6.0	5.8 kg	1.0 kg	4.5 kg	0.7 kg	1.5 kg	0.3 kg	1.4 kg	0.2 kg	106.2 MJ	17.7 MJ
Day 2	5.0	5.2 kg	1.0 kg	4.0 kg	0.8 kg	1.2 kg	0.2 kg	1.1 kg	0.2 kg	93.2 MJ	18.6 MJ
Day 3	4.5	6.0 kg	1.3 kg	4.6 kg	1.0 kg	2.2 kg	0.5 kg	2.1 kg	0.5 kg	119.1 MJ	26.5 MJ

Overall Results:	**Wet wood**	**Wet**	**Dry wood**	**Dry wood**	**Wet dung**	**Wet dung**	**Dry dung**	**Dry dung**	**Total**	**Energy**
Avg Daily Fuel	5.7 kg	1.1 kg	4.4 kg	0.9 kg	1.6 kg	0.3 kg	1.6 kg	0.3 kg	106.2 MJ	20.9 MJ
Standard deviation	0.4 kg	0.2 kg	0.3 kg	0.1 kg	0.5 kg	0.1 kg	0.5 kg	0.1 kg	13.0 MJ	4.8 MJ
CV (SD/Avg)	7%	17%	7%	17%	31%	43%	31%	43%	12%	23%

AFTER Intervention

Daily Results:		Wood consumption				Dung consumption				Energy	
	No. of adult equiv	Wet wood used in the past 24 hrs	Wet wood used per capita in past 24 hrs	Dry wood used in the past 24 hrs	Dry wood used per capita in past 24 hrs	Wet dung used in the past 24 hrs	Wet dung used per capita in past 24 hrs	Dry dung used in the past 24 hrs	Dry dung used per capita in past 24 hrs	Total energy	Per capita energy
Day 1	6.0	4.8 kg	0.8 kg	3.7 kg	0.6 kg	1.5 kg	0.3 kg	1.4 kg	0.2 kg	91.6 MJ	15.3 MJ
Day 2	5.0	4.5 kg	0.9 kg	3.5 kg	0.7 kg	1.1 kg	0.2 kg	1.0 kg	0.2 kg	81.5 MJ	16.3 MJ
Day 3	5.0	4.5 kg	0.9 kg	3.5 kg	0.7 kg	1.5 kg	0.3 kg	1.4 kg	0.3 kg	87.2 MJ	17.4 MJ

Overall Results:	**Wet wood**	**Wet wood per capita**	**Dry wood**	**Dry wood per capita**	**Wet dung**	**Wet dung per capita**	**Dry dung**	**Dry dung per capita**	**Total Energy**	**Energy per capita**
Avg Daily Fuel	4.6 kg	0.9 kg	3.5 kg	0.7 kg	1.4 kg	0.3 kg	1.3 kg	0.2 kg	86.8 MJ	16.3 MJ
Standard deviation	0.2 kg	0.1 kg	0.1 kg	0.0 kg	0.2 kg	0.0 kg	0.2 kg	0.0 kg	5.1 MJ	1.1 MJ
CV (SD/Avg)	4%	7%	4%	7%	17%	16%	17%	16%	6%	7%

Comparison of results:	**Absolute differenc**	**Percent differenc**
Per cap wood consumption	-0.19 kg	-22%
Per cap dung consumption	-0.07 kg	-21%
Per cap energy consumption	-4.6 MJ	-22%

This analysis assumes that wood has a moisture content of 20% (wet basis) and a calorific value of 19 MJ/kg. Dung has a moisture content of 5% (wet basis) and a calorific value of 15 MJ/kg.

