

Kitchen Performance Test (KPT)

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The Kitchen Performance Test (KPT) is the principal field-based procedure proposed for Shell HEH projects to demonstrate that they have met their stove performance objectives. There are two main goals of the KPT: (1) to compare the performance of improved stove(s) to the common or traditional stoves or to other improved stoves as they are used in the kitchens of real families and (2) to identify qualitative aspects of stove performance through a simple survey. To meet these two aims, the KPT includes both 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 more 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 are less controllable compared 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, or at the same time that the stoves are sold or distributed. The survey may include households that do not plan to use 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 this is not included as an essential part of the KPT.

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 at random 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 6 and the follow-up survey in Appendix 7.

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 fuel consumption between households using traditional cooking technologies and households using technologies promoted under the funded activities.
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;
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 only requires that stove testers conduct 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 the families use the traditional stove for a week followed by daily measurements as the same families use the improved stove for a week. This type of test makes a comparison of the individual 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 week, with one group using the traditional stove and the other group(s) using the improved stove(s). This is a cross-sectional study, where households with the two groups of stoves (old and new) are compared at one point in 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 is also true if families are tested in a paired-sample test, where the same set of households are first surveyed using the old stove and then using the new stove(s). In this case, weather conditions or local economic conditions may change in the period between the two surveys in ways that affect fuel consumption. For example,

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 or they may get misleading results. It is particularly important to minimize as much as possible difference in season in the paired measurements (See "Considerations in Study Design").

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 (or 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 (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).

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: The choice of families to survey for the KPT 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.¹ 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 claims about the outcome of KPTs that were not based on random samples are not statistically valid.*

We are not saying that tests can only be done on random samples: simply that general claims about the fuel-saving potential of an improved stove should only be made under those circumstances. 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.

¹ 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.

Random sampling over a large area, however, often leads to difficult transport and scheduling logistics because households can be far apart. Thus, for larger projects, cluster sampling is recommended by which communities or villages are first randomly chosen from the entire area and then households are randomly chosen from within the chosen communities. If the villages are similar in size, the result will still be statistically valid. 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 fuel consumption part of the KPT is also related to statistical factors. This test is designed to compare the average fuel consumption per person in households using the improved stove to average fuel consumption per person in households using the old or 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 households are evaluated - one group using the old stove and one group using the new group.

In the first case, we calculate the average change observed fuel consumption per person in each family before and after they switch to the improved stove. In the second case, we compare 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.

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.²
- ⇒ 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, which can contribute to overall fuel use. 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

² 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.

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

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%.³ 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 9 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 9 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.⁴ The box below gives a specific example of each testing method.

³ Variation in data is typically measured the coefficient of variation (CoV), 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 usually has a CV of 40% or more (FAO, 1983; Baldwin, 1986).

⁴ 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

If no local data are available at the start, another approach is to initiate either type of study and then, after completing tests in about 10 households, calculate the CV and then decide on the remaining household sample size according to the requirements based on the 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 any 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 older 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 seven 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.

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. Even though they observed a 40% reduction in fuel use in lab conditions, they realize that this may not occur in real field conditions, and 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%).

how factors other than the type of stove used by the household contribute to variability in fuel consumption, but these will not be discussed in detail here.

Equipment for the quantitative fuel consumption KPT

Balance for weighing fuelwood	A large capacity spring scale will be most appropriate
Pots and other cooking utensils	These should be supplied by each household. They need not be standardized.
Fuel	Depending on the local situation, the testers may want to provide fuel to the households participating in the quantitative part of the KPT. This can have both positive and negative impacts on the outcome of the KPT. A more detailed discussion follows.
Wood 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. Other methods may also be used to determine fuel moisture (see the discussion in the section on the WBT).

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.⁵ 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

⁵ 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.

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 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, 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.

Accounting for multiple fuel use

In some areas, stove testers may find that stoves are used with multiple fuels: for example various crop residues or dung. It is possible that these different fuels will be used at different times of the year or they may even be used during a single cooking activity. If this is the case, care must be taken to account for daily consumption of each fuel that is used. In order to compare overall fuel consumption in either type of study design, stove testers should convert the quantity of non-woody fuel consumed

into a mass of *fuelwood equivalent* by multiplying the mass of non-woody fuel consumed by the ratio of calorific value of the woody and non-woody fuel.

