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# EVALUATION OF MANUFACTURED WOOD-BURNING STOVES IN DADAAB REFUGEE CAMPS, KENYA

**FEBRUARY 2010**

This publication was produced for review by the United States Agency for International Development. It was prepared by Berkeley Air Monitoring Group.

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## **DISCLAIMER**

The author's views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

## EXECUTIVE SUMMARY

### INTRODUCTION TO STUDY AND TESTED STOVES

The purpose of this study was to obtain information on the potential suitability of a new generation of manufactured biomass cooking stoves for refugee and Internally Displaced Person (IDP) environments as well as disaster relief situations. Berkeley Air Monitoring Group (Berkeley Air) was asked to combine rigorous quantitative stove performance testing using the Controlled Cooking Test protocol with as much qualitative assessment of the acceptability and usability of each stove as feasible during a time-limited visit to a refugee camp designated by USAID. At USAID's request, UNHCR agreed to host and facilitate the stove performance testing at the Dadaab refugee camp, located in northeastern Kenya.

Five manufactured stoves were selected to be tested in the Dadaab refugee settlements. They were:

- Envirofit G-3300 Stove
- StoveTec Wood Stove (26 cm)
- Philips Natural Draft Stove
- Save80 Stove
- Vesto - The Variable Energy Stove

To qualify for the study, all of these stoves performed well in laboratory tests, were centrally manufactured, required no assembly, could be easily transported, and were designed to burn wood. In addition, a "three-stone fire" or ("open fire") was tested as the comparison baseline.

All of these stoves have cylindrical or hexagonal metal exteriors with a handle to facilitate moving them. They all have metal combustion chambers where the fire is contained, except for the StoveTec, which has a ceramic liner. Both the StoveTec and Envirofit stoves have an "L" shaped, front-loading combustion chamber, one of the design features that defines them as "rocket" stoves. All of these stoves have been designed to control the air flow through the stove in order to optimize the mix of combustible elements (e.g. the air to fuel ratio), improving the cleanliness and efficiency of the burning process. However, the technologies differ in that the Envirofit, StoveTec, and Save80 burn the fuel in a single combustion stage, whereas the Philips and Vesto stoves have a two-stage burning process and are sometimes known as "gasifier" or "semi-gasifier" stoves.

All of the stoves except the Philips were provided with certain "accessories" or components that are not integral to the functioning of the stove but are designed to improve its performance. The following choices were made regarding these accessories.

- The Save80 stove is supplied as a part of a cooking system that includes an integrated pot and an expanded polypropylene heat retention box called a Wonderbox. The integrated pot was used as designed, suspended above the combustion chamber on the metal edge of the stove. The Wonderbox, however, was not used in these tests, because it fell outside of the scope of the study.
- Both the StoveTec and Envirofit stoves came with metal skirts designed to contain and funnel the heat to the pot bottom more efficiently. While the skirts are not integral to the functioning of these stoves, they have been shown in laboratory environments to increase efficiency and were used in these tests.

## TEST OBJECTIVES AND METHODS

The Berkeley Air field team spent five days in each of the three settlements of the Dadaab complex testing stoves. The objective was to report the following metrics for each stove:

- fuel efficiency (specific consumption);
- cooking time;
- acceptability of stove to end users; and
- ease of use

Twenty refugee women took part in the study – six or seven cooks in each settlement – to conduct a total of 214 Controlled Cooking Tests (CCTs). The CCT is one of three standardized cookstove testing protocols commonly used in the household energy field to evaluate and compare technologies. The CCT yields two main quantitative outputs: the amount of wood and time required to complete the task of cooking a standardized local meal, in this case rice with tomatoes, onions, and spices. The CCT was chosen as the basis of this study because it provides a standardized comparison of stove performance within the real-world parameters of local fuel, food, and cooking practices. However, the evaluation of how well the community might accept the test stoves had to be measured separately with additional usability indicators.

The test plan was designed to address study priorities and inflexible operational constraints.

Priority #1: Achieve a statistically powerful comparison between each stove and the open fire despite uncertain field conditions.

Priority #2: Have each cook test all the stoves, in order to increase the value, fairness, and power of the qualitative assessment methods and to better understand variability in the quantitative data.

Priority #3: Collect as much usability information on the stoves as possible.

Constraint #1: The field team was given 15 days in December 2009 during which to complete the testing.

Constraint #2: The team's daily work hours were limited by security procedures to 8:30 am to 4:30 pm.

In response to these considerations, a study plan was developed that had each cook first create her own baseline by testing the open fire three times and then test each of the five manufactured stoves at least once. Each cook was given a short (e.g., 1-hour) training session on how to use the manufactured stoves. The plan prioritized the testing of three of the five stoves – Envirofit, StoveTec, and Philips – in order to maximize the chances of obtaining statistically valid results. These stoves were prioritized because of their strong performance in laboratory testing, as well as their producers' significant manufacturing capacity.

To the extent practicable, the tests were conducted in a manner consistent with the manufacturers' guidelines for optimal stove performance, and accessories were used where provided. This resulted in two potentially uneven comparisons: the Save80 was tested with its own sunken pot whereas all the other stoves were tested with a typical UNHCR-issued pot resting above the rim of the stove; and the Envirofit and StoveTec stoves were tested with the metal skirts surrounding the base of the pot. No tests were conducted without the skirts. Prior to

the start of the testing, the women received a concise, two-part training on how to use the stoves from the Berkeley Air team. This training was not designed to be extensive, but to simulate real life in a relief situation, where intensive user support often cannot be provided.

Three methods were used to assess the acceptability and usability of the five stoves.

- During each cooking session, a field team member completed a standardized observation checklist, designed to capture information about the cook’s use of the stove, the stove and pot stability, and the smoke output (n=187).
- A questionnaire on stove usability and preferences was administered to each cook after she completed the testing of any of the five manufactured stoves (n=86).
- On the final day at each settlement, a focus group was conducted so the six cooks could discuss which stoves might best and least met their needs and circumstances.

### QUANTITATIVE TEST RESULTS AND DISCUSSION

All five of the manufactured stoves had significantly lower fuel use than the open fire, with savings ranging from 32 – 65%. The first table below shows that the Save80 was the most fuel efficient stove tested, followed by the StoveTec and Envirofit rocket stoves. In contrast, the time savings, also summarized below, were minimal. Only the Vesto and Envirofit stoves had significantly faster cooking times than the open fire, and they saved only 7 and 5 minutes respectively. The other three stoves had cooking times that were not statistically different from the open fire.

**Table 1. Ranking of the manufactured stoves on fuel efficiency and cooking speed. Percent differences compared to the open fire are shown in parentheses.**

Rank	Most fuel efficient (% savings vs. Open fire)	Fastest cooking (% faster than Open fire)
1	Save80 (65%)	Vesto (12%) and Envirofit (8%)
2	StoveTec (54%) and EF (52%)	StoveTec (7%)
3	Philips (46%)	Save80 (2%) and Philips (-4%)
4	Vesto (32%)	---

Table 2 below shows quantitative stove performance results for each of the six stoves tested, including cooking time and specific consumption (fuel use), adjusted for the amount of moisture in the wood and the amount of charcoal that remains unburned at the end of the test. The table shows the number of tests completed, the averages, and the percent differences compared to the open fire.

**Table 2. Summary of quantitative stove performance results for the six stoves, showing the average and percentage difference versus the open fire.**

	(units)	Open fire	Envirofit	StoveTec	Philips	Vesto	Save80
# of Tests	na	54	38	38	38	24	22
Specific consumption	g wood/ kg food	295	143	136	159	202	110
Specific consumption	% diff. vs. Open fire	NA	-52%	-54%	-46%	-32%	-63%
Cooking time	min	54	49	50	56	47	52
Cooking time	% diff. vs. Open fire	NA	-8%	-7%	+4%	-12%	-2%

The results of the controlled cooking tests are strikingly consistent and show strong evidence that the stoves save fuel: of the 15 comparisons among stoves and the open fire, 13 of them are statistically significant. The similarity of the fuel use, cooking time, and burning rate patterns across all 18 cooks provides strong evidence that the differences in performance seen in this study are due to intrinsic differences among the stoves. At the same time, certain study design choices made either intentionally at the start of the work or out of necessity in the field, warrant investigation in case they skewed any of the results.

- The differing number of tests performed on each stove type may have caused slight differences, if a cook's familiarity with a stove enhanced her ability to operate it more efficiently. The consistency of the pattern of specific fuel consumption across test numbers, however, indicates that the differing number of tests did not skew the quantitative results in any material way.
- Use of the provided, integrated Save80 pot instead of the standard UNHCR pot (which was used with all five other stoves) likely reduced fuel use for the Save80 stove, but we cannot say by how much.
- Use of the provided skirts on the Envirofit and StoveTec stoves likely improved fuel efficiency, potentially by up to 30%.

### QUALITATIVE ASSESSMENT RESULTS AND DISCUSSION

The survey results showed that about three quarters of the cooks thought the Envirofit and StoveTec stoves would be an improvement over the stove they currently use in their own homes – a simple metal and clay Maendeleo stove, a simple brick rocket stove, or an open fire. Significantly, more than half thought that the other three stoves would not offer significant advantage, suggesting that they would not be motivated to adopt these new technologies without further incentives or training.

The focus group results underscored that the women preferred the StoveTec stove, with the Envirofit model a close second, because these stoves were stable, portable, comfortable, and fuel-efficient. The fact that these stoves are low to the ground was viewed as a plus, making them feel safer and allowing the women to sit while cooking. All the cooks reiterated their dislike of the metal skirts that came with the StoveTec and Envirofit stoves, but this did not prevent them from picking these stoves as their favorites. While each of the other three stoves garnered some praise, the women cited one or more of the following critical concerns: too small to hold family-sized cooking pot (Philips); forces cook to stand (Vesto); gives smoky/burnt taste to food (Vesto & Save80); is difficult to fuel (Save80); represents burn risk for family (Vesto). The participants also noted that the Philips, Vesto, and Save80 stoves required smaller pieces of wood than the StoveTec and Envirofit stoves, which they were not accustomed to and did not generally have the capacity to provide.

The choice of the Dadaab location may have introduced a bias in favor of the two rocket stoves, as these stoves most closely resemble locally produced stoves already used in the camp in terms of design, operation, and fuel size. The StoveTec and Envirofit stoves were almost immediately familiar to the women, and this familiarity almost certainly created a bias in the usability testing results. Thus, it is possible that the Philips, Vesto, and Save80 stoves would have been better accepted with additional exposure and that further training might allow the cooks to use these stoves more efficiently than they did in these tests. Additionally, the fact that each cook only performed one or two tests on the Vesto and Save80 stoves may have negatively impacted their usability ratings relative to the StoveTec, Envirofit, and Philips stoves, on which one to three tests were performed.

These results demonstrate that it is critical to pair survey methods with quantitative cooking tests such as the CCT, as the survey results alone may provide misleading indications of actual stove performance (there were some discrepancies between the cooks' *perceptions* of stove performance and the quantitative data supplied by the CCTs). On the other hand, the CCT alone does not offer any information on how readily the stoves would be used if they were disseminated in the community. In the Dadaab tests, neither the most fuel-efficient stove (Save80) nor the fastest cooker (Vesto) was immediately popular with the participants.

## CONCLUSIONS

- All five tested stoves outperformed the open fire, requiring significantly less fuel to cook the test meal. This result is not a foregone conclusion, as a skilled operator can cook very efficiently on an open fire.
- The study's strong consistent results demonstrate the quality of these five stoves and suggest it is likely that this performance differential would continue to be measurable across various operators and situations.
- Fuel efficiency is not the sole determinant of user preferences. Ease of use, safety, level of smoke, and taste of food are also key factors in the choice, assuming all models are equally available and affordable.
- None of these stoves offered noteworthy savings in cooking time.

- Familiar stove technologies and designs may be more readily accepted by potential beneficiaries, and therefore easier to introduce in humanitarian situations, where time and security constraints may limit extensive training.
- Technologies that require more behavior change on the part of the end user will also require more significant training on proper use than those that are more similar to current practices.
- Addressing fuel requirements is critical to successful adoption as users are not necessarily willing or able to chop fuel to accommodate improved stove requirements.

#### **RECOMMENDATIONS AND NEXT STEPS**

- Entities seeking to disseminate an improved stove should research user priorities and offer more than one design choice to potential beneficiaries in the design stage of their program. Ultimate stove selection must take into account the time and resources available to support significant transitions in user behavior.
- Additional useful data could be obtained by: engaging other test populations; testing other stove and fuel options; conducting longer-term in-home monitoring; and testing stove emissions or indoor air pollution impacts.
- It would be helpful to pilot programs that facilitate fuel preparation and provide implementation guidelines and case studies to humanitarian programs considering improved cookstoves.

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Berkeley Air wishes to thank the following individuals and organizations for their support and assistance with this project:

### **UNHCR**

Richard Floyer Acland (Head of Dadaab Sub Office)  
Bornwell Kantande (Senior Program Officer)  
Fortunata Ngonyani (Community Service Officer)  
Jamal Sisai Ayela (Community Service Officer)  
Lars Sommerlund (Supply Chain Officer, Nairobi)

### **CARE**

Humphrey Osundwa (CARE Dadaab Program Manager)

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### **THE DADAAB WOMEN'S GROUPS (IN DAGAHALEY, IFO, AND HAGADERA)**

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Save80 Stove - Klaus Trifellner

**WORLD LEARNING**

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We would especially like to thank all of the cooks and helpers who donated their time, energy, and insights to the project. Finally, we thank Seth Shonkoff and Simone Brant for reviewing the report.

## ABBREVIATIONS AND ACRONYMS

Item	Meaning
CCT	Controlled cooking test
EF	Envirofit G-3300 stove
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
IDP	Internally displaced person
OF	Open fire
PH	Philips natural draft stove
QA/QC	Quality assurance and quality control
S80	Save80 stove
ST	StoveTec stove
UNHCR	United Nations High Commission for Refugees
USAID	United States Agency for International Development
VE	Vesto stove
WBT	Water boiling test

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## 1.0 INTRODUCTION

### 1.1 BACKGROUND AND PURPOSE

The purpose of this study was to obtain information on the potential suitability of a new generation of manufactured biomass cooking stoves for refugee and Internally Displaced Person (IDP) environments as well as disaster relief situations. The US Agency for International Development (USAID) solicited Berkeley Air Monitoring Group's services to provide an independent evaluation of stoves that might be useful to USAID operations as well as those of other organizations active in humanitarian situations. The study would complement previous evaluations conducted by USAID consultants in Darfur and Northern Uganda ([http://www.usaid.gov/our\\_work/economic\\_growth\\_and\\_trade/energy/pubs/cookstoves.html](http://www.usaid.gov/our_work/economic_growth_and_trade/energy/pubs/cookstoves.html)).

The Berkeley Air Monitoring Group (Berkeley Air) team was asked to combine rigorous quantitative stove performance testing using the Controlled Cooking Test protocol with as much qualitative assessment of the acceptability and usability of each stove as feasible during a time-limited visit to a refugee camp designated by USAID. The objective was to report the following metrics for each stove:

- fuel efficiency (specific consumption);
- cooking time;
- acceptability; and
- ease of use.

The stoves selected for the testing met a set of criteria developed in collaboration with USAID. More information on the criteria and stoves is provided in Section 2 (Methods).

### 1.2 STUDY LOCATION



At USAID's request, UNHCR agreed to host and facilitate the stove performance testing at the Dadaab refugee camp, located in the northeastern part of Kenya. There are three different settlements/camps that make up this UNHCR complex: Dagahaley, Ifo, and Hagadera. The settlements were started in the early 1990s, and many residents have been there for over a decade, as unresolved conflicts have prevented them from returning to their countries of origin. The population of the overall camp stands at 266,000 as of November 30, 2009. Ninety-five percent of the population is of Somali origin, while other refugees come from Ethiopia, Rwanda, Sudan, Eritrea, etc.

According to UNHCR, Dadaab camp has suffered from fuel shortages in recent years, prompting a growing interest in finding more fuel-efficient cooking technologies. The average household of 8 family members typically depends on wood to meet all of its domestic energy needs. At the time of the testing, there were two programs providing improved cookstoves within the three settlements: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and Lifeline International. The GTZ program, operating since the founding of the Dadaab camp, facilitates fuel wood distribution and

distributes the Maendeleo wood-burning stove to refugees free of charge.<sup>1</sup> These stoves are produced on site, and are present in the many camp households. International Lifeline Fund has been producing rocket wood-burning stoves on site since 2006 and has reached 5000 families with this technology.<sup>2</sup> Other camp residents cook with the traditional open fire.