Table 2: Example of hypothetical data set from 20 Indian households using fuelwood and dung

	Before Intervention			After Intervention		
HH No.	Per cap wood consumption	Per cap dung consumption	Per cap energy consumption	Per cap wood consumption	Per cap dung consumption	Per cap energy consumption
1	0.89 kg	0.31 kg	21.6 MJ	0.69 kg	0.24 kg	16.8 MJ
2	1.02 kg	0.40 kg	25.4 MJ	0.92 kg	0.30 kg	22.1 MJ
3	0.71 kg	0.41 kg	19.6 MJ	0.59 kg	0.38 kg	17.0 MJ
4	1.02 kg	0.33 kg	24.4 MJ	0.52 kg	0.38 kg	15.5 MJ
5	1.13 kg	0.36 kg	26.8 MJ	0.58 kg	0.40 kg	16.9 MJ
6	1.18 kg	0.35 kg	27.7 MJ	0.88 kg	0.31 kg	21.4 MJ
7	1.24 kg	0.45 kg	30.3 MJ	0.78 kg	0.24 kg	18.4 MJ
8	0.87 kg	0.25 kg	20.3 MJ	0.77 kg	0.47 kg	21.7 MJ
9	0.94 kg	0.45 kg	24.6 MJ	0.60 kg	0.20 kg	14.4 MJ
10	0.82 kg	0.27 kg	19.7 MJ	0.69 kg	0.39 kg	18.9 MJ
11	1.18 kg	0.40 kg	28.6 MJ	0.73 kg	0.34 kg	18.9 MJ
12	0.75 kg	0.47 kg	21.3 MJ	0.54 kg	0.43 kg	16.8 MJ
13	0.79 kg	0.52 kg	22.7 MJ	0.99 kg	0.46 kg	25.6 MJ
14	0.94 kg	0.39 kg	23.7 MJ	0.97 kg	0.34 kg	23.6 MJ
15	0.94 kg	0.38 kg	23.6 MJ	0.78 kg	0.23 kg	18.4 MJ
16	1.32 kg	0.49 kg	32.4 MJ	0.89 kg	0.27 kg	20.9 MJ
17	0.81 kg	0.39 kg	21.2 MJ	0.90 kg	0.28 kg	21.3 MJ
18	1.08 kg	0.51 kg	28.1 MJ	0.77 kg	0.42 kg	20.9 MJ
19	1.17 kg	0.32 kg	27.1 MJ	0.64 kg	0.28 kg	16.3 MJ
20	1.22 kg	0.29 kg	27.5 MJ	0.85 kg	0.41 kg	22.3 MJ
Average	1.00 kg	0.39 kg	24.8 MJ	0.75 kg	0.34 kg	19.4 MJ
St dev	0.18 kg	0.08 kg	3.7 MJ	0.15 kg	0.08 kg	3.0 MJ
CV	18%	20%	15%	19%	24%	15%

	Per cap wood consumption	Per cap dung consumption	Per cap energy consumption
Difference (impv'd - trad'l)	-0.25 kg	-0.05 kg	-5.4 MJ
% diff	-25%	-12%	-22%
t-test	< 0.01	0.07	< 0.01

Supplying Fuel for the KPT

Wood availability is a very important factor in determining how much fuel a family consumes. There is a danger that if the stove testers provide fuel to the family, the family will adopt consumption patterns that they do not follow under normal circumstances. However, if fuel is not provided, and the family gathers it every one or two days, it becomes quite difficult to keep track of overall consumption. The impact of providing fuel to the family may be larger in areas that suffer badly from wood scarcity. As stove-testers organize the KPT, they may want to take a different approach depending on the extent of wood scarcity in the target community. If they choose to provide fuel to the family, they should be aware that the outcome of the

test might be affected.[10] For example, the family may simply use all the wood that is provided, even if it is much more than they normally consume. Alternatively, if the family is told that they can keep whatever fuel is not used at the end of the week of measurement, they may be more conservative than they are normally in order to save the "gift".

If the stove testers decide not to provide wood, they must make arrangements with each participating family to keep accurate accounting of fuel coming into the household each day. They have to ensure that fuel is not used without first being weighed. This can be difficult, especially in places where young children are involved in fuel collection, which is common in many parts of the world.