For example, if dung is used in combination with wood, as is common in many Indian villages, the mass of dung consumed should be converted into wood-equivalent units by using the following conversion:

$$\text{Fuelwood - equivalent mass} = (\text{Mass of non - woody fuel}) * \left(\frac{\text{LHV}_{\text{non-woody fuel}}}{\text{LHV}_{\text{fuelwood}}} \right)$$

If the calorific values are not known precisely, then an approximation based on previous studies should be used.

Procedure for fuel consumption measurements

As was discussed above, the KPT has two main goals: the quantitative measurement of daily fuel consumption, and 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 above). 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.
2. Define the testing period of *at least* 3 consecutive days. Avoid weekends and 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 four days in the field - 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 fuelwood at a specified time each day. **Encourage the family to only use the stove that is being tested throughout the entire week of surveying.** Stress to household members that their cooking practices should remain as close to normal

as possible for the duration of the test.⁶ If possible, ask household members to avoid using the stove for any purpose other than cooking food for household members (for example, cooking food for commercial sale or preparing food for livestock). Record the weight and moisture content of the initial stock of fuel.

4. Define an inventory area for fuel consumption measurement. If fuel is not provided as part of the testing protocol, stress to the family that they need to keep newly collected fuel separate from fuel that has already been weighed (if necessary, provide containers to help the family keep newly gathered fuel separate from fuel that is already measured).
5. Visit the household at roughly the same time each day, without being intrusive. Confirm that the stove is operating properly. With each daily visit, record the number of people that ate their meals in the household since your last visit. This may vary from one day to the next - avoid using a weekly average value if possible. Record the gender and age of each person (this information is used to calculate the number of *standard adult persons* served - see Table 1 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 1: "Standard adult" equivalence factors defined in terms of sex and age (from Guidelines for Woodfuel Surveys, for F.A.O. by Keith Openshaw).

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 Data and Calculation form to calculate specific daily consumption for each household, and then the mean and standard deviation. Compare the results with those from households using other stoves.

⁶ For example, if there is a festival, funeral or anything else out of the ordinary planned during the week of testing, delay the test, or omit the family from the study.

8. 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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Appendix 2

Stove Performance Testing

Tests of stove performance range from lab-based water boiling and cooking tests to qualitative and quantitative surveys of stove users in the field. There are advantages and disadvantages to both types of tests. Lab-based tests are more appropriate at the early stages of stove development in order to compare various technical aspects of stove design. For example, Baldwin recommends lab-based tests for comparing and optimizing different dimensions and other design details of the stove. Lab-based tests are also more appropriate when comparing stoves that are used in different regions of the world. There is a great amount of variation in cooking practices, fuels, and household environments throughout the world's developing regions that makes direct comparisons of actual stoves in people's kitchen very difficult. Lab-based tests in order to accommodate the many aspects of stove performance testing that eliminate the variability in factors that may affect stove performance other than the physical characteristics of the stove itself.

In order to accommodate the many aspects of stove performance testing that designers of improved cookstoves face, the protocols described in this manual include procedures for two types of lab-based tests as well as a field test. The lab tests include a modified version of VITA's Water Boiling Test (WBT) and as well as a Controlled Cooking Test (CCT). The field test includes two qualitative surveys: the first helps project designers to assess household cooking practices prior to the introduction of the improved stove and the other provides them with follow-up data 3-6 months after the stove has been introduced to the family. The field test also includes a procedure to compare fuel consumption in households using different types of stoves. This test is critical if project designers wish to make justifiable claims about real impacts on fuel consumption resulting from the stoves that they are promoting. ***Such claims can not be based on lab-based tests alone***

While lab-based tests allow stove developers to differentiate between well-designed and poorly-designed stoves, they give little indication of how the stoves are actually used by the people who are targeted by stove projects. In order to know if stove projects are having the desired impact (whether it is fuel conservation, smoke reduction, or both), the stoves must be measured under real conditions of use.