**GTZ Maendeleo stove<sup>3</sup>**



**International Lifeline Fund stove production facility**

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<sup>1</sup> <http://hedon.info/StoveImages:MaendeleoStove>

<sup>2</sup> <http://www.lifelinefund.org/index.html><sup>3</sup>

<sup>3</sup> <http://www.bioenergylists.org/files/images/Maendeleo.jpg>

## 2.0 METHODS

### 2.1 STOVE SELECTION PROCESS

Five manufactured stoves were selected to be tested in the Dadaab refugee settlements. In addition, a “three-stone fire” or (“open fire”) was also tested because it is the most generalizable baseline stove. In order to be included in this evaluation, the stoves needed to have the following characteristics:

- Previously tested in a laboratory and expected to significantly reduce wood usage;
- Manufactured in a centralized facility and able to be produced in large enough numbers to meet humanitarian agency procurement needs;
- No assembly required: the stove can be taken out of the box and used immediately;
- Easy to use, requiring minimal training and little or no adjustment time;
- Rugged enough to survive in the harsh conditions of a refugee camp;
- Designed to burn wood: no special fuels or electricity required;
- Portable and easily carried by a woman; and
- Able to be made available in Kenya in December 2009.

Because of time limitations, we were not able to test the Maendeleo and International Lifeline Fund stoves.

### 2.2 DESCRIPTION OF TEST STOVES

In the end, Berkeley Air identified five stoves that met the above criteria (shown below).



**Envirofit G-3300 Stove**

**Save80 Stove**

**Vesto - The Variable Energy Stove**



**Philips Natural Draft Stove**

**StoveTec Wood Stove (26 cm)**

All of these stoves have cylindrical or hexagonal metal exteriors with handles to facilitate moving them. All but the StoveTec stove have metal combustion chambers where the fire is contained. The StoveTec's combustion chamber has a refractive ceramic liner, and the Envirofit stove has a ceramic base plate that fits into the bottom of the stove to add insulation, weight, and stability. Both the StoveTec and Envirofit stoves also have an "L" shaped, front-loading combustion chamber, one of the design features that defines them as "rocket" stoves. The Envirofit and StoveTec stoves share a design history and both adhere to standard rocket stove principles.

As specified in the selection criteria, all of these stoves burn wood. To varying degrees, they may also accommodate other biomass fuels such as stalks from food crops, husks, twigs, leaves, wood pellets, etc. The two rocket stoves are fueled through an opening at the base of the stove. The Save80 has a small fueling port about midway up the stove body. The Philips and Vesto stoves are fueled from the top and can be loaded with a batch of fuel before lighting the stove. As needed, additional pieces of fuel can be slid into the opening between the pot and the stove body. For additional information about the fuel size and shape requirements for each stove, see Appendix 7.5.

All of these stoves have been designed to control the air flow through the stove in order to optimize the mix of combustible elements (e.g. the air to fuel ratio) in order to improve the cleanliness and efficiency of the process. The stoves' combustion technologies, however, can be divided into two groups. The Envirofit, StoveTec, and Save80 stoves are designed to burn the fuel in a single combustion stage. The Philips and Vesto stoves have a two-stage process where the wood (or other biomass fuel) is first burned in the lower part of the combustion chamber and then a second influx of air towards the top of the stove mixes and burns the gases released in the first stage. Such two-stage stoves are sometimes known as "gasifier" or "semi-gasifier" stoves.

All of the stoves except the Philips were provided with certain "accessories" or components that are not integral to the functioning of the stove but can improve its performance. The Vesto stove came with a metal stand and lid (designed to elevate the stove off of the ground and collect ash) as well as a grate that could be used to support the pot. The Save80 was the only stove provided with an integrated pot, which was used as designed, suspended above the combustion chamber on the metal edge of the stove. The Save80 also came with a retained heat cooker (called a Wonderbox) which is made of expanded polypropylene and molded to fit snugly

around the stove's pot. The manufacturer intends for the Wonderbox to be used to keep beans and other similar foods cooking without a direct heat source; thus the Save80 stove is not specifically designed to perform simmering.

Both the StoveTec and Envirofit stoves have a metal shelf that sits in front of the stove to support the fuel wood as it sits in the combustion chamber. These two stoves also came with metal skirts designed to fit around the base of the pot. The function of the skirt is to increase heat transfer to the pot and thereby increase the overall efficiency of the stove. The skirts are not integral to the functioning of the stoves, but they have been shown to increase efficiency in laboratory tests by approximately 30%, according to the manufacturers.



**Envirofit stove with skirt**



**StoveTec stove with skirt**



**Save80 with integral pot**

For information on how to contact the manufacturers of the tested stoves, see Appendix 7.1.

### **2.3 STUDY OVERVIEW**

A total of 214 controlled cooking tests (CCTs) were conducted in the three different settlements of the Dadaab complex: Dagahaley, Ifo, and Hagadera. The Berkeley Air field team spent five days in each of the three sites. All tests were conducted inside the CARE compound at each site, which provided an environment where the test participants could focus undisturbed on the cooking tests.



Ifo camp



Dagahaley camp



Hagadera camp

A total of 20 cooks were involved in the study, including 18 primary cooks (six women from each settlement). In two separate instances, one of the primary cooks was called away from the testing, and one of the test assistants (described below) took her place. UNHCR and CARE International were charged with selecting representative cooks for the study. They recruited the test participants from women's groups in each of the settlements. All of the cooks were Somali, as Somalis represent a large majority in the Dadaab camp, and covered a wide range of ages.

On the first day at each site, the Berkeley Air team explained the test activities and the participation expectations and requested verbal confirmation that the selected women still wished to take part in the study. The women were given all the cooked food to eat for lunch and/or to take back to their households. At the conclusion of the studies, Berkeley Air made a monetary donation to all three women's group in lieu of direct compensation to the cooks, translators, and helpers, as suggested by CARE and UNHCR.

In addition to the test cooks, the field teams included several other assistants from the local community who helped with critical activities, such as chopping the vegetables, washing dishes between tests, shopping for food in the local markets, and chopping the wood. By delegating these tasks to non-cooks, the team was able to increase efficiency and minimize variability across tests. Additionally, Somali translators from within each settlement facilitated communication between the field team and the participants during stove and CCT training, survey data collection, and focus group discussions. They were critical to the team's effectiveness, providing guidance, helping to build relationships, and allowing the team to receive feedback throughout the study.

### 2.3.1 Controlled Cooking Test

The Controlled Cooking Test (CCT) is one of three standardized cookstove testing protocols commonly used in the household energy field to evaluate and compare technologies. The CCT yields two main quantitative outputs: the amount of wood (or fuel, more broadly) and the amount of time required to complete the task of cooking a standardized meal, in this case rice with tomatoes, onion, and spices. According to standard practice and the CCT 2.0 Protocol, the wood was weighed for each of the participants by the field team prior to the start of the test. After the food was cooked, the leftover wood and charcoal were collected and weighed. The weight of the pot, lid, and cooked food was also recorded. The protocol recommends that at least three tests be conducted per cook for each stove, including the baseline technology (in this case, the open fire). See Appendix 7.3 for the full CCT protocol and Appendix 7.6 for a list of instruments and QA/QC practices used in the study.

The Controlled Cooking Test was chosen as the basis of this study because it provides a standardized comparison of stove performance within the real-world parameters of local fuel, food, and cooking practices. The CCT allows us to compare the stoves in the test with the open fire and each other and to extrapolate those results to other locations with similar cooking and fuel use patterns. However, an assessment of how well the tested stoves would be accepted into the community must be made from the additional usability metrics that were evaluated through structured observations, surveys, and focus group discussions (see Section 2.4 below).

### **2.3.2 Timing and Configuration of Testing**

In designing the testing plan, the team addressed a range of considerations. The top priority was to achieve a statistically powerful comparison between each stove and the open fire under whatever uncertain conditions might be encountered in the settlements. The second priority was to have each cook test all the stoves, chosen in order to increase the value, fairness, and power of the qualitative assessment methods and to help provide a better understanding of potential sources of variability in the quantitative assessment. The third priority was to collect as much usability information on the stoves as possible. In addition to meeting these priorities, the test design had to conform to certain inflexible operational constraints. Due to the limited visitor facilities at the camp complex, the field team was given a 15-day period in December 2009 during which to complete the testing. Further, it was requested that this time be evenly divided among the three camps that comprise Dadaab. Once on the ground in each site, the team's work hours were limited by security procedures to 8:30 am to 4:30 pm.

In response to these considerations, a study plan was developed that had each cook first create her own baseline by testing the open fire three times and then test each of the five manufactured stoves at least once. At the same time, the plan prioritized the testing of three of the five stoves – Envirofit, StoveTec, and Philips. In order to maximize the chances of obtaining some statistically valid results from the fieldwork, these three stoves would be tested three times by some cooks and would have the greatest cumulative number of tests. These stoves were prioritized because of their strong performance in laboratory testing, as well as their producers' established reputation for quality and significant manufacturing capacity. A discussion of the potential impact of this test plan on the results is presented in Section 4 (Discussion).

Once on the ground, the field team was able to deploy the test plan more or less as designed with relatively few problems. The most significant disruption came from the fact that the Philips stove could not be delivered until two-thirds of the way through the fieldwork, which necessitated some rearranging of the testing schedule. As a result, only 14 of the 18 cooks tested all five stoves: four cooks from Dagahaley camp did not test the Save80 stove. The Envirofit and StoveTec stoves were tested 2-3 times by most of the cooks, while the Vesto and Save80 stoves were tested 1-2 times by most. Finally, in two instances, a cook had to leave the testing unexpectedly. She was replaced by another woman who was familiar with the testing procedures but who had not tested the open fire. The final number of stove tests completed by each cook along with the total for each stove is shown in Appendix 7.7.

### **2.3.3 Study Design Choices: Fuel, Food, Pots, and Attachments**

To the extent practicable, the tests were conducted in a manner consistent with the manufacturers' guidelines for optimal stove performance, and attachments were used where provided. Two of the stoves - the StoveTec and Envirofit - were provided with metal skirts to

surround the base of the pot. The women were trained on how to use these devices and were asked to use them during testing to the best of their ability. No tests were conducted without the skirts. The Save80 also came with an expanded polypropylene retained heat cooker. This was not included in the testing as it would have disrupted the testing schedule and the standardization of the meal preparation process.

With the exception of the Save80, all the stoves were tested with an aluminum cooking pot typically distributed to the refugees by UNHCR. This pot has a volume of 10 liters and measures 27 cm in diameter. In all four cases, this pot was placed on top of the stove body, supported by a metal structure. All four stoves were able to accommodate this size pot, although the diameter of the pot exceeded the diameter of the Philips stove by approximately 3 cm. In the case of the Vesto stove, the UNHCR pot would have fit down into the body of the stove to rest on pot supports, but the test cooks resisted this arrangement because it would have required them to move the pot to refuel. For the Save80 stove, which was the only stove provided with an integral pot, the pot was used as designed. A discussion of the potential impact of these testing choices on the results is presented in Section 4 (Discussion).

The tests were conducted using a standardized meal of rice and vegetables, which the Somali participants identified as representative of their cooking practices. The typical method for preparing this meal was determined by the women at the first testing session (in Dagahaley) and vetted by the women at the subsequent settlements. As a matter of course, all the participants placed a lid fully on the pot to bring the water to a boil and then kept the lid slightly off-set from the pot while the rice was simmering. The details of the food preparation, ingredients, quantities, and the cooking method are shown in Appendix 7.4.



**Ingredients**

**Pots and scales**

**Cooked food**

All tests were conducted using wood sourced from local merchants. While the wood was not dried for the tests, moisture content was measured before each test and averaged 9.7% on the wet basis (with a standard deviation of 2.5%). The range of the average moisture content per stove type was 8.8% to 10.8%, suggesting that the wood moisture was low and consistent throughout the testing. The wood was cut up into pieces with a cross-sectional dimension of approximately 2 x 2 cm. These pieces were then cut into differing lengths of 15 to 40 cm, as appropriate for each stove. At the start of each test, the stove was lit using two plastic bags, in order to replicate typical camp practices.<sup>4</sup> For additional information on fuel wood species and sizing, see Appendix 7.5.

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<sup>4</sup> The practice of burning plastic at relatively low temperatures is known to have particularly hazardous emissions and is not recommended by USAID or Berkeley Air Monitoring Group.

### 2.3.4 Stove Use Training

Prior to the start of the testing, the women received a concise, two-part training on how to use the stoves from the Berkeley Air team. This training was not designed to be extensive, but to simulate real life in a relief situation, where individuals typically do not have the opportunity to receive intensive training on the use of new stoves. On the first day, they received an oral explanation and demonstration of the stoves' features. This preview session lasted approximately one hour, with equal time spent on each improved stove.<sup>5</sup> The second training phase was conducted immediately prior to the introduction of a new stove into the testing. At this time, a team member would review the operation and features of the stove with the cooks and then ask one cook to demonstrate lighting and operation for the other cooks. Particular attention was given to refueling methods and air vent operation. The training concluded with a thoroughly interactive discussion of the stove among the women and the trainers, with the aid of the translator.



**Stove use training**

In order to prepare themselves for this study, the Berkeley Air team took measures to familiarize themselves with the stoves prior to arriving in Dadaab. All team members studied the printed operations manuals and viewed videos and websites about the stoves. Furthermore, samples of all the test stoves were lit and operated at a site close to the Berkeley Air office in California. Finally, the team conducted practice CCTs at a home in Nairobi, Kenya immediately prior to arriving at Dadaab on all the stoves except the Philips, which was delayed in shipment.

## 2.4 USABILITY ASSESSMENT METHODS

During each of the CCTs, one Berkeley Air team member completed a structured observation form, designed to capture information about the cook's use of the stove (including her confidence with the stove, ease of use of the stove, refueling practices, etc.), the stove and pot stability, and smoke output. Structured observation forms were completed for 36 of the 54 open fire tests and for 151 of the 160 tests on the five manufactured stoves.

Each cook completed a brief survey on stove usability and preferences for each of the five manufactured stoves. These surveys were administered orally by the fieldworkers at the end of each day of testing. The fieldworkers conducted the survey as an open ended interview and

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<sup>5</sup> In Dagahaley and Ifo camps, the Philips stove was not available during the first preview phase of the training, as the shipment to Dadaab was delayed.

coded the cooks' replies into the proper response categories; they did not prompt the cooks with the response categories. In all, 86 surveys were collected, one for each stove-cook combination.

At the end of the five days of tests in each settlement, one focus group discussion was held with all six of the cooks. The purpose of these discussions was to invite the women to reflect on their experiences during the week and to draw some conclusions about which stoves they felt best and least fit their needs and circumstances. Each of the focus group discussions followed a pre-planned outline and used various types of questions and exercises to draw out the information from the participants.

Each group discussion was facilitated by Tiana Razafindrakoto (Berkeley Air field supervisor) with the translator acting as the bridge between the facilitator and the group. In the beginning of each focus group, the purpose of the meeting was discussed, and the participants were made aware that their opinion was valued and that there were no right or wrong answers.

For copies of the user survey and focus group discussion template, please see Appendices 7.9 and 7.10.

### 3.0 RESULTS

#### 3.1 QUANTITATIVE STOVE PERFORMANCE

This section summarizes the quantitative stove performance results from the controlled cooking tests (CCTs). The CCT yields two main quantitative outputs: the amount of wood (or fuel, more broadly) and the amount of time required to complete the task of cooking the standardized meal. According to standard practice (and the CCT 2.0 Protocol), the amount of wood used is reported as specific consumption. Specific consumption is a normalized measure of fuel use and is equal to the equivalent dry wood used divided by the final amount of food cooked. The measure “equivalent dry wood consumed” normalizes or adjusts the amount of wood used to complete the CCT for two factors: the amount of moisture in the wood and the amount of charcoal that remains unburned after the cooking task is complete. The standard units of specific consumption are grams of equivalent dry wood used per kilogram of food cooked (g/kg).

Table 1 below summarizes the quantitative stove performance results for each of the six stoves tested in Dadaab, including specific consumption (fuel use) and cooking time. The number of tests completed and the burning rate (the average amount of wood consumed per minute) are also shown for comparison. The table shows the averages and the standard deviations<sup>6</sup>, along with the percent differences compared to the open fire.

**Table 1. Summary of quantitative stove performance results for the six stoves, showing the average, standard deviation (in parentheses), and percentage difference versus the open fire.**

	(units)	OF	EF	ST	PH	VE	S80
# of Tests	na	54	38	38	38	24	22
Specific consumption	g wood/ kg food	295 (70)	143 (32)	136 (40)	159 (43)	202 (43)	110 (36)
Specific consumption	% diff. vs. OF	NA	-52%	-54%	-46%	-32%	-63%
Cooking time	min	54 (10)	49 (8)	50 (9)	56 (8)	47 (8)	52 (6)
Cooking time	% diff. vs. OF	NA	-8%	-7%	+4%	-12%	-2%
Burning rate	g wood/ min	30 (7)	16 (4)	15 (4)	16 (3)	23 (3)	12 (4)

Note: OF = open fire; EF = Envirofit G-3300; ST = StoveTec; PH = Philips Natural Draft; VE = Vesto; S80 = Save80

<sup>6</sup> Standard deviation is a statistical measure of the variability or spread of a set of measurements around the mean value. The more widely the values are spread, the larger the standard deviation.