The decision about whether or not to provide fuel is left to the stove testers. If testers feel that providing fuel to families will be too disruptive or has the potential to bias the results of the test, then they should not do it. On the other hand, if keeping account of daily fuel collected and consumed is too difficult, then they should provide each family with a measured amount of fuel.

If fuel is provided, ensure that an adequate supply is obtained, cut and dried well ahead of time. Separate it into reasonably sized bundles (similar to quantities of fuel as it is traded or carried locally – for example, a head-load). If possible, label each bundle ahead of time with its weight to facilitate weighing in the field (this will make daily measurements much easier). Provide the family with several days supply at the start of the testing period and resupply them as needed.

If the family is providing their own fuel for the test, explain that the person measuring fuel each day will need to account for daily additions and subtractions from the family's stock of fuel. Have them keep measured fuel separate from newly collected fuel and consider lending or giving them two large containers that they can use in order to sort measured and unmeasured fuel. In addition, if distinctly different types of wood are used (e.g. softwoods and hardwoods), ask them to separate to keep new stocks of wood separate from one another.

In either case, fuel should be kept dry. If the family does not normally store fuel indoors and there is a chance that rain may occur during the measurement period, request that the family moves the fuel inside or covers it to prevent it from getting wet.

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[10] When adequate fuel is provided to participating families, the results of the KPT indicate the impact of the improved stove relative to the traditional stove **in a situation of adequate fuelwood**, which may not reflect actual conditions. However, if the same amount of fuel is provided for use in both the improved and traditional stoves, then the test will indicate the relative difference between the two stoves, which is an important outcome.

Compensation for participating in the KPT

It may be appropriate to consider compensating the family for participating in the KPT. This depends very much on local circumstances. The organization promoting the stove should decide on the most appropriate form of compensation.

Compensation may be in the form of cash or a non-cash gift. A gift can simply be fuel provided for the week of the test, though this may impact the results of the test, as discussed above. In addition, households who participate in the KPT can be offered a stove for a reduced price. Other in-kind gifts can include food, cookware (pots and pans), a shelter or container to store wood, or even tree seedlings to augment future supplies of fuel, fruit and/or timber.

Equipment for the quantitative fuel consumption KPT

Table 3: Equipment for the KPT [11]

Balance for weighing wood and other solid fuels	A large capacity spring scale will be most appropriate with 0.1 – 0.5 kg accuracy
Fuel	As was discussed above, testers may want to provide fuel to the households participating in the quantitative part of the KPT. This should be considered carefully because it can bias the test is either a positive or negative direction.
Moisture meter	To be used to measure the moisture content of the fuel used in each household, which is required to normalize per capita daily fuel consumption. The recommended model of moisture meter *is not appropriate* for non-woody solid fuels. Other methods should be used for non-woody fuels and may also be used for wood (see the discussion in the WBT protocol).

If liquid or gaseous fuels or are used, additional equipment will be required.[12]

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[11] Pots and other cooking utensils should be supplied by each household and need not be standardized.

[12] The KPT can also be modified to accommodate households cooking with electricity. As more areas gain access, there may be households that use electricity in addition to other fuels for their cooking needs. If this is the case, stove testers may measure how electricity consumption changes when a new stove is introduced. Since this situation is not yet common, a full description of the necessary equipment is not included here, but if readers would like more information, they should contact the author.

Liquid fuels (e.g. kerosene or ethanol): consumption may be measured wither by mass or volume. If mass is to be measured, the same scale that is used for wood may not be appropriate because daily consumption is probably too low to register with only 0.1 – 0.5 kg resolution. An electronic balance such as the one recommended for the WBT is more appropriate. For measuring volume, a graduated container with 2-5 liter capacity would be appropriate.[13] Using this container will also help household members to keep the kerosene used for cooking separate from fuel used for other purposes like lighting as kerosene is a common lighting fuel in many parts of the world and families do not usually separate fuel for the two applications.

