Kitchen Performance Test (KPT)

Originally prepared in 2003 by Rob Bailis with input from Kirk R. Smith and Rufus Edwards for the Household Energy and Health Programme, Shell Foundation

Revised in 2018 by

Rob Bailis, Ryan Thompson, Nicholas Lam, Victor Berrueta, Godfrey Muhwezi and Esther Adams

The Kitchen Performance Test (KPT) is the principal field–based procedure to measure household fuel consumption. The primary objective of the KPT is to quantify fuel consumption under typical household and stove usage conditions. The materials here provide guidance on the minimum set of procedures needed to meet the primary aim of the KPT, a quantitative measure of fuel consumption. KPTs are often combined with household surveys, which help to contextualize fuel consumption practices. Earlier versions of KPTs included model survey questions, which are omitted from this update in order to focus exclusively on fuel measurement but can be accessed from the Global Alliance for Clean Cookstoves at the following URL: http://cleancookstoves.org/technologyand-fuels/testing/protocols.html.

Because it occurs in the homes of stove users, this type of testing, when conducted carefully, is the best way to understand the stove's impact on fuel use and, when complemented with the appropriate surveys, on general household characteristics and behaviors (Lillywhite, 1984; VITA, 1985). However, the KPT is also a particularly 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 are 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 to gauge 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, economic and cooking information of the 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 Household Energy and Health (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. Whenever this is the case, they may rely on survey data that has already been collected or conduct a shorter version of the qualitative survey to fill data gaps.

A follow-up survey could be conducted sometime after the stove has been in use 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 could be applied to the same households that participated in the initial survey in order to capture changes in a more statistically sound way. It may also be useful for stove promoters to conduct a follow-up survey that targets households that do not use the stove in order to better understand why some people choose not to use it.

Selecting Households to Participate

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. A full discussion of sampling is outside the scope of this discussion, but some of the more important points will be mentioned.[1] For projects that target a small number of households in a limited area, it may be possible to include 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. 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. For example, a selection that only includes families that live along a main road, or a selection that leaves out families that belong to a certain parish, would be biased.

Sample size is also an important consideration, because samples should be large enough to ensure statistically valid results. Gold Standard recommends the following sizes based on the overall size of the target population (The Gold Standard Foundation, 2011):

- Group size < 300: either 30 or population size, whichever is smaller
- Group size 300 to 1000: 10% of group size
- Group size > 1000: at least 100

Applications of the KPT

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 cookstove 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).

[1] For more details, see (Edwards, Hubbard, et. al 2007).

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.

Implementing the KPT

The 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 two groups of households, one using the old stove and one using the new stove, are compared at the same time.

When practicable, 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[2]

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 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.[3] 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.*[4]

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

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[2] 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.

[3] Random selection may sound complicated, but it doesn't have to be. Many simple calculators have a random number function, as 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

[4] 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.

(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. People of different ages and genders have different caloric requirements, which can affect fuel consumption. To facilitate comparisons across households with different age and gender compositions, the KPT converts household members into "adult-equivalent" units (explained in more detail below). 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 households are evaluated—one group using the old stove and one group using the new stove.

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

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.[5]
- 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 fuel consumption per adult-equivalent of over 40%, where the

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

$$\sigma^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})}{n-1}$$

where:

- x_i represents each individual measurement
- *n* is the total number of measurements
- $\bar{x}$ is the average of all measurements

CV in the WBT is typically about 10%.[6] 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 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 1 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 1 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 at least 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.[7] 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

[6] 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 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).

[7] If different clusters are grouped together for analysis, multiple factors influencing fuel consumption per adult-equivalent 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

the entire sample is modeled by the CV of the initial sub-sample base the remaining sample size on this locally determined CV.

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 1). 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 1). 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 wood burning stove for all of their cooking needs. While this still occurs in some areas, it is common for households to use more than one combination of stoves and fuels (Masera et al., 2005).[8] 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.[9]

[8] 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.

[9] 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.

Through the KPT, stove testers will measure daily fuel consumption in order to calculate the average adult-equivalent 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 lower heating value of that fuel. See Appendix 2 for a discussion of the heating 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 household's 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 fuel consumption per adult-equivalent 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.

The analysis in Table 2 shows that average per adult-equivalent consumption of wood and dung have both decreased after the households switched to the improved stove. Of course, average energy consumption per adult-equivalent 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.[10]

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 heating value of the fuel. This will be explained in more detail in the KPT procedure below.