Figures 1 and 2 below show the average specific consumption and cooking time, respectively, for the six stoves.

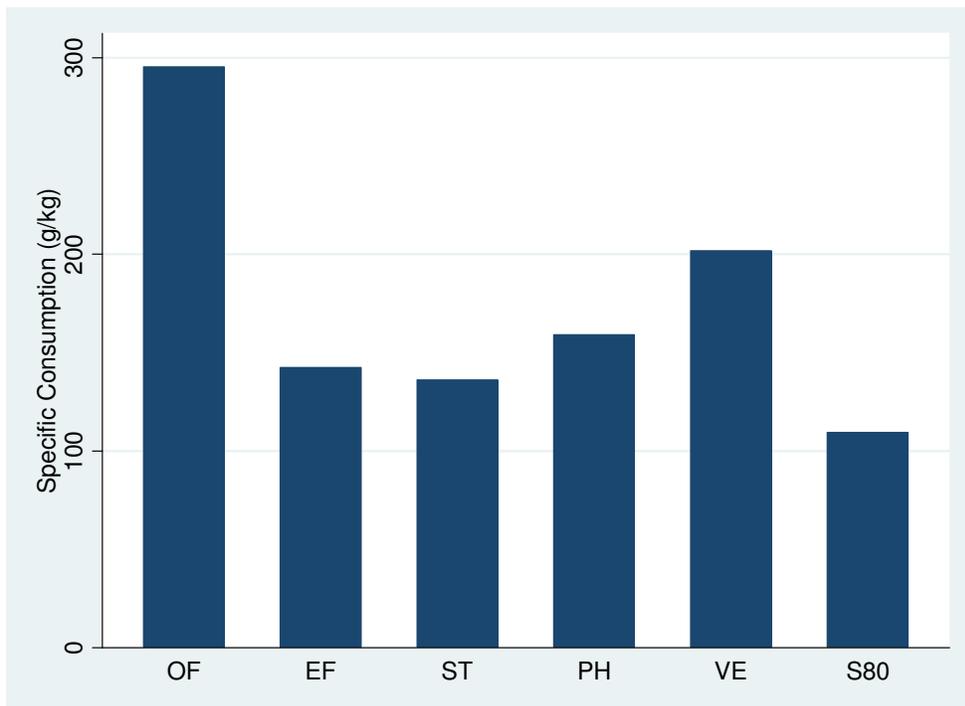


Figure 1. Average specific consumption (g wood per kg food) for each stove type in all tests.

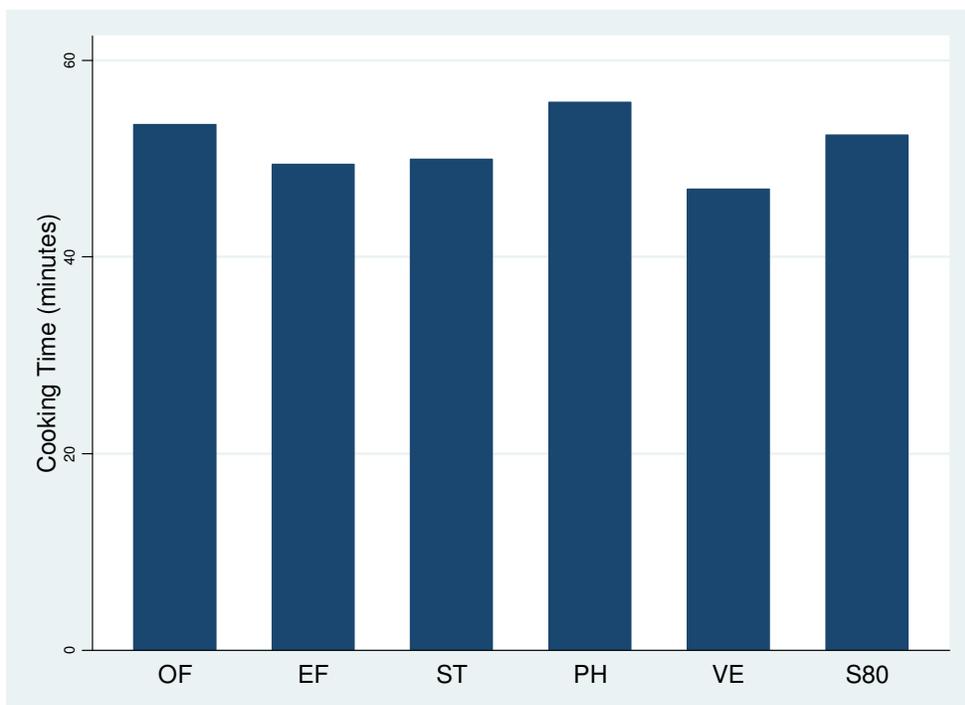


Figure 2. Average cooking time (minutes) for each stove type in all tests.

A series of statistical tests were performed to compare the average specific consumption and cooking time of each stove to each of the other five stoves in order to determine whether the performance of the stoves was statistically different or not. The test is known as the “Student’s t-test for significance,” and the values generated are known as “p-values.” A p-value of less than 0.05 is considered “statistically significant” and indicates that there is greater than 95% certainty that the difference between the two measured values did not occur by chance.

Tables 2 and 3 below show the results of the t-tests comparing specific consumption and cooking time, respectively, for each of the stoves. In each cell of Table 2 is a stove vs. stove comparison that indicates which stove had lower specific consumption (lower fuel use) and shows the p-value of the t-test. Table 3 shows the same for cooking time. P-values lower than 0.05 indicate that the two values are statistically different. Cells where the two compared values are not significantly different are shown in red font color and are marked as the same.

Table 2 shows that all five of the manufactured stoves had significantly lower fuel use than the open fire. Table 3 shows that only the Vesto and Envirofit stoves had significantly faster cooking times than the open fire. The other three stoves had cooking times that were not statistically different from the open fire.

**Table 2. A stove versus stove comparison of specific consumption (fuel use), showing the stove with the lower fuel use and the p-value of the t-test for significance**

	OF	EF	ST	PH	VE
EF	EF lower (p=0.000)				
ST	ST lower (p=0.000)	same (p=0.46)			
PH	PH lower (p=0.000)	same (p=0.062)	ST lower (p=0.019)		
VE	VE lower (p=0.000)	EF lower (p=0.000)	ST lower (p=0.000)	PH lower (p=0.000)	
S80	S80 lower (p=0.000)	S80 lower (p=0.001)	S80 lower (p=0.013)	S80 lower (p=0.000)	S80 lower (p=0.000)

**Table 3. A stove versus stove comparison of the cooking time, showing the faster stove and the p-value of a t-test for significance**

	OF	EF	ST	PH	VE
EF	EF faster (p=0.045)				
ST	same (p=0.090)	same (p=0.78)			
PH	same (p=0.27)	EF faster (p=0.001)	ST faster (p=0.004)		
VE	VE faster (p=0.006)	same (p=0.23)	same (p=0.17)	VE faster (p=0.000)	
S80	same (p=0.66)	same (p=0.14)	same (p=0.26)	same (p=0.11)	VE faster (p=0.011)

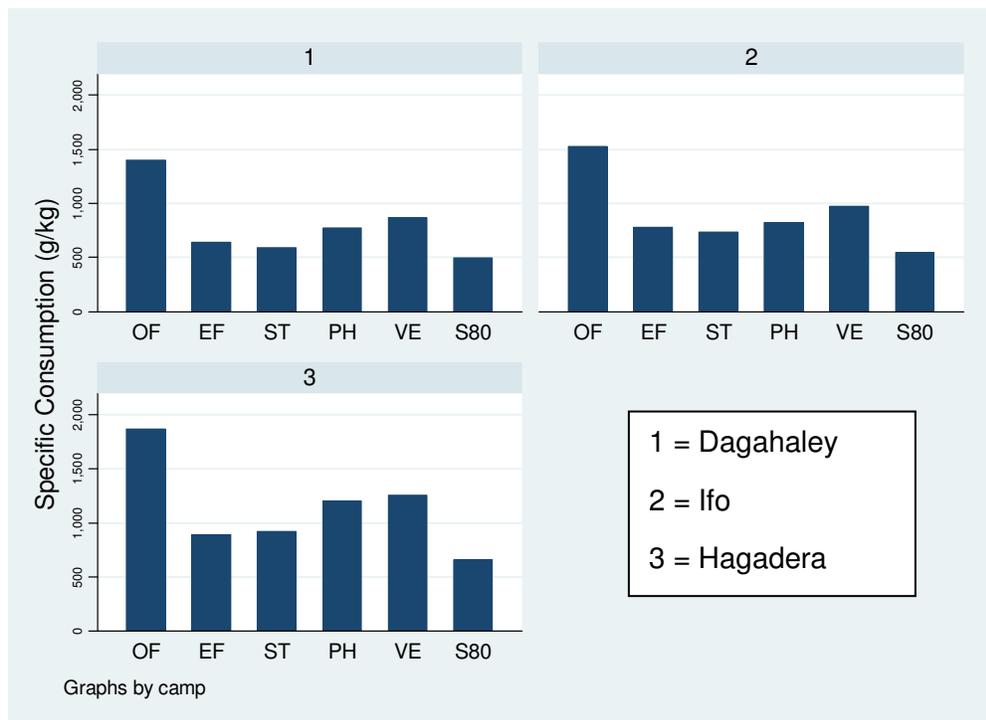
Table 4, below, shows a ranking of the five manufactured stoves on each of the two measures of stove performance. The percent differences compared to the open fire are also displayed in parentheses (as in Table 1). The Save80 was the most fuel efficient. While the StoveTec stove was slightly more efficient than the Envirofit stove, the two were statistically equal and are hence tied for second best. The Philips stove is close behind in third place. The Philips stove was actually statistically identical to the Envirofit stove in specific consumption, though statistically less efficient than the StoveTec stove.

Overall, there was very little difference in cooking times among the six stoves. The Vesto and Envirofit stove both ranked first in cooking time (while Vesto was the fastest, it was not significantly different from the Envirofit and StoveTec stoves). The StoveTec stove was only slightly slower than the Envirofit stove (50 versus 49 minutes), but, unlike the Envirofit stove, the StoveTec was not significantly faster than the open fire. Hence, the StoveTec stove is ranked second. The Save80 and the Philips stoves had statistically identical cooking times and are ranked third.

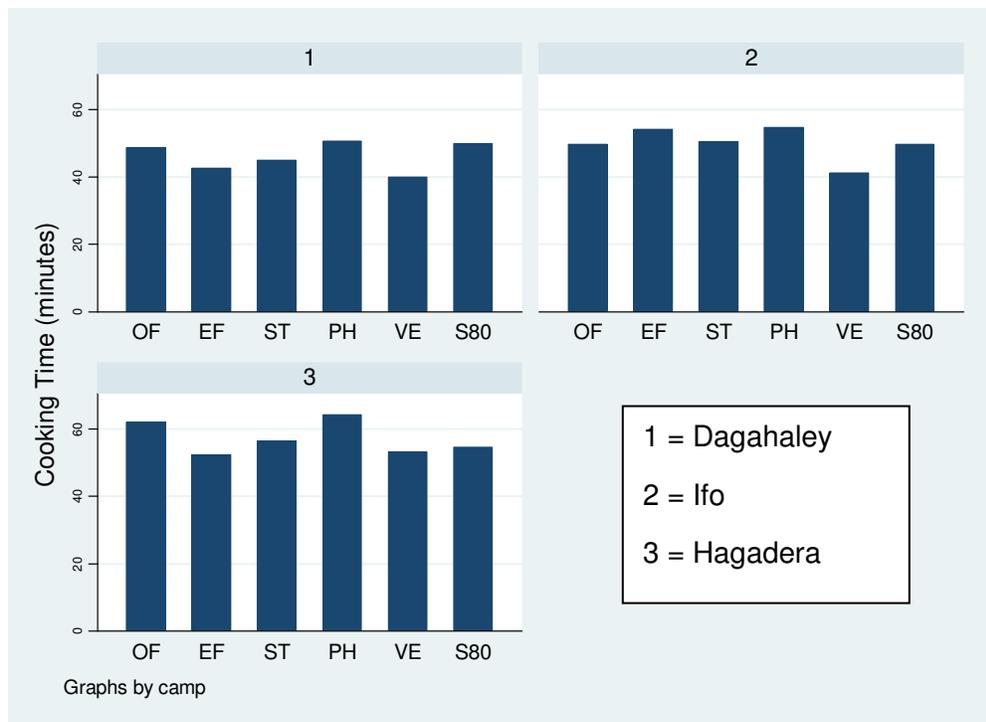
**Table 4. Ranking of the manufactured stoves on fuel efficiency and cooking speed. Percent differences compared to the open fire are shown in parentheses.**

Rank	Most fuel efficient (% savings vs. OF)	Fastest cooking (% faster than OF)
1	S80 (65%)	VE (12%) and EF (8%)
2	ST (54%) and EF (52%)	ST (7%)
3	PH (46%)	S80 (2%) and PH (-4%)
4	VE (32%)	---

Figures 3 and 4 below show the average specific consumption and cooking time for each stove in each of the three settlements (Dagahaley, Ifo, and Hagadera). The pattern (or relative values) of specific consumption by stove type is extremely similar in all three sites. Additionally, Dagahaley and Ifo had very similar absolute specific consumption values for each stove type, while the Hagadera camp specific consumption values are systematically higher for each stove type. The same can be said for cooking time. The three settlements' patterns of cooking time by stove type were quite similar, although not as similar as are the patterns for fuel use.



**Figure 3. Average specific consumption (g/kg) for each stove type in each of the three camps of the Dadaab complex.**



**Figure 4. Average cooking time (minutes) for each stove type in each of the three camps.**

The patterns of specific consumption, cooking time, and burning rate by stove type are also quite similar for each of the 18 cooks (these are shown in Appendix 7.11). The similarity of the fuel use, cooking time, and burning rate patterns across all 18 cooks provides evidence that the differences in performance seen in this study are due to the intrinsic differences between the stoves.

Further discussion of these results and the potential implications on them of various study design choices can be found in Section 4 (Discussion of Issues Possibly Impacting Results).

### 3.2 USABILITY ASSESSMENT

Three methods were used to assess the usability of the five stoves:

- A member of the field team completed a standardized observation checklist during each cooking session;
- Each cook completed one survey for each of the manufactured stoves she tested; and
- A focus group was conducted in each camp on the last day of testing with all of the cooks from that camp (six).

#### 3.2.1 Structured Observations

The field team completed structured observation forms during 187 of the 214 controlled cooking tests (36 of the 54 open fire tests, 36/38 of the Envirofit tests, 31/38 of the StoveTec tests, all 38 of the Philips tests, all 24 of the Vesto tests, and all 22 of the Save80 tests). Table 5, below, summarizes some of the primary results of the structured observations. The table shows the average number of times per test the field team tallied incidents of stove refueling, the stove

needing to be relit with a match, and periods of high smoke. It also shows the observers' average rating of the physical comfort of the cook while tending the fire during cooking. The comfort rating categories were the following: (1) Physically relaxed, (2) Physically awkward, and (3) Physically straining.