Gaseous fuel (e.g. LPG): If LPG is used, the fuel mass must be measured. This is difficult because the tank holding the gas is much heavier than the amount consumed on a daily basis, particularly in areas where large (35 kg) tanks are common. Without using a high capacity high accuracy scale, which can be very expensive, it may be difficult to resolve daily consumption. If such a scale is not available, then the only option is to may be to measure LPG consumption at the start and finish of the test and calculate a daily average that way. For this measurement, the same scale that is used for wood will probably be sufficient.

Procedure for fuel consumption measurements

As was discussed above, the KPT has two main goals: 1) the quantitative measurement of daily cooking fuel consumption and 2) qualitative assessment of field performance and acceptability of the stove to the households using it. The qualitative surveys do not take a long time, and should be conducted separate from the quantitative part of the KPT. Importantly, the qualitative survey includes a question about whether the household will be willing to participate in a detailed study of fuel consumption. If the family answers "no" to that question, they should not be included when drawing a random sample of households for the quantitative part of the KPT.

The procedure that follows is for the fuel consumption measurement itself. It assumes that the first qualitative survey has already been conducted and a pool of potential families has been identified from that survey.

1. Determine if the KPT is to be performed as a *cross-sectional* or *paired-sample* study. Also determine the number of households that are to be tested and select the households (see Appendix 3 and the related discussion). If possible, select families at random based on the families who agreed to participate when responding to the initial survey. If random sampling is not possible, choose households as local circumstances allow.

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[13] Such a container could be bought from a chemistry supplier. One could also be made using a clear plastic container, a small (e.g. 25 or 50 ml) graduated cylinder and an thin permanent marker. Simply fill the container by pouring water from the graduated cylinder and marking the level of water in the container after each pour. Depending on the cross section of the container, this should be sufficient to measure liquid fuel daily consumption.

2. Define the testing period of *at least* 3 consecutive days. Try to avoid weekends unless testing is to extend over an entire week. Also avoid holidays and be aware of local events like market days that may involve above average fuel consumption. Be aware that 3 days of testing involves 4 days in contact with the family – the first day is spent briefing families, as explained in the next step.

3. Explain to family members the purpose of the test, and arrange to measure their fuel consumption at a roughly the same time each day. Stress to household members that their cooking practices should remain as close to normal as possible for the duration of the test.[14] Record the weight and moisture content of the initial stock of solid fuels. If liquid and/or gaseous fuels are used, also record the initial stock of fuel and ask the family to keep newly acquired fuel separate from the fuel you have already measured.

4. Ask the family to define an inventory area to store the fuel during the test. If the family is going to collect or purchase solid fuel during the days of the test, ask them to keep newly collected or purchased solid fuel separate from fuel that has already been tested for moisture and weighed. If necessary, provide containers to help the family keep newly gathered fuel separate from fuel that is already measured.

5. Visit each household at roughly the same time each day, without being intrusive. With each daily visit, record the number of people that ate their meals in the household since your last visit. As this number can vary from one day to the next try to avoid using an average value. Record the gender and age of each person (this information is used to calculate the number of *standard adult persons* served – see Table 4 below). Record fuel consumption by weighing the remaining wood. If the family is providing their own fuel, record the weight and moisture content of newly collected fuel before it is added to the family's stock.

Table 4: "Standard adult" equivalence factors defined in terms of sex and age (from Guidelines for Woodfuel Surveys, for F.A.O. by Keith Openshaw cited in (Joseph, 1990)).

Gender and age	Fraction of standard adult
Child: 0-14 years	0.5
Female: over 14 years	0.8
Male: 15-59 years	1.0
Male: over 59 years	0.8

[14] For example, if there is a festival, funeral or anything else out of the ordinary planned during the testing period, delay the test, or omit the family from the study.

6. If wood is being provided to the family, check to see that they have adequate supplies and add to their stock as needed.

7. Compile the results at the end of the test period (at least three days of measurements). Use the KPT Household Data and Calculation form to calculate the total and per capita daily consumption of all fuels. The form will also calculate the total and per capita daily energy consumption as well as the standard deviation.