Two major stove programs and their use of stove performance tests

In addition to the tests introduced by VITA and elaborated by Baldwin, other large-scale efforts have been conducted to assess the performance of improved stoves and stove programs. Two of the most notable efforts are those that have been conducted over the past 20 years in India and China. Taken together, these programs represent the vast majority of improved stoves introduced globally: with well over 200 million stoves disseminated between them. These programs have undergone numerous

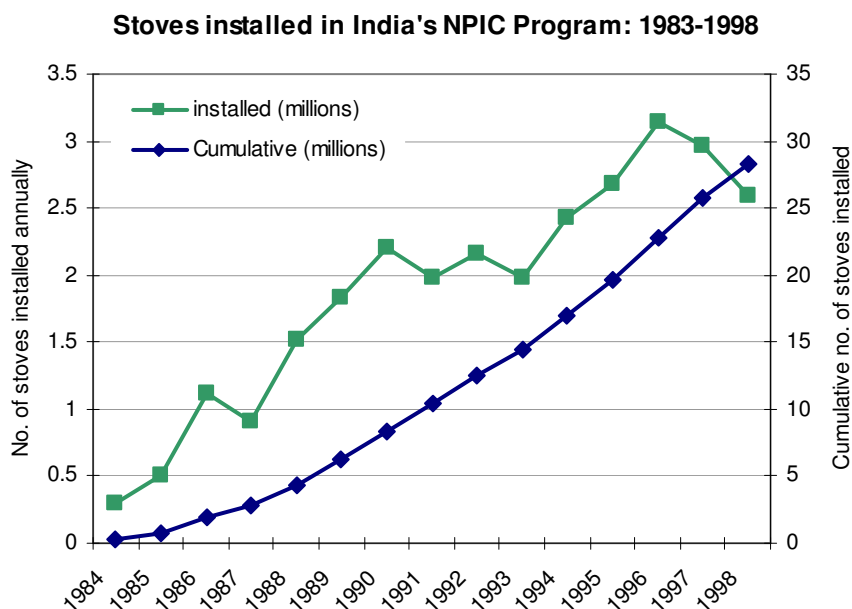
changes since their inception in the early 1980s. A full review of these programs is beyond the scope of this document, but a brief review of each is given below, with attention to the stove performance monitoring methods that have been used. References are also provided for further reading.

India's National Improved Chula Program (NPIC)

This program, which has been underway for nearly two decades, had five stated objectives:

- to conserve and optimize the use of fuelwood, especially in the rural and semi-urban areas
- to help alleviate deforestation
- to reduce the drudgery associated with cooking, especially on women, and the health hazards caused by smoke and heat exposure in the kitchen
- to bring about improvements in household sanitation and general living conditions
- employment generation in rural areas

By 1999, NPIC activities had disseminated over 28 million stoves (Kishore and Ramana, 2002). The graph below illustrates the number of stoves disseminated during the first 15 years of project activity.



Based on data from (Kishore and Ramana, 2002)

Despite the impressive numbers, NPIC is not considered an unqualified success. Firstly, the cumulative data hide the fact that most stoves have a limited lifetime -

typically no more than two years - so that the total number of stoves in use in 1998 was actually a small fraction of the cumulative number shown in the graph. Several other factors also contributed to NPIC's problems. These are summed up well in the following passage, which is taken from a recent World Bank report on India's experience with cookstoves in the context of indoor air pollution reduction:

In the early programs it was assumed that if improved stoves were presented to people, they would be quickly adopted and the intervention would lead to self-sustaining programs. This often did not happen for several reasons. One reason was that the energy efficiencies achieved in laboratories did not translate into similar efficiency gains in rural homes. Another reason lay in an obvious failure to identify the market for improved stoves; for example, some programs introduced stoves into regions where people purchased neither their traditional stoves nor fuelwood, thus having little appreciation of efficiency gains. The health benefits of the improved stoves were not well advertised. Finally, the price of an improved stove was a significant barrier to adoption, especially in areas where there was very little cash outlay for stoves or fuel (World Bank, 2002).

While each of these problems presents significant obstacles for stove project designers, the problem of linking lab-based efficiency to actual fuel consumption in rural homes is of greatest concern to the ideas presented in this document. We will discuss this issue in much more detail below.

NPIC reports claimed that each stove reduced fuelwood consumption by 30-40% relative to a traditional chulha, which represents roughly 700 kg of fuelwood family per year (FAO, 1993). The World Bank reports more modest savings of 19-23% relative to traditional stoves. Kishore and Ramana also report smaller improvements. They cite one study that found savings of about 35 kg fuelwood per year and another that actually found a **net increase** in fuel consumption. The results of the latter study are shown in Table 2 below. These data are the result of fuel consumption surveys that followed VITA's kitchen performance test protocol (VITA, 1985; Kishore and Ramana, 2002). The results show that in many cases, NPIC stoves consumed more fuel than the traditional chulas that they were meant to replace.