**Table 5. Summary of structured observations of cooks by field team.**

Stove	# of Stove Refuelings per Test	# of Times Relit with Match per Test	# of Periods of High Smoke per Test	Comfort Rating while Tending Fire
Open fire	0.2	0.1	2.3	1.0
Envirofit	3.6	0.0	1.0	1.2
StoveTec	4.3	0.2	0.8	1.1
Philips	7.3	0.1	1.6	1.3
Vesto	6.2	0.0	1.2	1.4
Save80	8.5	0.6	1.5	1.5

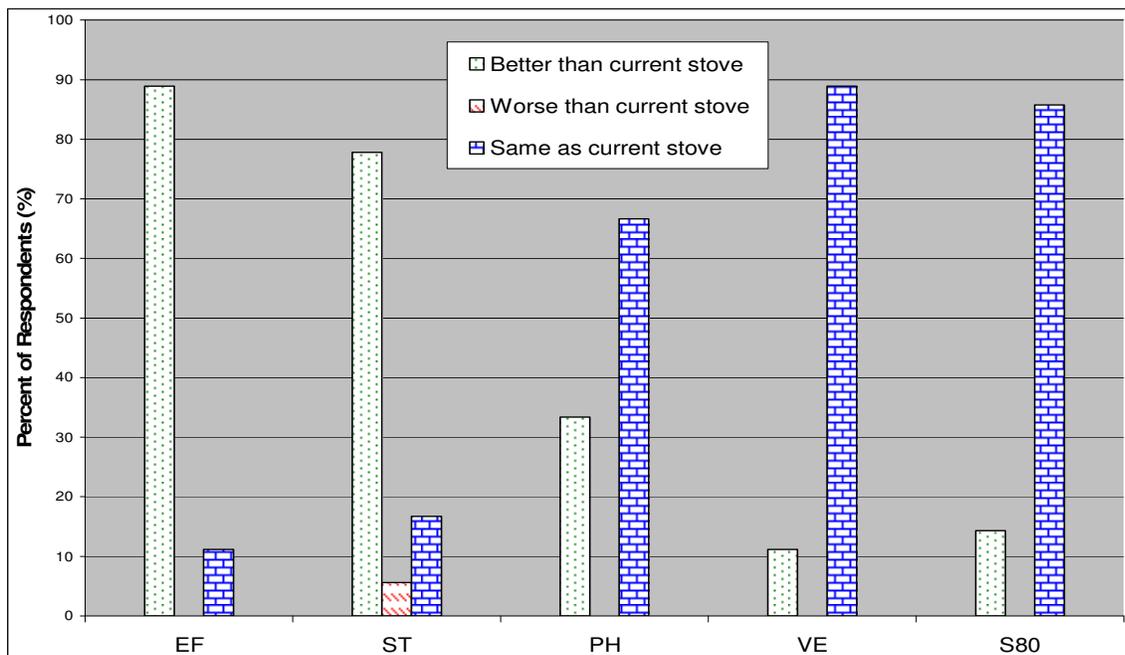
As expected, all manufactured stoves required more refueling events than the open fire, with the two rocket stoves (Envirofit and StoveTec) requiring less refueling than the other three stoves. This finding is in line with the fuel sizing requirements of each stove. The women needed to relight the Save80 stove more than the other stoves, likely due to the difficulty of seeing the fire and the overall newness of the stove to them. All manufactured stoves had fewer visible periods of high smoke than the open fire, with the StoveTec having the lowest, followed by the Envirofit and the Vesto.

Lastly, the two taller stoves, the Save80 and the Vesto, scored a bit lower than the others in the observers' rating of the cook's physical comfort tending the fire during cooking, as the cooks visibly appeared to find the height of these stoves awkward, since they were used to cooking low to the ground. Note that the Vesto stove was tested while placed in a stand that is designed to be used in indoor environments and was unnecessary in this outdoor test environment. Also, the fact that the Vesto was operated with the pot on top of a grate instead of sunken into the stove added further to its cooking height. These two factors added 7.5 inches to the cooking height of the Vesto. It is possible that the women would have been more comfortable with the height of the Vesto if not for these two factors.

### 3.2.2 User Survey

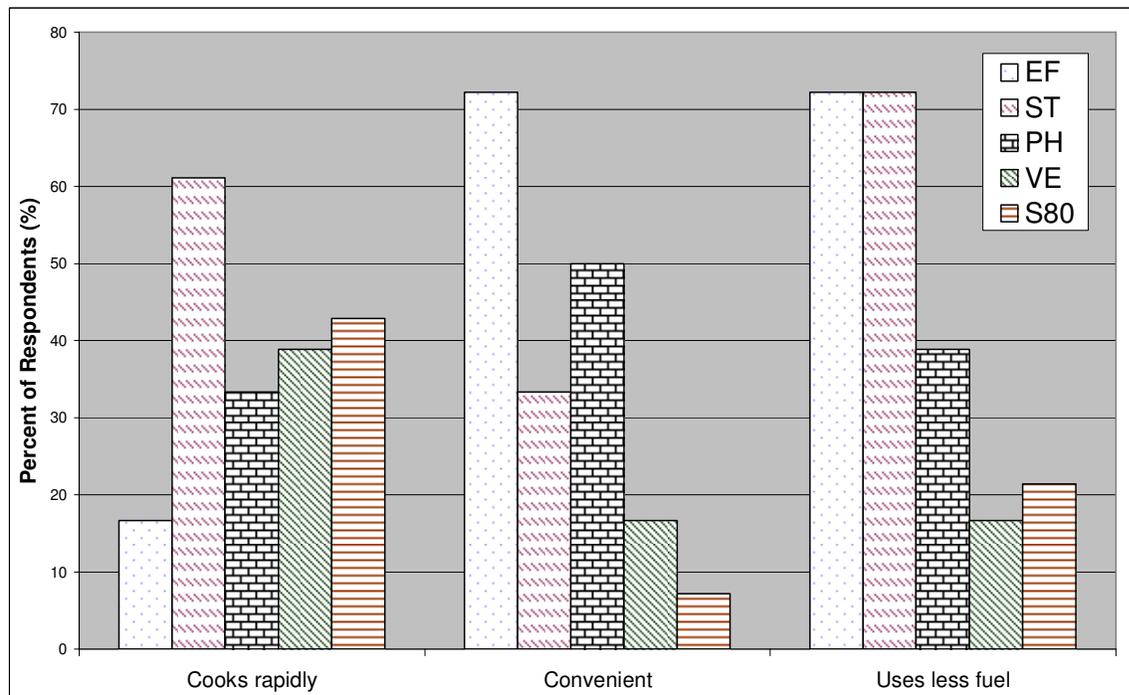
This section summarizes the results of the surveys completed by each cook after she finished testing each improved stove one to three times. All but 4 of the 18 cooks tested all five improved stoves. The surveys were designed to capture the cooks' impressions of the stoves' applicability in their daily lives and their preferences among the five options. These survey results, together with the structured observations and the focus group discussions, provide an important supplement to the CCT results, which do not offer any information on how readily the stoves would be used if they were disseminated as part of an intervention.

The first figure below (Figure 5) shows how well the cooks liked each of the manufactured stoves relative to the stove they currently use in their own homes. Information on the cooks' own stoves was not part of the project scope; however, most Dadaab households have a simple metal and clay Maendeleo stove, a simple brick rocket stove, or an open fire. The figure shows that about three quarters of the cooks thought the Envirofit and StoveTec stoves would be an improvement over their existing appliance. Significantly, more than half thought that the other three stoves would not offer significant advantage, suggesting that they would not be motivated to adopt these new technologies without further incentives or training. Also worth noting is the fact that only one cook registered a strong negative comment about a stove, saying it would be worse than her current stove. This aversion to overt criticism may be due to cultural norms or to the refugees' low standard of living, which may incite them not to discourage any form of aid.



**Figure 5. The cooks' overall impressions of the manufactured stoves, relative to their traditional stove.**

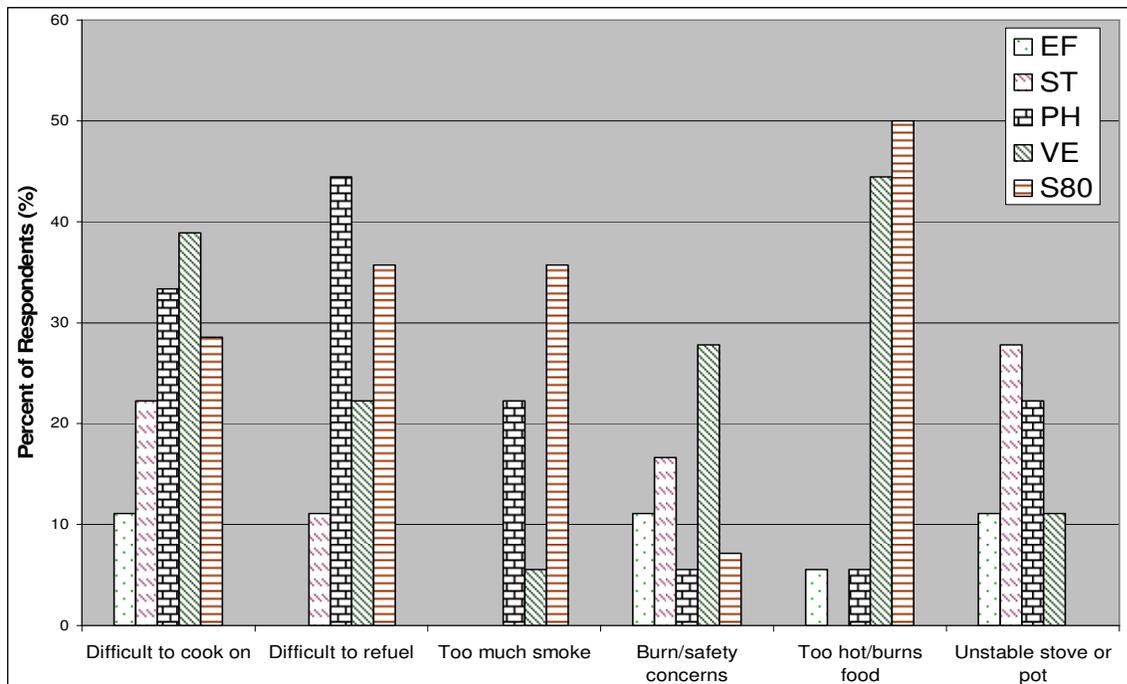
The following two graphs (Figures 6 and 7) explore the attributes of each stove that most impressed the women positively and negatively, offering insights into the cooks' primary criteria for selecting a new stove. Overwhelmingly, the three positive attributes mentioned most frequently were cooking speed, convenience, and fuel savings. Over 70% associated the Envirofit stove with convenience and fuel savings, and over 60% associated the StoveTec stove with fuel savings and rapid cooking. Further, 50% of respondents said that convenience was one of the Philips' stoves top attributes. (The term "convenience" was used here to denote primarily ergonomic comfort and ease of use, rather than to suggest that the stove was easy to integrate into their daily lives.)



**Figure 6. A summary of the three most common responses regarding the best aspects of the stoves.**

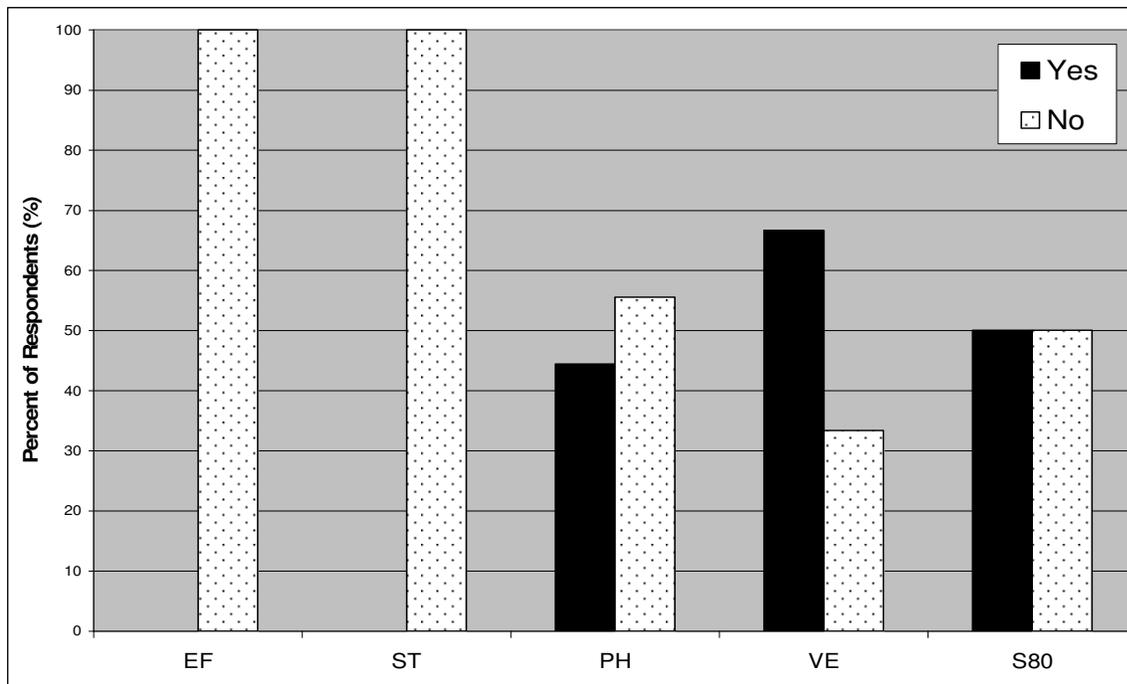
There was less agreement among the cooks on the negative attributes associated with each stove. About 50% of respondents noted that the Vesto and Save80 stoves put out too much heat. Other negatives noted by one third or more participants were that the Vesto was difficult to cook on; the Save80 was difficult to refuel; and the Philips was both difficult to cook on and to refuel. In the case of the Philips stove, it appears the cooks were fairly split between those who liked the stove’s compact design and those who did not.

It is also interesting to note that cooks’ perceptions of the stoves were not necessarily matched to the quantitative results, as the cooks were not informed of the fuel use and cooking time results at any time in the study, nor did they have a way of measuring these parameters directly for themselves. Only 20% of the cooks noted that the Save80 saved fuel, whereas in fact it was the top performer in this category according to the CCTs. Also, while the Vesto stove was the fastest stove in the CCTs, it placed third in terms of the percent of respondents reporting that it cooked rapidly.



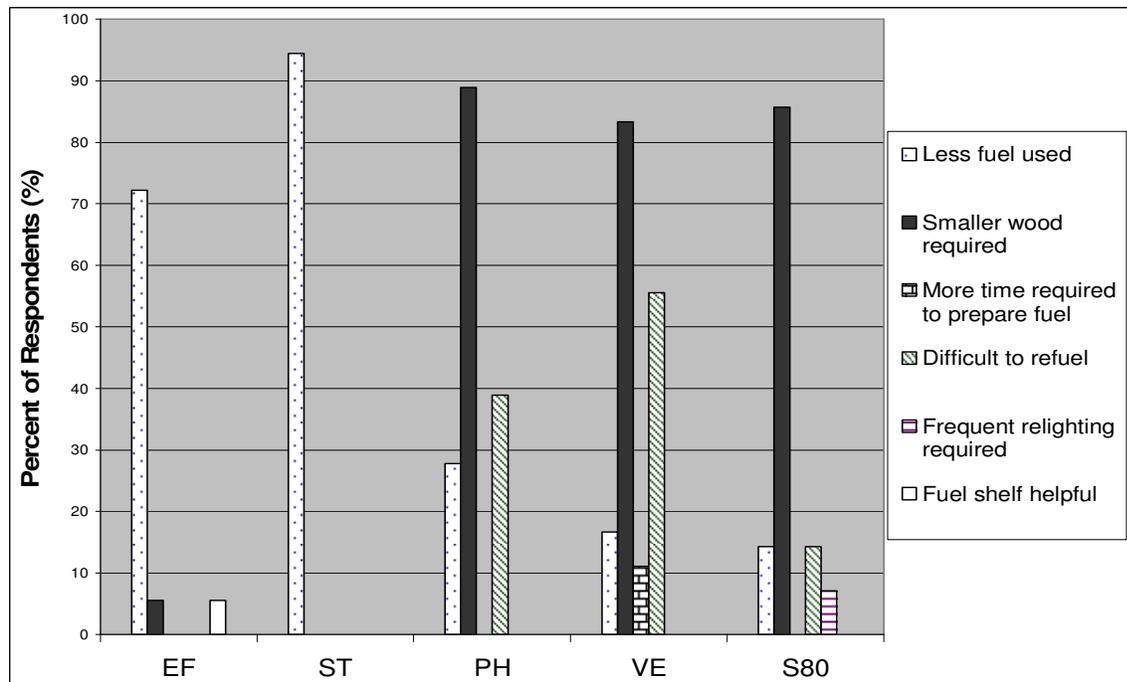
**Figure 7. A summary of the six most common responses regarding the worst aspects of the stoves.**

The survey attempted to gauge how much behavior change would be needed for the cooks to adopt each of the stoves at home. Figure 8 below provides strong evidence that the cooks were much more comfortable with the two rocket stoves (Envirofit and StoveTec) than with the other models: none of them thought they would have to make any adjustments in the way they cook if they owned these stoves. By contrast, the women were approximately evenly split on the question of whether the Save80 and Philips stoves would require adjustments, while approximately two thirds of the women thought the Vesto would require adjustments.



**Figure 8. The percent of cooks who reported having to change the way they cooked due to the stove.**

The survey also attempted to illuminate what kinds of changes the women felt they would need to make. The team hypothesized that fueling practices would be impacted and asked the cooks to describe any changes in fuel-related activities that they experienced with each stove. Figure 9 shows that 70 to 90% of the cooks reported that the only impact the Envirofit or StoveTec stoves had on fuel-related activities was to cause them to use less wood. By contrast, about the same percentage noted that smaller pieces of wood were needed in order to operate the Philips, Vesto, or Save80.



**Figure 9. The impact of the stove on fuel practices and fuel use.**

At the conclusion of the survey, the cooks were asked what would motivate them to buy or not buy each stove (assuming it was available at an affordable price). These responses were aggregated to create a general view of the factors in a stove purchase decision for these women and are shown in Tables 6 and 7. The same three “best aspects” that women highlighted about each individual stove (as shown in Figure 6) were present again among the top 5 reasons for purchasing a stove: saves fuel, is convenient, and cooks faster. Two additional factors noted by the women were the need for portability and the desire to reduce smoke. The emission of too much smoke was cited by some cooks as one of the worst aspects of the Philips and Save80 stoves, so this finding is not too surprising. As shown in Table 7, here again the main traits that would deter the cooks from buying one of the stoves are similar to the negative attributes displayed in Figure 7.