8. Once the study of each all households is complete, fill the KPT Overall Analysis form in order to compare results of household fuel and energy consumption with and without the improved stove(s).

9. Once they are obtained, inform participating families of the results, thank them for their cooperation, and provide them with the form of compensation considered appropriate by the project implementers (as discussed above).

REFERENCES

Baldwin, S. F. (1986). Biomass Stoves: Engineering Design, Development, and Dissemination, Center for Energy and Environmental Studies: PU/CEES Report, 224, 287. Available at:

FAO (1983). Wood fuel surveys, UN Food and Agriculture Organization: Forestry for local community development programme, GCP/INT/365/SWE. Available at: http://www.fao.org/docrep/X5555E/x5555e00.htm#Contents.

FAO (1993). Chinese Fuel-Saving Stoves: A Compendium, Regional Wood Energy Development Program (RWEDP), FAO field document No. 40, 57. Available at:

IEA (2005). Key World Energy Statistics. Paris, International Energy Agency.International Energy Agency, 82.

Joseph, S. (1990). Guidelines for planning, monitoring and evaluating cookstove programmes, UNFAO: Community Forestry Field Manual 1. Available at: http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/u1310e/u1310e00.HTM.

Lillywhite, M. (1984). Improved Cookstoves: A Training Manual, Domestic Technology International, Inc. under subcontract to: Denver Research Institute for the US Peace Corps: Training Manual, T-40, 254. Available at: http://mng-unix1.marasconewton.com/peacecorps/Documents/T0040/t0040e/t0040e00.htm#Contents.

Masera, O., Diaz, R., et al. (2005). "From cookstoves to cooking systems: the integrated program on sustainable household energy use in Mexico." Energy for Sustainable Development **9**(1): 25-36.

Pennise, D., Smith, K. R., et al. (2001). "Emissions of Greenhouse Gases and Other Airborne Pollutants from Charcoal-Making in Kenya and Brazil." Journal of Geophysical Research-Atmosphere **106**: 24143-24155.

Smith, K., Uma, R., et al. (2000). Greenhouse Gases From Small-Scale Combustion Devices In Developing Countries Phase IIa: Household Stoves In India, US Environmental Protection Agency, EPA-600/R-00-052, 98. Available at:

VITA (1985). Testing The Efficiency Of Wood-Burning Cookstoves: Provisional International Standards, Volunteers in Technical Assistance, 0-86619-229-8, 76. Available at:

Zhang, J., Smith, K. R., et al. (2000). "Greenhouse Gases and Other Airborne Pollutants from Household Stoves in China: A database for emission factors." Atmospheric Environment **34**: 4537-4549.

Appendix 1

KITCHEN PERFORMANCE TEST - Preliminary survey questions

1. Date		
2. Name of Interviewer		
3. Household code		
4. Village ID		
5. Community ID		
6. GPS coordinates (if possible)	_____ °long. _____ °lat. _____ altitude (meters)	
7. List gender and age of HH members (up to 10 people):	Gender/Age	Count
	Children 0-14	
	Women over 14	
	Men 15-59	
	Men over 59	
8. Primary income generating activities (circle one):	Farming only Wage labor only Farming and wage labor Shopkeeping Farming and shop-keeping Other - _____	If farming, list crops: a) b) c)
9. Who is primarily responsible for cooking?	List gender and age as in question 7 above:	
10. Is cooking done indoors, outdoors, or both?		
11. Is the kitchen separate from the main house? (circle one)		Yes/No