Kishore and Ramana's review of the NPIC stove performance relied on field tests, but the NPIC program itself based its assessments of stove performance primarily on "thermal efficiency" tests. Thermal efficiency was defined as "the ratio of heat actually utilized to the heat theoretically produced by complete combustion of a given quantity of fuel," (FAO, 1993, p. 96). In order to qualify for inclusion in NPIC, improved chulhas were required to have a minimum efficiency of 20% for fixed mud stoves and 25% for portable metal stoves. The lab-based tests that were used differ substantially from the WBT designed by VITA and presented below with slight modifications. See (FAO, 1993, Annex 2) for a full description of the procedure.

Table 2: Comparison of fuel consumption in Improved and Traditional Chulhas in 3 Indian States

	Improved chulha		Traditional chulha		Percent savings of improved chulha compared to traditional chulha
	No. of households	Wood consumption kg/day/stove ^a	No. of households	Wood consumption kg/day/stove ^a	
<i>Tamil Nadu</i>					
Manachai	14	5.99	8	5.34	-12
Muthupattai	10	7.27	10	4.77	-62
<i>Rajasthan</i>					
Motuka	11	7.2	12	5.91	-22
<i>West Bengal</i>					
Golti	14	9.34	14	11.65	19.8
Iswarigacha	15	7.34	13	7.83	6.3
<i>Average</i>					-14

From (Kishore and Ramana, 2002)

^a Assuming six persons per family, one chulha per family and a calorific value of 17.6 MJ/kg for wood.

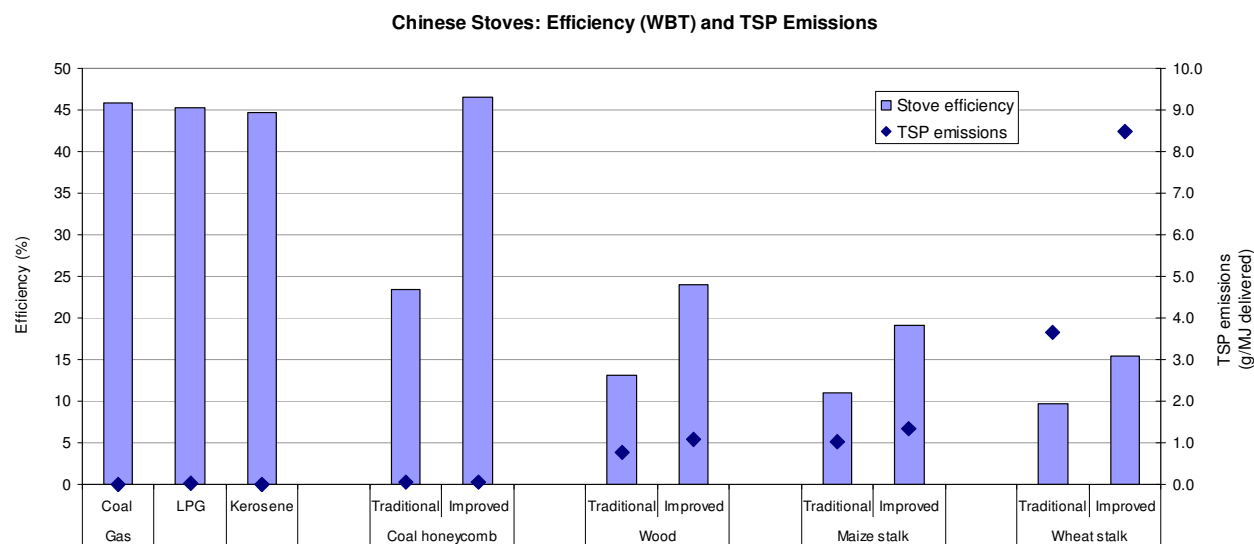
NPIC continued until 2002, when the Indian government devolved authority to the state level so that individual states in India are now responsible for implementing improved stove programs. Additionally, in recent years, many non-governmental agencies have become involved in stove development and dissemination, both in partnership with and independent of, state-run projects.