**Table 6. A summary of the reasons why the cooks would buy one or other of the manufactured stoves, if they could afford it.**

Comment	Number of Responses
Less fuel / more economical	36
Light, small, or portable	16
Less smoke	12
Cooks faster	11
Convenient	9
Better tasting food	6
Beautiful	4
Durable	2
Stable	2
Can cook all foods	1
Easier to refuel	1
Has regulator for heat adjustment	1

**Table 7. A summary of the reasons why the cooks would not buy one or other of the manufactured stoves, even if they could afford it.**

Comment	Number of Responses
Uncomfortable to use	10
Burns food	10
Need to be skilled to use	9
Dangerous (burns)	8
Can't cook all foods	5
Pot is unstable / doesn't fit well	4
Stove is unstable	3
Requires small pieces of wood	3
Uses more fuel	2
Difficult to refuel	2
Can't do other things while cooking	2
Too many parts	1
Insufficient cooking capacity	1

### 3.2.3 Focus Group Discussions

According to the focus groups, the StoveTec stove was the preferred choice of the participants, with the Envirofit model a close second, because these stoves were stable, portable, comfortable, and fuel-efficient. Participants noted that both stoves burned wood at an acceptable rate and produced less smoke than the other stoves in the test. The participants felt that the reduced smoke improved the taste of the food. The fact that the StoveTec and Envirofit stoves were low to the ground was valued highly for two reasons. The participants expressed a preference to be able to kneel or sit while cooking and felt that the two allowed them to cook in

this position. Additionally, the cooks felt that both Envirofit and StoveTec stoves had a reduced risk of being toppled over and causing injury or fire.



### Focus group discussion

Although the women liked both the rocket stoves, there was a general preference for the StoveTec design over the Envirofit one. Participants appreciated the fact that the StoveTec stove has a heavier clay liner, much more like the traditional cooking stoves they are used to. The test cooks felt that the clay liner improved the stove's safety, making it less susceptible to being overturned and creating a more uniform exterior temperature with fewer hot spots that could cause burns. The StoveTec was also seen as a bit more efficient in the use of wood, even though their measured fuel consumption was statistically the same. Some participants, especially the Dagahaley group, felt that the Envirofit design was easier to use. They noted that the skirt design was more intuitive than the StoveTec one, making it easier to set up and operate.

Nonetheless, all focus group participants reiterated their general dislike of the metal skirts that they were asked to use with the StoveTec and Envirofit stoves. The cooks complained that the StoveTec skirt, which screws onto the pot, was difficult to put on the pot at the outset and then even more difficult to remove once the food was cooked and the hot pot needed to be taken off the stove and placed on the ground. The Envirofit skirt was seen as a better design and easier to use, but it regularly fell apart and had to be reassembled when the stove was moved.

The focus group participants agreed that the Philips stove had many positive attributes, but they perceived that it was not able to hold a pot large enough for their families. (Interestingly, this finding was not evident in the user survey data.) They also thought that it could be easily knocked over by their children inside their homes because of its size.

The Vesto stove received approval from some of the cooks, especially the Hagadera group, for its fuel efficiency and ability to cook food quickly. The biggest negative aspect of the Vesto was that it forced them to stand while cooking, which they described as awkward because they prefer to sit. Furthermore, some participants reported it to be very smoky, which they felt made the food taste bad. They also said that it seemed easy to burn themselves on the body of the Vesto, and that it was too light and could easily be knocked over by children.

Although the Save80 stove received some recognition from the Hagadera cooks who accurately identified it as the most efficient stove in the test, it was generally unpopular with all three groups. The chief complaint was that this stove was difficult to use due to the need to frequently tend the fire. It was particularly challenging for the participants to get the pieces of wood into the stove due to the size of the fueling port and its location relative to the combustion chamber. The design of the Save80 pot was also foreign to the cooks, and some of them felt it caused them to burn the food, creating an unpleasant taste.

The topic of fuel size and preparation prompted significant discussion with all three groups. The participants noted repeatedly that the Philips, Vesto, and Save80 stoves required smaller pieces of wood than the StoveTec and Envirofit stoves. The participants were not accustomed to cutting wood into small pieces and they wondered how they would meet this requirement if they had one of these stoves in their homes. The Envirofit and StoveTec stoves were more familiar for them regarding stove type as well as the size of the required wood.

Towards the end of each focus group discussion, participants were asked to choose the stove that best met their expectations for each of four categories: most fuel efficient, safest, most likely to be durable, and easiest to use. The results of this exercise, showing a strong preference for the StoveTec design primarily and the Envirofit one secondarily, are presented in Table 8. The cooks were also asked to rank all five stoves from 1 (most preferred) to 5 (least preferred). The results of this exercise, presented in Table 9, again show the clear dominance of the rocket stoves, but also the mixed response to the Philips.

**Table 8. A summary of focus group consensus regarding the best stove in four important categories**

	Dagahaley camp	Ifo camp	Hagadera camp
<b>Most fuel efficient</b>	Envirofit and StoveTec	StoveTec	Save80
<b>Safest</b>	StoveTec	StoveTec	StoveTec
<b>Most durable</b>	StoveTec	StoveTec	StoveTec
<b>Easiest to use</b>	Envirofit	StoveTec	StoveTec

**Table 9. Stove rankings from the focus groups (most preferred to least preferred)**

Stove Rank	Dagahaley camp	Ifo camp	Hagadera camp
<b>1</b>	Envirofit	StoveTec	StoveTec
<b>2</b>	StoveTec	Envirofit	Envirofit
<b>3</b>	Philips	Philips	Vesto
<b>4</b>	Save80	Save80	Philips
<b>5</b>	Vesto	Vesto	Save80

### **3.3 ADDITIONAL FIELD TEAM REMARKS**

Over the course of the testing, the field team made some informal observations that are not necessarily captured in the structured observations, survey results, or focus group discussions. Their ad hoc notes are presented below.

- It seemed that the women had more difficulty operating the stoves that did not offer them an easy way to see the fire, as it was difficult for them to gauge when the stove needed to be refueled. The lack of sightlines to the fire sometimes resulted in fires that went out but more often caused overheating and burnt food, especially in the Save80 and Vesto tests. Note that the Vesto stove is designed to allow the user to see the fire, if the holes in the inner and outer stove body are properly aligned.
- Dealing with the smaller wood pieces required for the Philips, Vesto, and Save80 stoves added much to the learning curve and adjustment to these stoves.
- As described in Section 3.2.3 on the focus group discussions, the cooks generally had difficulty using the skirts. Similar to a vegetable steamer basket, the Envirofit skirt was composed of overlapping flaps of metal attached to the stove around the base of the pot supports. This design required less handling than the StoveTec detachable skirt, but it had a design flaw that caused some of the flaps to fall off the stove when it was moved from one location to another. This was the primary cause of the cooks' frustrations with the Envirofit skirt.
- Placing large amounts of wood into the Vesto combustion chamber at the start of the cooking test caused flames to shoot out from around the side of the pot.

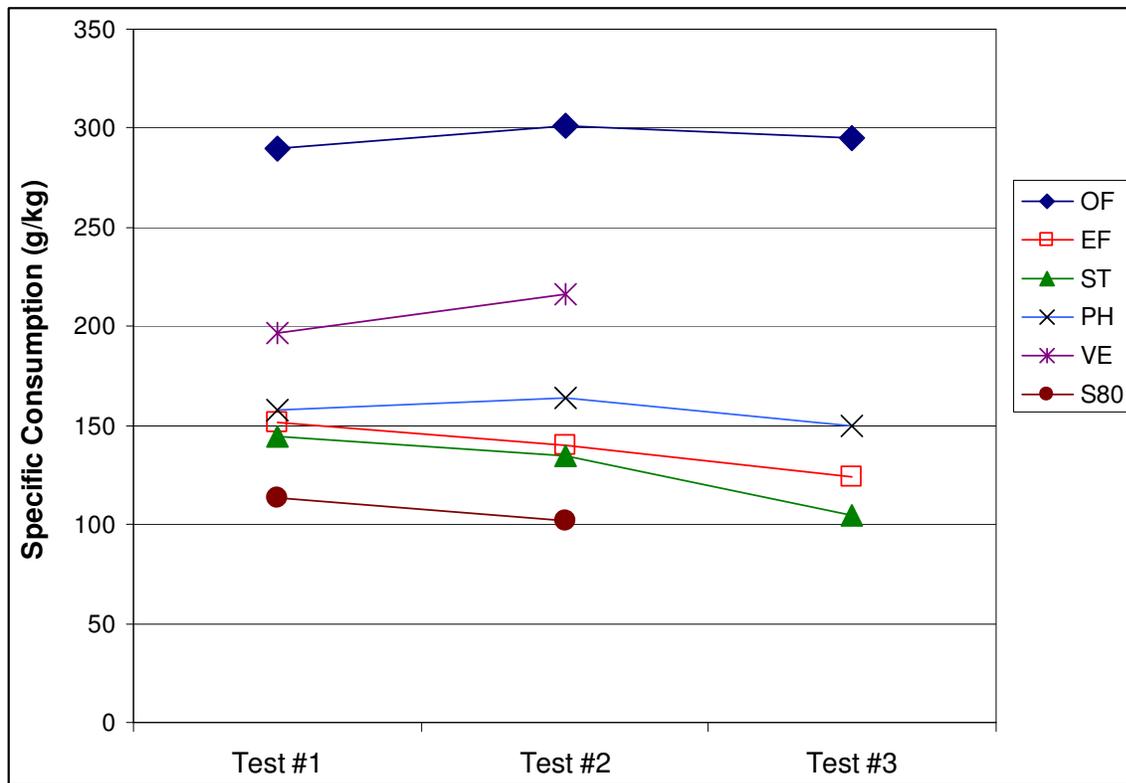
## **4.0 DISCUSSION OF ISSUES POSSIBLY IMPACTING RESULTS**

The results of the controlled cooking test are strikingly consistent and show strong evidence that the stoves save fuel: of the 15 comparisons among stoves and the open fire, 13 of them are statistically significant. The similarity of the fuel use, cooking time, and burning rate patterns across all 18 cooks provides strong evidence that the differences in performance seen in this study are due to the intrinsic differences between the stoves. At the same time, certain study design choices made either intentionally at the start of the work or out of necessity in the field, warrant investigation in case they skewed any of the results.

### **4.1 DIFFERING NUMBERS OF TESTS PER STOVE**

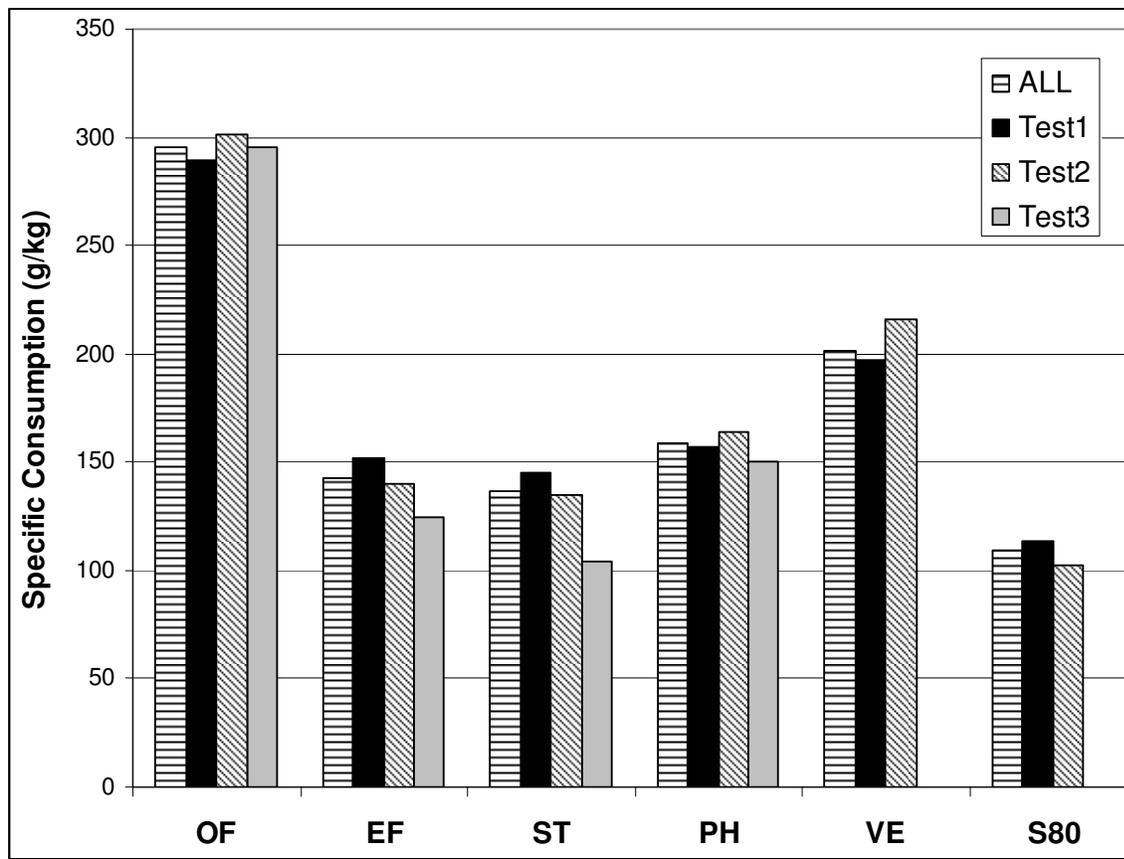
While the standard CCT protocol recommends that each cook test a stove three times, the Berkeley Air team decided instead to prioritize the total number of tests and having each cook test each stove so that she could compare them all knowledgeably and fairly in the focus group discussions. Each cook did conduct three open fire tests in order to create a strong baseline reference point against which her subsequent test results on each manufactured stove could be compared. The differing number of repeated tests performed by each cook for each stove type may have caused slight differences, particularly in the potential for increased stove performance due to increased familiarity. The consistency of the pattern of specific fuel consumption across test number, however, indicates that the fact that the stoves were not tested the same number of times (due to time constraints) did not skew the results in any material way.

Figure 10 shows the specific consumption for each stove for each test number (the repeated tests by each cook on each stove). This figure shows how fuel use changed as the cooks increased their familiarity with the stove. While there may appear to be some trends, for a given stove type, none of the tests were statistically different (e.g. tests 1, 2, and 3 were statistically the same for each stove).



**Figure 10. Specific consumption for each stove for each test number (the repeated tests by each cook on each stove).**

This information is also displayed in Figure 11 below, which shows that the pattern of specific consumption across the six stoves seen in the average of all of the tests is quite consistent across test number.



**Figure 11. Specific consumption for each test number for the six stoves. The average of all tests is shown as well for each stove.**

Nonetheless, in order to investigate the potential effect of the differing number of repeated tests, the specific consumption values were compared using only the first tests of each stove (as 18 first tests were completed for all stoves other than the Save80, which had 14 first tests). This analysis revealed only one change in the results as detailed in Table 6. While the StoveTec used significantly less fuel than the Philips when all tests were included, the two were statistically the same when only the first tests were included. Thus, the one change in the findings in going from all tests to only first tests did not involve the Vesto and Save80, which had a limited number of second tests and no third tests. Therefore, the Vesto and Save80 were not unfairly disadvantaged and the findings based on all tests regarding specific consumption are valid. The similarity of the first tests to all tests regarding specific consumption can be seen in Figure 11.

Because none of the five manufactured stoves saved substantial time relative to the open fire, we did not present an analysis of the total cooking time based on the test number.

It is possible that the Vesto and Save80 stoves were slightly disadvantaged regarding the women’s assessment of their usability, because they performed only one or two tests on these two stoves instead of one to three tests.

#### **4.2 POT AND SKIRT CHOICES**

Use of the provided, integral Save80 pot instead of the standard UNHCR pot (which was used with all five other stoves) likely reduced fuel use for the Save80 stove, but we cannot say by how much. Placing the pot on the grate on top of the Vesto stove instead of placing the pot inside of the Vesto stove likely caused an increase in fuel use for the Vesto stove, but we cannot say by how much. Doing so also increased the working height of the Vesto, which may have exacerbated the issue that some cooks had with its height.

Use of the skirts on the StoveTec and Envirofit stoves, though not integral to their functioning, likely increased their fuel efficiency. While both manufacturers report thermal efficiency gains of up to 30% in laboratory water boiling tests, we do not know their effect in these tests.