[10] 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 past 24 hrs.	Wet wood used per adult equiv. in past 24 hrs.	Dry wood used in past 24 hrs.	Dry wood used per adult equiv. in past 24 hrs.	Wet dung used in past 24 hrs.	Wet dung used per adult equiv. in past 24 hrs.	Dry dung used in past 24 hrs.	Dry dung used per adult equiv. in past 24 hrs.	Total energy	Per adult equiv. 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 wood per adult equiv.	Dry wood	Dry wood per adult equiv.	Wet dung	Wet dung per adult equiv.	Dry dung	Dry dung per adult equiv.	Total energy	Energy per adult equiv.
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 past 24 hrs.	Wet wood used per adult equiv. in past 24 hrs.	Dry wood used in past 24 hrs.	Dry wood used per adult equiv. in past 24 hrs.	Wet dung used in past 24 hrs.	Wet dung used per adult equiv. in past 24 hrs.	Dry dung used in past 24 hrs.	Dry dung used per adult equiv. in past 24 hrs.	Total energy	Per adult equiv. 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 adult equiv.	Dry wood	Dry wood per adult equiv.	Wet dung	Wet dung per adult equiv.	Dry dung	Dry dung per adult equiv.	Total energy	Energy per adult equiv.
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

Comparison of results	Absolute difference	Percent difference	Comments
Per adult equiv..wood consumption	-0.19 kg	-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.
Per adult equiv..dung consumption	-0.07 kg	-21%	
Per adult equiv..energy consumption	-4.6 MJ	-22%	

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

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

Summary of results

	Per adult equiv. wood consumption	**Per adult equiv. dung consumption**	**Per adult equiv. energy consumption**
Difference (improved - traditional)	-0.25 kg	-0.05 kg	-5.4 MJ
% difference t-	-25%	-12%	-22%
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.[11] 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.

[11] 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.

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.

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, although 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[12]

Balance for weighing wood and other solid fuels	A hanging scale (digital or spring type) is appropriate which has a resolution of 0.1 kg or better, an accuracy 5% of reading or better, and a capacity of 10-30 kg.
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 in either a positive or negative direction.
Moisture meter	A moisture should be used to measure the moisture content of the wood fuel used in each household, which is required to normalize fuel consumption per adult-equivalent daily. Pin-type or pinless handheld moisture meters are acceptable with a resolution of 1% RH and accuracy of 10% of reading or better. Moisture meters are not appropriate for non-woody solid fuels unless calibrated for the specific fuel. The oven method should be used for non-woody fuels and may also be used for wood.
Airtight container	Airtight bag/container for transporting fuel samples.

If liquid or gaseous fuels or are used, additional equipment will be required.[13]

Liquid and gaseous fuels (e.g. kerosene, ethanol, LPG, and piped gas or biogas): consumption may be measured whether 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

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

[13] 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.

0.1 – 0.5 kg resolution. An electronic balance is recommended which has a range greater than the mass of the fuel container (typically 5 – 10 kg) and a resolution and accuracy less than 5% of the expected daily fuel mass consumed (typically .001 kg). For measuring volume, a graduated container with 2-5 liter capacity would be appropriate.[14] 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. If LPG is used, the fuel mass must be measured. This is difficult because the tank holding the gas is typically much heavier than the amount of fuel consumed in a day. Scales used to measure biomass may not have the accuracy or capacity to measure LPG tanks on a daily basis. Longer durations between weighings of LPG tanks can be a strategy for capturing consumption without purchase of new scales specifically for LPG. For biogas, or other piped gas, consumption can be measured with gas flow meters.

Procedure for fuel consumption measurements

As was discussed above, the primary objective of the KPT is to quantify fuel consumption under typical household and stove usage conditions.

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 1 and the related discussion). If possible, select families at random based on the families who agreed to participate when responding to the initial qualitative survey. If random sampling is not possible, choose households as local circumstances allow.
2. Define a 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. [15]
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.

[14] 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 a 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.

[15] One study found that variability in daily fuel consumption decreases with increasing days of measurement and suggests measuring for at least four consecutive days (Berrueta, Edwards, and Masera 2008).

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

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 daily consumption per adult-equivalent of all fuels. The form will also calculate the total and daily energy consumption per adult-equivalent 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).

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