The Chinese National Improved Stove Program (CNISP)

China has undertaken the most extensive improved stove program in the world. Between its inception in 1983 and 1998, roughly 185 million stoves were disseminated in China (Edwards, Smith et al., 2004). Like India's NPIC, CNISP was originally intended to conserve biomass fuels and reduce the time and effort household members had to devote to meeting their energy needs.⁷ Because of its sheer scale and the extent of social and economic changes China has undergone during the time that the program has been in place, the impact that CNISP has had is difficult to assess independent of other changes in rural China. Biomass fuel consumption in some rural areas has decreased, but this may be attributed to fuel switching rather than to gains in energy efficiency. Many rural families have begun using coal, electricity, or other fuels in addition to biofuels, which would likely result in decreased biofuel consumption regardless of the type of stove in use.

⁷ One expert has pointed out that in addition to the goals of biofuel conservation and reduced workload on the rural household, China's stove program was also a state-driven effort to modernize biofuel consumption in order to reduce and/or delay growth in demand for fossil fuels among China's massive rural population (Smith, Shuhua et al., 1993).

As Smith indicated over 10 years ago, information about quantitative aspects of China's improved stoves is not widely available (Smith, Shuhua et al., 1993). Data about the performance of stoves disseminated through CNISP are not widely published. Zhang and colleagues tested emissions and efficiencies of 28 fuel-stove combinations in China. They report average lab-based efficiencies derived from a 3 repetitions of a modified version of VITA's WBT (Zhang, Smith et al., 2000). A sample of their results are reproduced below in the graph below showing four pairs of traditional and improved Chinese stoves each using a different solid fuel: coal, wood, maize stalks and wheat stalks. Three popular fossil fuel options are also included for comparison. Notice the efficiency determined by the modified WBT is higher in improved stoves. However, the biomass stoves tested are far less efficient than liquid and gaseous fossil fuels. Another interesting result concerns health impact of stoves; the biofuels used in improved stoves appear to result in higher emissions of particulate matter (measured as *Total Suspended Particulates* or TSP). All of these stoves tested have chimneys, so the increase in TSP is not necessarily a cause for concern as long as the chimneys are functioning well, however it does indicate that higher overall efficiency in these improved stoves has likely been achieved at the expense of combustion efficiency.



Based on data from (Zhang, Smith et al., 2000)

However, it is difficult to predict fuel consumption by rural families under real cooking conditions solely through the results of energy efficiency determined by WBTs. Unfortunately, few reports of actual fuel consumption by improved stoves in China have been published outside of China. The authors would welcome any information about field performance of improved stoves in China.

Appendix 6

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	

12. What kind of stove(s) are used? What is the age and frequency of use of each stove?	Stove/fuel	Age of stove (yrs)	Frequency of use (times per day, week, or month)
	a)		
	b)		
	c)		
13. Whose job is it to obtain cooking fuel?	For each Stove/fuel from question 12, list the family members' gender and age as in question 7 above: a) b) c)		
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)?	Give answers for each Stove/fuel given in question 12		
	Location	Distance from household	
	a)	a)	
	b)	b)	
	c)	c)	
15. How much is consumed 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 12		

	Monthly fuel consumption	Monthly expenditure on fuel
	a)	a)
	b)	b)
	c)	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?	<u>Type of maintenance</u> Cleaning stove of ashes Cleaning flue Repairing cracks Other task - _____ _____	<u>Frequency (circle appropriate response)</u> 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? <i>If the respondent responds positively, provide information about how they can get a new stove</i>		
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?		
<i>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.</i>		

Appendix 7

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):	<u>Gender/Age</u>	<u>Count</u>
	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?	Yes/No	
a. Is the stove warm to the touch?	Yes/No	
b. Are there ashes or embers inside?	Yes/No	
c. Is there soot around the fuel chamber?	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?	<u>Type of maintenance</u> Cleaning stove of ashes Cleaning flue Repairing cracks Other task - _____ _____	<u>Frequency (circle appropriate response)</u> 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	Monthly expenditure on fuel	
	a)	a)	
	b)	b)	
	c)	c)	
23. Is it easier or more difficult to cook with the new stove? Describe why.	<u>Easier</u> <u>Harder</u>	Why?	
24. Do meals take longer to prepare using the new stove? If yes, list the meals that take longer to prepare.	<u>Yes</u> <u>No</u>	Meals:	
25. Are there any cooking tasks easier to accomplish with the new stove? If yes, list these tasks.	<u>Yes</u> <u>No</u>	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)	<u>Better/worse than old stove:</u>	

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) • • •		
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Appendix 9

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

SAMPLE SIZE REQUIRED FOR A 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 A 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