#### **4.3 DIFFERENCES IN THE HAGADERA RESULTS**

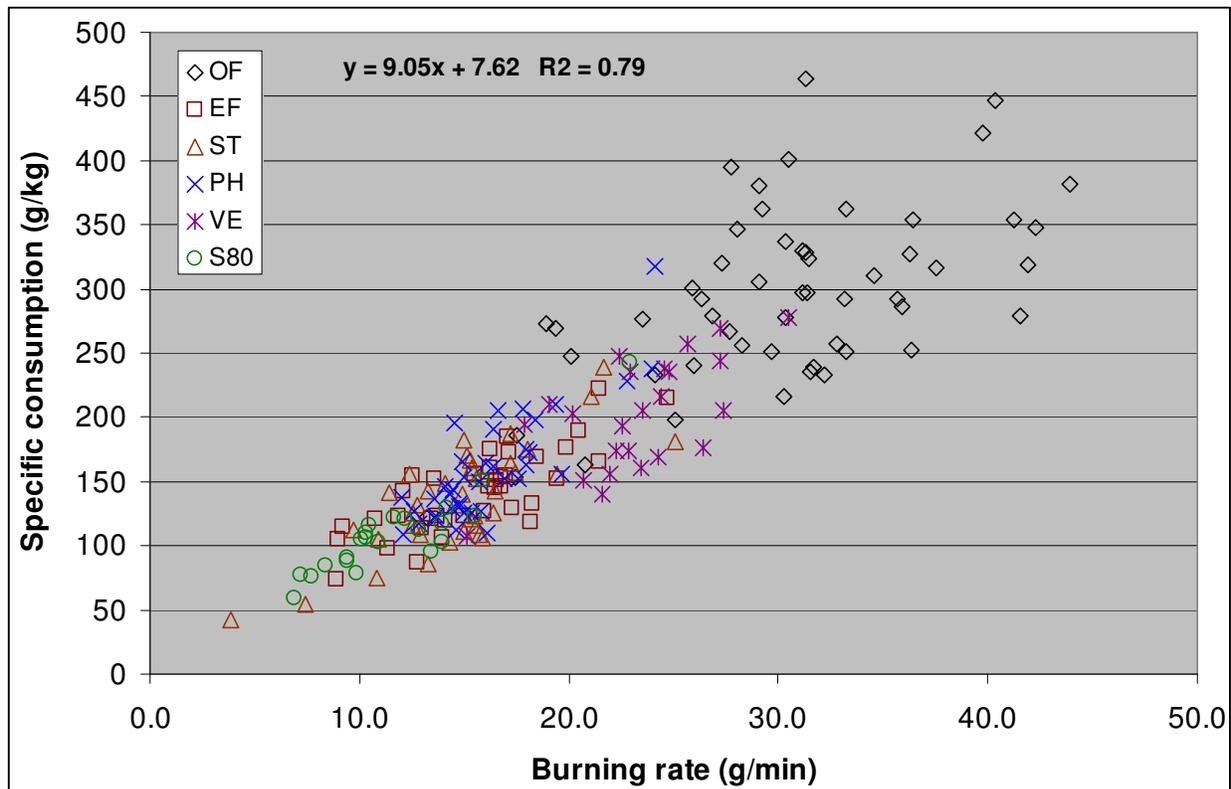
In both the quantitative and qualitative measurements, Hagadera camp seemed to stand apart from the other two camps. It may be significant that Hagadera used a different type of wood than the other two camps, although the average wood moisture was very similar in all three camps. It is not known if the process for procuring and distributing fuelwood is different in Hagadera than in the other two camps. It is also possible that the Hagadera households have somewhat different traditional cooking methods or stoves than the other camps. We are not otherwise able to explain the differences seen in Hagadera camp, as such an analysis fell outside the scope of this study.

#### **4.4 POTENTIAL EFFECTS OF FAMILIARITY WITH IMPROVED COOKSTOVES**

One of the unanticipated effects of the choice of Dadaab as the location for the testing was that the cooks there already had significant exposure to some improved cookstoves. The two models of improved stoves in use there most closely resemble the manufactured Envirofit and StoveTec rocket stoves. The design, operation, and fuel size of the StoveTec and Envirofit stoves were therefore almost immediately familiar to the women, and this familiarity almost certainly created a bias in the usability testing results. Thus, it is possible that the other three stoves would have been accepted and appreciated as readily with additional exposure and support. It is also possible that additional training would allow the cooks to use the Philips, Vesto, and Save80 stoves more efficiently than they did in these tests, after gaining a better understanding of their ideal operation, fuel loading methods, and wood size requirements. Finally, it is further possible that, if the women could operate the non-rocket stoves at their peak efficiency, the benefits of the additional fuel savings might provide further incentive to adapt to some of those stoves' usability constraints.

#### **4.5 FUEL USE VERSUS BURNING RATE**

Figure 12 below shows a plot of fuel use (specific consumption) versus burning rate (the amount of fuel consumed in the stove per minute) for all 214 stove tests. The figure shows that fuel use was fairly highly correlated with burning rate across all six stove types (the correlation coefficient,  $R^2$ , of 0.79 is indicative of a fairly strong relationship between the two parameters).



**Figure 12. Fuel use (specific consumption) versus burning rate for all 214 controlled cooking tests.**

Figure 12 indicates that the stoves that were able to operate effectively with lesser amounts of fuel burning at a time and/or encouraged the cooks to put less fuel into the combustion chamber at one time (thereby achieving a lower burning rate) required less wood to complete the controlled cooking test. For each of the six stoves, loading more wood into the fire (increasing the burning rate) resulted in more fuel used to complete the cooking task. This indicates that a stove that is able to operate effectively at lower burning rates without requiring the user to constantly tend the stove will both save fuel and be able to meet users' needs for ease of use.

## **5.0 CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 ALL STOVES SIGNIFICANTLY OUTPERFORMED THE OPEN FIRE**

The most notable conclusion from this study is perhaps the fact that all five tested stoves outperformed the open fire, requiring significantly less fuel to cook the test meal. Furthermore, this performance difference was robust and consistent across the three test sites and the 20 test cooks.

While this result may seem like a foregone conclusion, it is in fact not as common as one might think. In the hands of a skilled operator, the open fire can be a very effective cooking device. At the same time, some supposedly improved stoves have not been sufficiently tested or not consistently configured, leading to wildly variable and sometimes very poor performance in the field. It is therefore a real testament to the quality of the stoves tested in this study that they all outperformed the open fire, and it is likely that this performance differential would continue to be measurable across various operators and situations.

### **5.2 FUEL EFFICIENCY IS NOT THE SOLE DETERMINANT OF USER PREFERENCES**

Ease of use, level of smoke, and cooking speed are also key factors in a woman's decision to buy one of these stoves, assuming all were equally available and affordable. At the same time, the results demonstrated that, on their own, user perceptions of stove performance are not always accurate. The Dadaab findings highlight several instances where the quantitative data does not match the users' perceptions of fuel use and cooking speed. Quantitative tests are needed to measure these indicators in order to set realistic expectations and meet overall human and environmental impact goals.

This leads to the recommendation that any program seeking to disseminate an improved stove would do well to research user priorities among its target population and perhaps also to offer more than one design choice. Although not explicit in the results, there is also the related implicit conclusion that familiar stove technologies and designs may be more readily acceptable than new ones. This suggests that implementers might base part of their stove selection on the time and resources available to support significant transitions in user behavior.

### **5.3 ADDRESSING FUEL REQUIREMENTS IS CRITICAL TO SUCCESSFUL ADOPTION**

One of the design features common to highly-efficient improved stove designs is the regulation of the fuel supply. These stoves perform best when the fuel is fed into a restricted chamber at regular intervals. This fact was not lost on the test cooks, and the concerns related to fuel preparation and fuel tending were raised in both the surveys and the focus group discussions. In the Dadaab camp complex, the women generally felt comfortable with the thin but long sticks that the two rocket stoves require, even though the fuel still needed to be pre-cut for these two stoves. They were vocally less enthusiastic about chopping the wood into the smaller chunks needed to fuel the Vesto, Philips, and Save80.

### **5.4 NO SIGNIFICANT TIME SAVINGS**

The quantitative data revealed that none of the tested stoves offered a large time benefit to the cooks. Even though two stoves did show a statistically significant decrease in cooking time over the open fire and the other stoves, the actual number of minutes saved was so small that it would not likely have much impact on the cook's overall daily time-activity patterns.

These results need to be viewed within the context of the structure of the CCT, which is not designed to provide a nuanced assessment of time savings. The test only measures total cooking time and does not provide any information on whether the woman is fully occupied during that time or whether she could be engaged in other activities while cooking, due a change in the intensity of the process. The CCT test also does not measure time needed to collect or prepare fuel, which are the activities most likely to be affected by the adoption of an improved stove.

The lack of a significant improvement in cooking time is also reflected in the ambivalent qualitative data on this point. At least two cooks cited on their surveys that “faster cooking” was a benefit of each stove, and more than 50% of the women listed rapid cooking as one of the best attributes of the StoveTec stove. On the other hand, for every stove except the Save80, at least four women complained that the stove cooked too slowly, and just under half the women cited slow cooking as one of the worst attributes of the Vesto stove, even though it was, in fact, the fastest.

### **5.5 SAVE80 LEADS THE WAY IN FUEL EFFICIENCY BUT PRESENTS USABILITY CHALLENGES**

Climate Management’s Save80 stove proved to have the highest fuel savings, and this finding was highly statistically significant. One of the factors contributing to its performance was likely the integrated pot design, which suspends the cooking surface directly above the fire and in the midst of the hot gases. On the other hand, the stove was the least popular among the cooks, with only 7% saying they would buy the stove if it were available in the market at an affordable price. The most frequently cited reasons were that the Save80 burns the food, is uncomfortable to use, and requires special skill to operate. The focus groups also revealed that the constant need to refuel was a key usability challenge. These findings lead to the recommendation that any program seeking to introduce the Save80 should plan for substantial user training and troubleshooting support. The fact that the cooks performed only one or two tests on the Save80 (compared to one to three on the Envirofit, StoveTec, and Philips) may have contributed to its lower usability rating.

### **5.6 FAMILIAR ROCKET STOVES PROVE BOTH FUEL EFFICIENT AND POPULAR**

Both the rocket stoves tested in this study offered strong fuel performance and received high marks from the women for usability. Although on average the StoveTec stove had 2% greater fuel savings over the open fire than the Envirofit stove, the difference is not statistically significant. The cooks’ frustrations with the skirts did not dissuade them, as one hundred percent of them affirmed that they would buy the StoveTec and the Envirofit stoves, assuming they were available at an affordable price. All of the cooks also stated that neither of these stoves would require them to make any change in the way that they cook their food. Finally, one or the other of these two stoves was the top pick of the women in each of the three focus groups.

The strength of these findings point to the StoveTec and Envirofit rocket stoves as a good choice for the Dadaab sites and potentially for other refugee situations environments in Sub-Saharan Africa as well. It seems likely that these stoves would have a higher chance of being adopted even if the program implementers were unable to provide in-depth training and/or sustained support, especially if the target population had already had some exposure to rocket

stove technology and/or already used a size and shape of fuel that fits comfortably into the rocket combustion chamber. Nonetheless, it remains critical for implementers to check for a good fit between local preferences and the height of the stove, the size and shape of the available fuel, the size and shape of cooking vessels and the type of cooking tasks regularly performed.

#### **5.7 GASIFIER DESIGNS LESS EFFECTIVE; MAY REQUIRE MORE TRAINING AND SUPPORT**

There were two stoves in the study that employ gasifier technology: the Philips and the Vesto. Both of these stoves demonstrated consistent fuel savings over the open fire, with the Philips outperforming the Vesto, but both also had design features that the cooks found undesirable. Both these stoves require smaller pieces of fuel, which raises the question for program implementers of how the fuel will be cut up and by whom, and creates a potential barrier to adoption. In both the surveys and the focus groups, the cooks also mentioned that the gasifiers were difficult to keep lit and fueled, and required advanced skill to operate.

These findings lead us to tentatively conclude that these gasifier stoves would be more difficult to introduce at the Dadaab settlements. Users would appear to need more training and support to successfully operate the stove and to feel confident in its performance. Thoughtful marketing and outreach could help manufacturers build user trust and comfort with the gasifier design, although in the case of the Vesto, actual design changes may also be needed to enhance the stove's safety.

## **6.0 NEXT STEPS**

### **6.1 ENGAGE OTHER TEST POPULATIONS AND TEST OTHER STOVE AND FUEL OPTIONS**

Although the findings from this study provide some robust quantitative performance data and clear qualitative information, it is important to keep in mind that the results are not necessarily generalizable to all populations. Not only was the work conducted in just one refugee complex, but all the test cooks were of Somali origin. One obvious next step would be to repeat this study in a different environment with users of different cultures cooking different foods.

Due to resource constraints, this study did not examine the suitability of stove technologies that rely on other forms of biomass, such as pellets, or other alternative fuel sources such as solar or ethanol. Also excluded from the research were stoves with fans or blowers, which many see as the most promising technological innovation for solid-fuel stoves. At the time the stoves were sourced, the study team was not aware of any fan stoves that did not require either some grid power or pelletized fuel. Follow-up studies could look at the potential of these alternative technologies.

### **6.2 TEST STOVE EMISSIONS OR INDOOR AIR POLLUTION EFFECTS IN THE FIELD**

Emissions of particulates, carbon monoxide, and other health- and climate-damaging pollutants are an enormous negative consequence of the use of solid biomass fuel for household energy. Reducing smoke for personal comfort and to improve the taste of the food was also a usability criterion for the Dadaab test participants. While most of the stoves included in this project had also undergone emissions testing in the lab, it is important to extend this assessment into the field, where the particulars of local fuel, operator skill, and cooking habits can have a significant impact on outcomes. The testing done at the Dadaab complex did not address this aspect of stove performance, and it cannot be inferred that stoves with high fuel efficiency also have lower emissions.

### **6.3 CONDUCT LONGER-TERM IN-HOME MONITORING**

The selection of the controlled cooking test was well suited to the current program needs as it provided both comparable quantitative performance metrics and real-world usability information. However, these tests are still highly controlled and do not always reveal the full spectrum of implementation and adoption challenges. Also excluded from the scope of the testing was any assessment of the relative emissions from the stoves or their impact on air quality and health. Both of these objectives could be met through a follow-up study of fuel use, stove emissions, and indoor air quality measured in homes over the course of 24 or 48 hours of normal cooking.

### **6.4 PILOT PROGRAMS THAT FACILITATE FUEL PREPARATION**

Any program seeking to implement an improved stove should consider the relationship between the available fuel and the fuel size and shape requirements of the potential intervention stoves. Further, it seems likely that anything the program can do to alleviate the individual burden of converting the fuel into the optimal size and shape could greatly enhance the likelihood of sustained stove adoption and accrual of sustainable benefits. To date, relatively little attention has been paid to the impact of fuel requirements on stove adoption. An initiative to pilot

innovative ways to overcome this adoption challenge would add significantly to the overall success of stove programs in refugee and IDP environments.

#### **6.5 PROVIDE IMPLEMENTATION GUIDELINES AND CASE STUDIES**

The lessons learned from this work together with other past and potential stove tests can be incorporated into USAID's program toolkit to assist implementers in selecting and implementing improved stoves. This information lends itself to both general guidelines as well as case studies highlighting specific challenges such as selecting or adapting stoves for particular cooking needs or matching stove and fuel types.

## 7.0 APPENDICES

### 7.1 CONTACT INFORMATION FOR STOVE MANUFACTURERS AND RETAIL STOVE PRICES

**Model: Envirofit G3300 Stove**

Manufacturer: Envirofit International

Contact: Tim Bauer

Email: [tim.bauer@envirofit.org](mailto:tim.bauer@envirofit.org)

Website: [www.envirofit.org](http://www.envirofit.org)

Postal Address: 109 North College Avenue, Fort Collins, CO 80524-2602, USA

**Model: StoveTec Wood Stove**

Manufacturer: StoveTec

Contact: Ben West

Email: [ben@stovetec.net](mailto:ben@stovetec.net)

Tel: +1 541-767-0287

Website: [www.stovetec.net](http://www.stovetec.net)

Postal Address: P.O. Box 1175, Cottage Grove, OR 97424, USA

**Model: Natural Draft Stove**

Manufacturer: Philips Electronics India Limited

Contact: Pawandeep Singh

Email: [Pawandeep.Singh@philips.com](mailto:Pawandeep.Singh@philips.com)

Tel: +91 124 4606000 (Extn. 6066)

Fax: +91 124 4606666

Website: [www.philips.com](http://www.philips.com)

Postal Address: 9th Floor; DLF 9-B; DLF Cyber City; DLF Phase 3; GURGAON - 122002; India

**Model: Vesto Stove**

Manufacturer: New Dawn Engineering

Contact: Thabsile Shongwe

Email: [thabsile.s@newdawnengineering.com](mailto:thabsile.s@newdawnengineering.com)

General inquires and information: [thabsile.s@newdawnengineering.com](mailto:thabsile.s@newdawnengineering.com)

Sales information: [sales@newdawnengineering.com](mailto:sales@newdawnengineering.com)

Product support: [support@newdawnengineering.com](mailto:support@newdawnengineering.com)

Tel: +268 518-5016 or 518-4194

Website: [www.newdawnengineering.com](http://www.newdawnengineering.com)

Postal Address: P.O. Box 3223 Manzini, MZ200, Swaziland

**Model: Save80**

Distributor: Climate InterChange AG

Lichtenbergst. 8, 85748 Garching / Munich / Germany

Website: [www.climateinterchange.com](http://www.climateinterchange.com)

Contact: Dr.-Ing. Dieter Seifert

Email: [info@climateinterchange.com](mailto:info@climateinterchange.com)

## Evaluation of Manufactured Wood Stoves in Dadaab Refugee Camps, Kenya

Tel: +49 89 5484 2840

Fax: +49 89 5484 2848

Distributor in Zambia: Climate Management Ltd.