<table>
<tr><td rowspan="4">12. What kind of stove(s) are used? What is the age and frequency of use of each stove?</td><td>Stove/fuel</td><td>Age of stove (yrs)</td><td>Frequency of use (times per day, week, or month)</td></tr>
<tr><td>a)</td><td></td><td></td></tr>
<tr><td>b)</td><td></td><td></td></tr>
<tr><td>c)</td><td></td><td></td></tr>
<tr><td>13. Whose job is it to obtain cooking fuel?</td><td colspan="3">For each Stove/fuel from question 12, list the family members' gender and age as in question 7 above:

a)

b)

c)</td></tr>
<tr><td rowspan="2">14. Where is cooking fuel obtained and roughly how far is the source of fuel from the household (record distance or time needed to walk to source)?</td><td colspan="3">Give answers for each Stove/fuel given in question 12</td></tr>
<tr><td colspan="2">Location

a)

b)

c)</td><td>Distance from household

a)

b)

c)</td></tr>
<tr><td>15. How much is consumed and how much does the family spend on each type of fuel per month</td><td colspan="3">Give answers for each Stove/fuel listed in the response to question 12</td></tr>
</table>

	Monthly fuel consumption a) b) c)	Monthly expenditure on fuel a) b) c)

Questions about the main wood burning stove		
16. What kinds of pots are used for cooking (e.g. round or flat bottom, metal or ceramic, etc.)?		
17. Are pot-lids usually used for cooking?		
18. How is the fire normally controlled?		
19. Does the family perform maintenance on the improved stove?	Type of maintenance Cleaning stove of ashes Cleaning flue Repairing cracks Other task - _____ _____	Frequency (circle appropriate response) Never Daily Weekly Monthly Never Daily Weekly Monthly Never Daily Weekly Monthly Never Daily Weekly Monthly
20. Is the stove used for any purpose other than cooking food for the family (circle as appropriate)?	Preparing food for livestock Preparing food/drink for commercial sale Other? _____	
21. What does the primary cook like about the stove (list replies)?		
22. What does the primary cook dislike about the stove (list replies)?		

23. Describe condition and appearance of primary woodstove and kitchen (if possible, make a sketch or take a photo).	
24. If the family is not currently using a new stove, are they interested in using one? *If the respondent responds positively, provide information about how they can get a new stove*	
25. Is the family willing to participate in a more detailed study that involves daily measurements of fuel consumption?	
26. Is the family willing to participate in a follow-up survey to assess their satisfaction with the new stove 3-6 months from now?	
Thank the respondent for participating and, if they responded positively to questions 25 or 26, tell them that you will be in contact with them in the future.	

Appendix 2

KITCHEN PERFORMANCE TEST – Follow-up survey questions (to be administered at least one month after starting to use the improved stove)

1. Date		
2. Name of Interviewer		
3. HH Code		
4. Village ID		
5. Community ID		
6. GPS coordinates (if applicable)	_____ °long. _____ °lat. _____ m-asl	
7. List gender and age of HH members (up to 10 people):	Gender/Age	Count
	Children 0-14	
	Women over 14	
	Men 15-59	
	Men over 59	
Observable Information (to be recorded by the Interviewer)		
8. What Types of stoves are present in the kitchen?		
9. Does the improved stove appear as if it has been used recently? a. Is the stove warm to the touch? b. Are there ashes or embers inside? c. Is there soot around the fuel chamber?	Yes/No Yes/No Yes/No Yes/No	

10. Where is the stove (circle appropriate answer)?	Inside main house Inside separate kitchen Outside Other - _____
11. Does it appear as if other stove(s) are also being used? What kind(s) of stove(s)?	Yes/No Stoves:
12. Describe the fuel that is being used (describe kind of wood, size, moisture, etc)?	Species - _____ Size - _____
13. What is the condition of the stove? Are there cracks in the stove? Is the flue/chimney attached? Are there holes in the flue/chimney? Is there a door? Is there other noticeable damage?	(circle appropriate answer) Yes/No – if yes, where? _____ Yes/No Yes/No Yes/No Yes/No - if yes, describe: _____ _____
14. Is there any evidence of repairs made to the stove (describe)?	
15. If the stove has air-holes or other control mechanisms, are they functioning (describe details)?	Yes/No
Questions to be posed to the principle user of the improved stove	
16. How long has the family been using this stove (months or years)?	

17. How often does the family use the stove (circle as appropriate)?		Every day Several times a week One time per week Less than weekly Never
a. If the respondent answers once a week or less, ask why it is not used more frequently.		Reason:
18. What kinds of pots are being used in the new stove (describe)?		
19. Does the family perform maintenance on the improved stove?	Type of maintenance Cleaning stove of ashes Cleaning flue Repairing cracks Other task - _____ _____	Frequency (circle appropriate response) Never Daily Weekly Monthly Never Daily Weekly Monthly Never Daily Weekly Monthly Never Daily Weekly Monthly
20. Is the stove used for any purpose other than cooking food for the family (circle applicable response)?	Preparing food for livestock Preparing food/drink for commercial sale Other? _____	

21. Does the family use any other kinds of stoves in addition to the improved stove? If yes, list them here (up to two other stoves in addition to the improved stove)	Stove/fuel	Age of stove (yrs)	Frequency of use (times per day, week, or month)
	a) Improved stove		
	b)		

	c)		

22. How much fuel is consumed by each stove and how much does the family spend on each type of fuel per month?	Give answers for each Stove/fuel listed in the response to question	
	Monthly fuel consumption a) b) c)	Monthly expenditure on fuel a) b) c)

23. Is it easier or more difficult to cook with the new stove? Describe why.	Easier Harder	Why?
24. Do meals take longer to prepare using the new stove? If yes, list the meals that take longer to prepare.	Yes No	Meals:
25. Are there any cooking tasks easier to accomplish with the new stove? If yes, list these tasks.	Yes No	Tasks:
26. What does the cook like most about the stove?		
27. Is there anything that the cook would change about the new stove?		

28. What problems does the cook have with the improved stove? Review the following list and indicate Yes or No as appropriate. Also ask if the new stove is better or worse than the old stove with respect to each problem.

	Problem exists (Yes/No)	Better/worse than old stove:

a. The stove causes burns		
b. The pots are not stable		
c. The pots do not fit		
d. Fire turns pots black		
e. Stove makes a lot of smoke		
f. Stove takes long to get hot		
g. Stove is hard to start		
h. Fire goes out easily		
i. Hard to control temperature		
j. It is difficult to cook certain foods (list locally appropriate foods below) • • •		
k. Stove uses too much wood		
l. Can not fit preferred size of fuel		
m. Stove does not heat the room during cold seasons		
n. Stove does not provide light		
o. Stove breaks easily		
p. Stove needs a lot of maintenance		

q. Other problems (list) • • •		

Appendix 3

Sample size required to show statistically significant reductions in per capita fuel consumption (95% confidence)

SAMPLE SIZE REQUIRED FOR THE PAIRED-SAMPLE TEST METHOD

	Pooled CV of measurements												
Detectable difference in means	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**
10%	8	31	71	126	196	283	385	502	636	785	950	1130	1326
20%	2	8	18	31	49	71	96	126	159	196	237	283	332
30%	1	3	8	**14**	22	31	43	56	71	87	106	126	147
40%	0	2	4	8	12	18	24	31	40	49	59	71	83
50%	0	1	3	5	8	11	15	20	25	31	38	45	53
60%	0	1	2	3	5	8	11	14	18	22	26	31	37
70%	0	1	1	3	4	6	8	10	13	16	19	23	27
80%	0	0	1	2	3	4	6	8	10	12	15	18	21
90%	0	0	1	2	2	3	5	6	8	10	12	14	16
100%	0	0	1	1	2	3	4	5	6	8	9	11	13

SAMPLE SIZE REQUIRED IN EACH GROUP FOR THE CROSS-SECTIONAL TEST METHOD

				Pooled CV of measurements									
Detectable difference in means	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**
10%	16	63	142	251	393	565	769	1005	1272	1570	1900	2261	2653
20%	4	16	36	63	98	142	193	251	318	393	475	565	663
30%	2	7	16	**28**	44	63	86	112	142	175	211	251	295
40%	1	4	9	16	25	36	48	63	80	98	119	142	166
50%	1	3	6	10	16	23	31	40	51	63	76	91	106
60%	1	2	4	7	11	16	22	28	36	44	53	63	74
70%	1	2	3	5	8	12	16	21	26	32	39	46	54
80%	0	1	2	4	6	9	12	16	20	25	30	36	42
90%	0	1	2	3	5	7	10	13	16	20	24	28	33
100%	0	1	2	3	4	6	8	10	13	16	19	23	27