Lima Garden, Lusaka

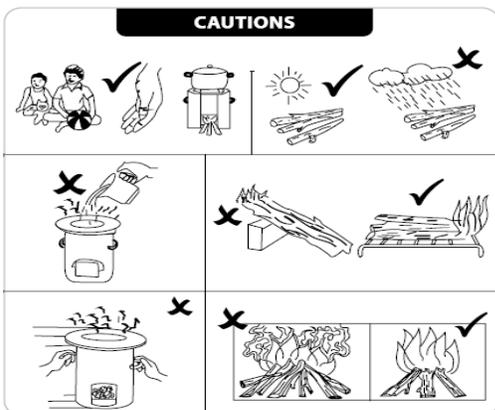
Email: [Zambia@climateinterchange.com](mailto:Zambia@climateinterchange.com)

Tel: [+260 955 863295](tel:+260955863295), [+260 211 242141](tel:+260211242141)

**Retail Prices of Stoves.** All of these manufactured stoves were available for less than 100 USD each at the time of this study. Exact stove prices are based on quantity ordered and location. Please contact the manufacturers for pricing details.

## 7.2 STOVE MANUALS

### 7.2.1 Envirofit G-3300 Stove



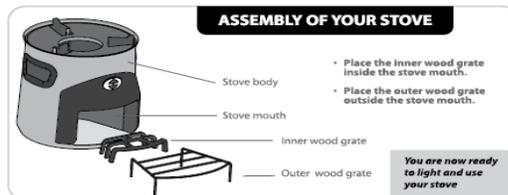
## ENVIROFIT COOKSTOVE G-3300 USER MANUAL



**You just purchased the finest biomass burning stove in India**

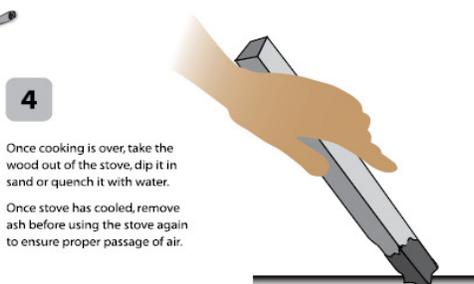
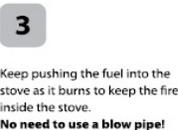
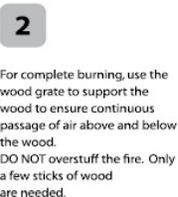
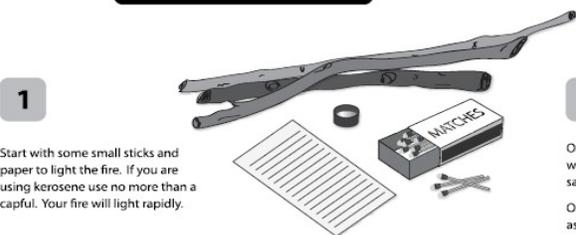
Your Envirofit G-3300 cookstove is made of the most durable, quality materials to ensure a longer life. Its unique design makes it easier to start a fire quickly and produces a much hotter and cleaner fire that uses significantly less fuel. This means faster cooking, time and fuel savings, cleaner pots and kitchen walls, and a safer home where your family can breathe cleaner air.

**We wish you a happy, healthy cooking experience!**



Stove Brought to you by:  
Envirofit (India) Private Ltd  
212, 1st B Cross, East of NGEF layout,  
Kasturinagar  
Bangalore - 560043  
Tel: 080 - 41153808  
Fax: 080 - 41153809  
Email: info@envirofitcookstoves.org  
www.envirofitcookstoves.org

### COOKING WITH YOUR STOVE



Use a small quantity of wood to cook the food. Large quantities of wood are not required and will only make the stove smoke. **Do not thrust large quantities of wood into the stove at one time.**

## 7.2.2 Philips Natural Draft Stove

**PHILIPS**

### Using the Woodstove

वुडस्टोव का उपयोग / वुडस्टोवचा उपयोग करणे

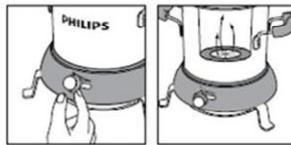
- 1** Only use biomass fuel. For the best results use dry wood pieces of 2 x 3 x 10cm.

सिर्फ जैविक (लकड़ी, सूखे पौधे, उपले इत्यादि) ईंधन का उपयोग करें. उत्तम कार्य क्षमता के लिए 2 x 3 x 10 से.मी. सूखी लकड़ियों का उपयोग करें. केवल बायोमास ईंधनका उपयोग करावा. सर्वोत्कृष्ट कामगिरीसाठी केवल २ x ३ x १० से.मी. आकाराच्या कोरड्या लाकडाच्या तुकड्यांचा उपयोग करावा.



- 2** To start the Woodstove, open the air grid by moving the heat control knob to the far left.

वुडस्टोव शुरू करने के लिए हीट कंट्रोल नॉब को बिलकुल बाएँ घुमाकर एयर ग्रिड खोलें. वुडस्टोव सुरु करण्यासाठी हीट कंट्रोल नॉब अगदी डावीकडे फिरवून एअर ग्रिड उघडा



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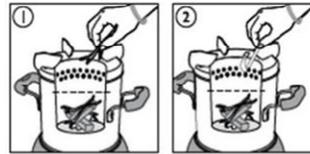
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**PHILIPS**

- 3** Put some small, dry wood twigs inside the burning chamber, add paper and light the fire. Do not fill the chamber more than half. Initially there will be some smoke.

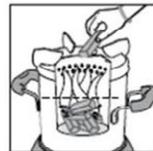
बर्निंग चेंबर के भीतर कुछ छोटे, सूखे लकड़ी के तिनके रखें, कागज के टुकड़े डालें और आग जलाएँ. चेंबर को आधे से ज्यादा मत भरें. शुरुआत में थोड़ा धुआँ हो सकता है.

बर्निंग चेंबरच्या आत लहान, कोरडे लाकडाचे फांदीचे तुकडे टाकावेत, कागद टाकून आग पेटवा. चेंबर अर्ध्याहून अधिक भरू नका. सुरुवातीला थोडा धूर होऊ शकतो.



- 4** While the fire is getting bigger, add some extra wood. Do not fill the chamber more than half.

जब आग बड़ी होने लगे तब कुछ और लकड़ी डालें. बर्निंग चेंबर में आधे से ज्यादा लकड़ी नहीं भरनी चाहिए. जेव्हा आग मोठी होण्यास सुरुवात होईल तेव्हा थोडे अधिक लाकूड टाका. चेंबर अर्ध्याहून अधिक भरू नका.



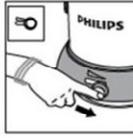
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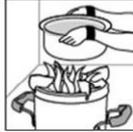
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## PHILIPS

- 5** When the fuel is burning properly move the heat control knob to the right to control the heat.  
जब ईंधन ठीक से जलने लगे तब ऑफ को नियंत्रित करने के लिए हीट कंट्रोल नॉब को दाएँ घुमाएँ।  
जेव्हा ईंधन योग्य प्रकारे जळू लागेल तेव्हा उष्णतेवर योग्य नियंत्रण देवण्यासाठी हीट कंट्रोल नॉब उजवीकडे फिरवा



- 6** When the smoke is reduced, the Woodstove is ready for use. Place a pot on top.  
धुआँ घट जाने पर वुडस्टोव उपयोग के लिए तैयार हो जाता है।  
जेव्हा धूर कमी होईल तेव्हा वुडस्टोव वापरण्यास तयार असेल.भांडे बर ठेवा.



- 7** Add fuel once in a while when flames are low. Do not add too much at a time, but in intervals to prevent smoke.  
जब ऑफ धीमी होने तब ईंधन के टुकड़े बीच-बीच में डालें. एक बार में ज्यादा नहीं डालें, बल्कि धुएँ से बचाव के लिए एक-एक कर डालें।  
जेव्हा जाळ कमी असेल तेव्हा मधूनमधून ईंधन टाका. धूर होऊ नये ह्यासाठी एकाच वेळी खूप टाकू नका परंतु मधूनमधून टाका.



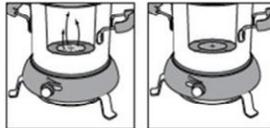
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## PHILIPS

- 8** Move the heat regulator to adjust the amount of air inlet. For example, move to the extreme left when fire almost dies out and needs more air.  
भीतर जानेवाली हवा का तालमेल करने के लिए हीट रेग्युलेटर घुमाइए. उदाहरण के लिए जब आग तकरीबन खत्म होने लगे और ज्यादा हवा की जरूरत हो तब उसे बिल्कुल बाई तरफ घुमाएँ।  
आत येगारी हवा कमीअधिक करण्यासाठी हीट रेग्युलेटर फिरवा. उदाहरणार्थ, जेव्हा आग जयजयवब विझत येईल तेव्हा आणि अधिक हवेची गरज असेल तेव्हा पूर्ण डावीकडे फिरवा.



- 9** When cooking is finished stop adding wood. The fire will die out in sometime.  
जब रसोई पूरी हो जाए तब लकड़ी डालना रोक दें. थोड़ी देर में आग बुझ जाएगी।  
जेव्हा स्वयंपाक पूर्ण होईल तेव्हा लाकूड टाकणे थांबवा. आग थोड्या वेळात विझून जाईल.



- 10** Empty the Woodstove by turning it upside down using the handles.  
हॅंडल्स को पकड़ कर वुडस्टोव को उल्टा करके खाली करें।  
वुडस्टोव रिकामा करण्यासाठी हॅंडलचा उपयोग करून तो उलटा करा.



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### 7.2.3 Save80 Stove

## Fact Sheet of the Highly Efficient Stove Save80®

The name "Save80" means that an experienced person can save 80% of the firewood consumption of a traditional open fireplace (3-stone-fire). The "Save80" needs around 250 g of dry firewood to bring 6 litres of water to the boil.

**Nominal effective thermal power:** 1.5 kW  
**Pot capacity:** 8 litres  
**Recommended pot content:** 6 litres

The interior parts of "Save80" are made of stainless steel to ensure a life-span of many years, high efficiency and burning at high temperatures for complete combustion with low emission of smoke.

Time for bringing 6 litres of water to the boil:  
about 25 minutes

The supply of air is regulated automatically by the design of the cooker.

"Save80" is not affected by the wind.

**Manufacturing information:** Mass production has started; capacity of production can be adapted in a short time to any quantity needed.

### Transport Information "Save80"

**Packaging dimensions:** width: 35 cm; height: 45 cm.

**Weight:** about 5 kg

**Weight of pot with lid:** about 1 kg

"Save80" is delivered in parts. One 40 foot sea container holds about 2000 Save80-kits.

Assembling is simple and can be learnt quickly by men and women.

### Basic Rules for the Use of "Save80"

"Save80" can be used mainly for cooking, frying and deep frying.

Kindling is done by setting fire to a sheet of paper and some small pieces of wood in the burning chamber. When the fire is lighting, the pot is inserted. Afterwards the fire is maintained by throwing small firewood sticks through the quadratic aperture.

What is of particular importance is, that small pieces of wood, which are not traditionally collected and burnt, can be used in the "Save80".



## Fact Sheet of the Heat Retaining Box Wonderbox®

The "Wonderbox" is used for cooking with retained heat and for conserving high temperature of the content for many hours. It is suited to the 8-litre-pot (with lid) of "Save80".

After 2 hours the temperature of 6 litres of water will decrease from 100°C to about 90°C; after 12 hours the temperature is still above 65°C.

The "Wonderbox" can save more than half of the firewood consumption, in addition to the saving by the "Save80".

The material of the "Wonderbox" is specially designed for the heat retaining of food and water, up to the boiling point and has a life-span of years (no polystyrene).

**Manufacturing information:** Mass production has started; capacity of production can be adapted in a short time to any quantity needed

### Transport Information "Wonderbox"

Weight (upper and lower part): about 900 grams

The parts are stackable

About 2000 "Wonderboxes" can be transported in a 40-foot sea container, in addition to about 2000 "Save80"-kits.

### Basic Rules for the Use of the "Wonderbox"

Cooking by retained heat is very simple and needs no surveillance.

The pot is introduced into the lower part and the "Wonderbox" is closed by putting on the upper part. After bringing the pot content to boiling point, the pot is introduced into the "Wonderbox". Porridge, for example, can be cooked without stirring.



## Examples for Using Save80<sup>®</sup> in Combination with Wonderbox<sup>®</sup>

(According to the experience of cooking instructor Imma Seifert, Neuötting)

Note: The higher the amount of cooked water or food in the 8 litre-pot, the larger is the percentage of firewood saved by "Save80" and "Wonderbox"

### Rice

- 5 litres of water, 800 g rice

Bring the water (with a teaspoonful of salt) to the boil by "Save80" and add the rice. Boil it up and place the pot with lid into the heat retaining box. The rice is ready after 30 minutes in the "Wonderbox".

Fire wood consumption: about 250 g

### Dried Vegetables (Beans, Peas, Lentils)

- 4,5 litres of water, 1 kg dried vegetables

Add the dried vegetables to the cold water, without salt and bring it to the boil by the "Save80". Boil up and put the pot with lid into the "Wonderbox". After about 2 hours the peas, beans or lentils are cooked. Season only at the end. Soak the beans (especially large beans) overnight in cold water.

The "Wonderbox" saves all the labour usually connected with the time and firewood consuming cooking of dried vegetables. The pot remains in the box without supervision and without any fire burning.

Firewood consumption: about 250 g

### Maize porridge

- 5 litres of water, 1 kg maize flour

Bring the water to the boil and pour the maize meal into the boiling water stirring continuously. Boil up briefly and put the pot with lid into the "Wonderbox". After 30 minutes the porridge is ready.

The porridge is the same grade as encountered in Africa. The smaller the amount of maize porridge one is preparing, the better the mixing has to be done. Minimum time in the "Wonderbox" is half an hour.

The "Wonderbox" saves the tedious stirring of the porridge when it is thickening and it avoids the danger of scorching. In a well closed heat retaining box the porridge is kept hot, unattended, for many hours.

Firewood consumption: less than 300 g



### Potatoes

- 3 kg potatoes (large potatoes cut into halves), 3 litres of water

Put the potatoes into the pot with the cold water. Heat it to the boiling point by "Save80". This takes about 25 minutes. Cook the potatoes 5 minutes.

Transfer the pot with the boiling content into the "Wonderbox". It takes 30 minutes in the "Wonderbox" to finish the cooking of the potatoes.

Firewood consumption: about 250 g

### Meat and chicken (comparative test)

- 800 g meat (400 g one lump; 400 g cut into pieces), a big chicken leg, 6 litres of water, some vegetables, herbs

The pot content was brought to the boil and the pot was transferred to the "Wonderbox". Before the transfer to the "Wonderbox", the big piece of beef (400g) was half done, the smaller pieces were nearly cooked. The chicken was already finished. After two hours in the "Wonderbox" the chicken meat was detached from the bone and was very soft. The meat was well done.

Firewood consumption: about 250 g

### Fish

#### Boiling fish:

- 3 fishes (trout), each 250 g, 2 litres of fish brew

Bring the brew with the spices to the boil by "Save80". Then insert the fish into the brew. Place the pot with lid into the "Wonderbox". The cooking is finished after 30 minutes.

Firewood consumption: about 200 g

#### Frying fish:

- fish, cooking oil/fat, spices

For frying by "Save80" use a low fire in the burning chamber. Pour cooking oil/fat into the pot and fry the prepared fish.

Firewood consumption: less than 200 g

### Flatbread

- 260 g flour, 20 g yeast, 120 g water, spices: salt, fennel, coriander, caraway

Roll 8 thin flatbreads (diameter about 15 cm). Brush the flatbread with vegetable oil before baking. It takes about 2 minutes to bake a flatbread (about 1 minute each side ) on the bottom of the pot - without using a lid. Baking of flatbread is quick and un-problematic, if an appropriate small shovel is used for turn-over and taking out of the bread.

Firewood consumption: In total about 160 g (20 g per bread).