Appendix 4

The KPT is designed to accommodate many stove-fuel combinations in addition to the standard woodstove. This includes stoves that burn liquid and gaseous fuels, as well as solid fuels like coal, charcoal, crop residues and dung. However, if fuels other than wood are used then there are some special factors to consider when filling the data entry and calculation forms. These are discussed below for each fuel.

Liquid and gaseous fuels:

If liquid and/or gaseous fuels are used, the procedure is simplified because there is neither char nor ash to be measured. Moreover, many liquid and gaseous stoves are small enough to directly measure on a scale, so that fuel consumption can be very straightforward. However, if the stoves are too large to put on the scale, then fuel consumption may be difficult to assess. Similarly, if the gas is from a piped source (as with gas stoves in the US), then a flow meter may be needed to measure the quantity of fuel consumed. In addition, the tester must know the calorific value of the fuel. For fossil fuels, this can vary depending on exact mix of distillates that are used. Some calorific values that have been reported in the literature are given below, but we suggest the tester use a locally specific value if possible.

Fuel	Calorific value (MJ/kg)	Source
Kerosene	43.3	(Zhang et al., 2000)
	43.6	(IEA, 2005)
	43.1	(Smith et al., 2000)
LPG	49.0	(Zhang et al., 2000)
	47.1	(IEA, 2005)
	45.8	(Smith et al., 2000)
Natural gas	51.3	(Zhang et al., 2000)
Biogas	17.7	(Smith et al., 2000)

Non-wood solid fuels:
With non-woody solid fuels two complications arise. The first is that the moisture meter used to measure wood moisture content can not measure the moisture content of non-woody fuels. Therefore testers must use the oven method to determine moisture content. Second, the calorific value of the fuel, which is affected by the moisture content, must be determined. As with liquid and gaseous fuels, solid fuels have a range of calorific values. However, if possible, testers should try to ascertain the specific calorific value of their fuel through calorimetry. This procedure requires specialized equipment and

training.[15] If possible, testers should check with a local university to see if testing facilities are available. If testing can not be done locally, use values from published studies, understanding that this introduces additional uncertainty into the test. Some calorific values of non-woody solid fuels reported in previous household energy studies are given in the table below and have been included in the accompanying Data and Calculations spreadsheet.

Fuel	Calorific value (MJ/kg)	Source
Charcoal	25.7 @ 1.7 % MC_{wet}	(Smith et al., 2000)
	27.6-31.5 @ ~5 % MC_{wet}	(Pennise et al., 2001)
Maize stalks	16.1 @ 9.1 % MC_{wet}	(Zhang et al., 2000)
	15.4 @ 5.0 % MC_{wet}	(FAO, 1993)
Wheat stalks	14.0 @ 7.3 % MC_{wet}	(Zhang et al., 2000)
	15.4 @ 5.0 % MC_{wet}	(FAO, 1993)
Rice stalks	13.0 @ 8.8 % MC_{wet}	(Smith et al., 2000)
	14.2 @ 5.0 % MC_{wet}	(FAO, 1993)
Dung	11.8 @ 7.3 % MC_{wet}	(Smith et al., 2000)
	15.4 @ 5.0 % MC_{wet}	(FAO, 1993)
Coal		
China	22.5	(IEA, 2005)
China	27.3 @ 2.1 % MC_{wet}	(Zhang et al., 2000)
China (washed)	30.1 @ 4.7 % MC_{wet}	(Zhang et al., 2000)
US	26.2	(IEA, 2005)
India	18.4	(IEA, 2005)
South Africa	23.5	(IEA, 2005)

[15] See, for example, http://web.umr.edu/~gbert/cal/cal.html, for an explanation and a simulation of the procedure.