## 7.2.4 StoveTec Wood Stove (26 cm)

### One-Door Stove Manual



This instruction manual can be translated into the local language. For a template, please contact:

StoveTec  
PO Box 1175  
79093 Highway 99  
Cottage Grove, Oregon 97424  
USA  
541-767-0287

Instructions by Evan Shenkin and Nordica MacCarty

[www.stovetec.net](http://www.stovetec.net)

### Detailed Instructions for One-Door Wood Stove

- To light the stove, place some kindling inside the combustion chamber. Add larger pieces of wood when the flame is established. Continue pushing sticks into the stove as they are burned. Do not overfill the stove.
  - Clean ashes from stove after each use.
  - The adjustable pot skirt helps to save fuel! Loosen the nut and adjust the skirt so that it touches the top of the stove. Then tighten the nut.
  - Always use the stick support so air can come up through the burning sticks.
- **Use the stove only in a well-ventilated area!**
- **Do not use the stove indoors.**
- **Keep the stove out of the rain. Keep it dry.**

1. Remove stove from box.



2. Place wood shelf inside fuel door. Shelf will sit inside stove body slightly.



3. Place pot skirt under bottom of pot.



4. Press pot skirt together and tighten screw.



5. Place the pot and pot skirt on top of the stove. Push the pot skirt down onto the top of the stove.

**\*\*Using the pot skirt will save about 25% of the fuel!**



6. Light fire with kindling.



# Evaluation of Manufactured Wood Stoves in Dadaab Refugee Camps, Kenya

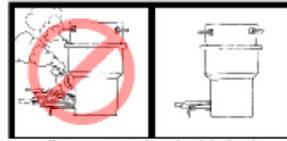
- 7. Larger sticks catch fire from the kindling underneath them.
- 8. Burning the sticks at the tip will create much less smoke. Push sticks into the stove as they burn up.



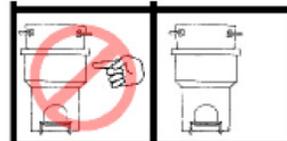
- 9. After the stove is cool, remove fuel tray and clean out ashes. Clean stove with water and a soft cloth.



- 10. When moving stove wait until cool. Carry using both handles.



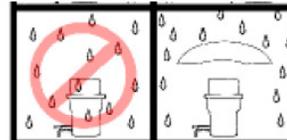
Do not overload with fuel



The stove body is hot – do not touch



Use only with ventilation



Protect from rain

### 7.2.5 Vesto – The Variable Energy Stove



VESTO Cooker - Satisfying your family's needs.

Wood, dung, charcoal, mielle cobs: any biomass can be used in the Vesto. Do not use coal!

The Vesto is very economical and saves more than half the fuel. Do not over-fill the firebox. Doing so will cause smoke. Cut the wood into short, fat pieces. The smaller the pieces, the faster and hotter the fuel burns. One piece is suitable for simmering. The wood used should not be taller than this pamphlet.

smoke, while bottom lighting gets to a hot flame faster.

After about 1 or 2 minutes, there should be no more smoke visible. The smoke is burned by the flames once the grate and air tube around it gets hot. This secondary combustion of the smoke is the reason for the very clean burning, low emissions and high efficiency.

If the fire is smoking, there is probably have too much fuel in the Fire Grate, or else it is too small in size and is burning faster than air can get in.



When the food is boiling you can turn down the fire with the control lever to save fuel. The fumes increase when you do this so it is better to use high heat only when indoors. When you have finished



#### Sealing the Bottom

If the stove is placed on a flat surface like a cement floor then the bottom is sealed and air does not get under the side. This is correct Air should not be able to get to the fire except through the holes in the side. If the ground is very soft you can press the Vesto downwards gently while rotating it which will cause the bottom to sink in and create a seal.

If the ground is not flat, then use the lid and place it under the Vesto body so that the bottom is sealed (see photo). If you do not seal it, the fire control lever will not function.



#### The Fire Grate

Keep the top of the fuel below the triple-line of holes as shown in the photo. When burning dung, start a small wood fire first then add dung.

You could start the fire by putting in some paper and wood, then add fuel a little at a time, or you could first load in the paper and wood then light the top or the bottom. You can take out the Fire Grate to light the fire. Top lighting creates less initial

cooking, enjoy the meal with your family.



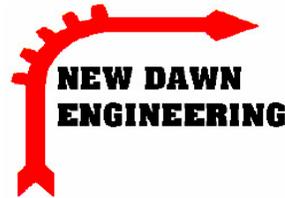
The Vesto is mostly made from Stainless steel. The Fire Grate and its bottom where the fuel sits can be replaced separately.

The Vesto is made to ensure your safety however the outside can become hot and children should be kept away when you are cooking

Enjoy the convenience and safety of modern, renewable energy cooking!



There is one waiting for you!



P.O. Box 3223 Manzini  
Swaziland  
Tel: 518-4194 Fax: 518-5016  
Email: [sales@newdawn.sz](mailto:sales@newdawn.sz)  
Web: [www.newdawnengineering.com](http://www.newdawnengineering.com)  
On Matsapha Crescent behind YKK



VESTO

### 7.3 CONTROLLED COOKING TEST PROTOCOL V2

*Prepared by Rob Ballis for the Household Energy and Health (HEH) Programme, Shell Foundation*

(Not currently included in Shell HEH Stove Performance Protocols)

The controlled cooking test (CCT) is designed to assess the performance of the improved stove relative to the common or traditional stoves that the improved model is meant to replace. Stoves are compared as they perform a standard cooking task that is closer to the actual cooking that local people do every day. However, the tests are designed in a way that minimizes the influence of other factors and allows for the test conditions to be reproduced.

#### 7.3.1 Equipment

The equipment required to conduct a series of CCTs is similar to the equipment required to perform the WBT. In addition, a sufficient quantity of food will be needed to conduct all of the tests. This is discussed in more detail below.

- **Fuel:** A homogeneous mix of air-dried fuel wood should be procured. Sufficient wood for all of the CCTs should be obtained ahead of time. Use local input to determine the quantity of fuel required to cook a “standard meal” on a traditional stove. Assume that each stove will be tested at least 3 times and allow for some margin of error. For example, if local people report that a standard meal requires ~2.5 kg of fuel wood and three stoves are to be tested, then the full range of tests will require

$$2.5 \frac{\text{kg}}{\text{meal}} \times 3 \text{ stoves} \times 3 \frac{\text{tests}}{\text{stove}} \times 2$$

The final factor of two is included to allow for aborted tests and other contingencies. This is roughly 45 kg of wood. As in the WBT, the fuel may be divided into pre-weighed bundles to save time during testing.

- **Food and water:** Testers should be sure they have sufficient food and water for the entire range of tests. Like fuel, the food should be homogenous so that variability in food does not bias the results of the test.
- **Cooking pot(s):** if possible, use the standard pots supplied with the testing kits. If the standard pots do not fit one or more of the stoves being tested, use the most appropriate pots and be sure to record the specifications in the Data and Calculation form. If possible, the same type (size, shape, and material) of pots should be used to test each stove. However, unlike the WBT, **lids should be used if local cooks commonly use them.**
- **Scale:** Supplied with testing kit: (at least 6 kg capacity and 1 gram accuracy): (see note in WBT section).
- Heat resistant pad to protect scale when weighing hot charcoal.
- Wood moisture meter
- Timer.

- Thermometer (this is only for recording ambient temperature – food temperatures are not recorded in this CCT).
- Small shovel/spatula to remove charcoal from stove for weighing.
- Dust pan for transferring charcoal.
- Metal tray to hold charcoal for weighing.
- Heat resistant gloves.

### 7.3.2 CCT Testing Procedure

The CCT described here is meant primarily to compare the performance of an improved stove to a traditional stove in a standardized cooking task. The procedure that follows should be applied to type of stove commonly in use in the community as well as the model or models of stove being promoted. Three repetitions of the CCT for each stove that is being compared are recommended.

1. The first step in conducting the CCT is to consult with people in the location where the stove or stoves are going to be introduced in order to choose an appropriate cooking task. This should be done well ahead of time, to ensure that sufficient food can be obtained to conduct all of the necessary tests.

- If the stove is designed for home use, then the task should be a typical meal consisting of foods that are regularly eaten in the community. It may include one or more dishes, though foods requiring complicated preparations should be avoided in the interest of time. In addition to the type of food, the testers and community participants must also decide on the precise quantity of food that is best representative of a typical family’s meal. This is critical to ensure that tests are uniform. If local measures are used, the testers should convert this into standard measurements and record these on the Data and Calculations form. The Box below shows an example of the food used for a CCT in West Africa (from Baldwin, 1987).
- If the stove is designed for specialized applications, for example making tortillas or chapati, then the cooking task requires less input and testers must simply decide on the exact amount of food on which to base the test.

Example of food used in a CCT (adapted from Baldwin, 1987, p. 94)		
<u>Dish</u>	<u>Ingredient</u>	<u>Quantity (g)</u>
Porridge	water	4000
	Millet flour	1000
Sauce:	oil	100
	meat	450
	tomatoes	300
	water	2500
	onions	70
	spices	50

- Once a cooking task has been decided on, ensure that sufficient food is available to conduct the tests.

2. After deciding on a cooking task, the procedure should be described in as much detail as possible and recorded in a way that both stove users and testers can understand and follow.

This is important to ensure that the cooking task is performed identically on each stove. If possible, include an objective measure of when the meal is “done”. In other words, it is preferable to define the end of the cooking task by an observable factor like “the skins come off the beans” rather than a subjective measure like “the sauce tastes right” (VITA, 1985, CCT Procedural note 2).

After sufficient ingredients and fuel have been obtained and the steps of the cooking task are written up and well understood by all participants, the actual testing can begin. **The cooking itself should be done by a local person who is familiar with both the meal that is being cooked and the operation of the stove to be tested.** If the stove is a new design that differs significantly from traditional cooking practices, some training will probably be required before conducting the actual tests.<sup>7</sup> When comparing stoves with the CCT, if more than one cook is used, each cook should test each stove the same number of times, in order to remove the cook as a potential source of bias in the tests. In addition, to ensure that the testers have control over the testing environment, the tests should be conducted in a controllable setting such as a lab or workshop rather than in a private home.

3. Record local conditions as instructed on the Data and Calculation form.
4. Weigh the predetermined ingredients and do all of the preparations (washing, peeling, cutting, etc) as described by the cooking directions recorded in step 2 above. To save time, for non-perishable food, the preparation can be done in bulk, so that food for all of the tests is prepared at once.
5. Start with a pre-weighed bundle of fuel that is roughly double the amount that local people consider necessary to complete the cooking task. Record the weight in the appropriate place on the Data and Calculation form.
6. Starting with a cool stove, allow the cook(s) to light the fire in a way that reflects local practices. Start the timer and record the time on the Data and Calculation form.
7. While the cook performs the cooking task, record any relevant observations and comments that the cook makes (for example, difficulties that they encounter, excessive heat, smoke, instability of the stove or pot, etc).
8. When the task is finished, record the time in the Data and Calculation form (see the comments on determining when the task is complete in step 2 above).
9. Remove the pot(s) of food from the stove and weigh each pot with its food on the balance. Record the weight in grams on the Data and Calculation form.
10. Remove the unburned wood from the fire and extinguish it. Knock the charcoal from the ends of the unburned wood. Weigh the unburned wood from the stove with the remaining wood from the original bundle. Place all of the charcoal in the designated tray and weigh this too. Record both measurements on the Data and Calculation form.

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<sup>7</sup> Of course, if a great deal of training is required in order for a local user to “master” the use of the stove, then the stove-testers should probably reconsider that particular stove design.

11. The test is now complete – you may now enjoy the food that was cooked or proceed by testing the next stove – each stove should be tested at least 3 times.

Note: this procedure only requires the use of **one standardized cooking task**. However, stove testers are encouraged to develop a CCT for several different cooking tasks – particularly if the communities where the stove is being promoted cook meals that are equally popular, but differ significantly in their specific cooking requirements (for example, one task that involves slow boiling and another task that involves frying).

### 7.3.3 Analysis

After each test, transfer data from the Data and Calculation forms into the software. Once three tests for each stove are complete, the software provides a value of specific consumption and total cooking for each individual test as well as an average of three tests for each stove. Once CCTs for two stoves are completed, the software will compare the results and test for statistical significance. In addition, any qualitative observations made during each test should be noted. Each data form contains space for qualitative observations to be recorded and summarized on the “Results” page.

### 7.3.4 Analysis of the CCT (Appendix 5)

The calculations produced by the Data and Calculation form are somewhat more straightforward than the calculations for the WBT. They are explained in **Error! Reference source not found.**

#### VARIABLES

As in the WBT, there are a number of variables that are directly measured. These include environmental variables and physical test parameters. The environmental variables may vary slightly from one test to another, but should be nearly constant. The physical test parameters should be constant for all tests.

#### **ENVIRONMENTAL VARIABLES:**

Wind conditions  
Air temperature

#### **PHYSICAL TEST PARAMETERS:**

Variable	Label
Avg dimensions of wood (centimeters)	--
Wood moisture content (% - wet basis)	m
Empty weight of Pot # 1 (grams)	P1
Empty weight of Pot # 2 (grams)	P2
Empty weight of Pot # 3 (grams)	P3
Empty weight of Pot # 4 (grams)	P4
Weight of container for char (grams)	k
Local boiling point of water (°C)	Tb

### 7.3.5 Measurements and Calculations

Upon finishing the test, a number of measurements are taken. These include:

Initial weight of fuelwood (wet basis) (grams)	$f_i$
Final weight of fuelwood (wet basis) (grams)	$f_f$
Weight of charcoal with container (grams)	$c_c$
The weight of each pot with cooked food (grams)	$P_{j_f}$ (j is an index for the cooking pot ranging from 1–4 depending on the number of pots used for cooking)
Start and finish times of cooking (minutes)	$t_i$ and $t_f$

These measurements are then used to calculate the following indicators of stove performance:

**Total weight of food cooked ( $W_f$ )** – this is the final weight of all food cooked; it is simply calculated by subtracting the weight of the empty pots from the pots and food after the cooking task is complete:

$$W_f = \sum_{j=1}^4 (P_{j_f} - P_j) \text{ where } j \text{ is an index for each pot (up to four).}$$

**Weight of char remaining ( $\Delta c_c$ )** – the mass of charcoal from within the stove, including the char removed from the ends of the unburned fuel that is extinguished just at the end of the cooking task. This is found by simple subtraction:

$$\Delta c_c = c_c - k$$

**Equivalent dry wood consumed ( $f_d$ )** – This is defined as for the WBT, adjusting for the amount of wood that was burned in order to account for two factors: (1) the wood that must be burned in order to vaporize moisture in the wood and (2) the amount of char remaining unburned after the cooking task is complete. The calculation is done in the following way:

$$f_d = (f_f - f_i) * (1 - (1.12 * m)) - 1.5 * \Delta c_c$$

**Specific fuel consumption (SC)** – This is the principal indicator of stove performance for the CCT. It tells the tester the quantity of fuel required to cook a given amount of food for the “standard cooking task”. It is calculated as a simple ratio of fuel to food:

$$SC = \frac{f_d}{W_f} * 1000$$

Notice this is reported in grams of fuel per *kilogram* food cooked, whereas  $W_f$  is reported in *grams*. Thus a factor of 1000 is included in the calculation.

**Total cooking time ( $\Delta t$ )** – This is also an important indicator of stove performance in the CCT. Depending on local conditions and individual preferences, stove users may value this indicator more or less than the fuel consumption indicator. This is calculated as a simple clock difference:

$$\Delta t = t_f - t_i$$

#### 7.4 STANDARD MEAL DETAILS

The CCTs were conducted using a standardized meal of rice and vegetables, which the Somali participants identified as representative of their cooking practices. The ingredients, quantities, and the cooking method are shown in Table A1.

**Table A1. CCT ingredients and cooking method**

<b>Ingredient</b>	<b>Initial Mass</b>	<b>Cooking Method</b>
Rice	1434 g	1. Fry the onion in the oil until soft and browned
Water	4158 g	2. Add fresh chopped tomatoes, bullion, spices, and salt
Tomatoes	330 g	3. Cook until fully blended
Tomato paste	65 g	4. Add tomato paste and a little water
Onion	66 g	5. Add remaining water
Oil	184 g	6. Bring to a boil
Jumbo (seasoning bullion)	41 g	7. Add washed rice
Garlic	37 g	8. Simmer until done
Spice	29 g	
Salt	3 g	

### 7.5 FUEL TYPE, PREPARATION, AND SIZE

The wood fuel was procured from local wood merchants. On the first day of the study in each of the settlements a donkey cart full of wood was delivered to the testing site. *Acacia reficiens* wood was used in Dagahaley and Ifo, and *Terminalia spp* was used in Hagadera.



#### Local wood merchant delivering wood to project site

Upon delivery, the wood was cut by women hired from the camp for this purpose into pieces of various sizes in order to accommodate the wood sizing requirements of all the stoves. . The wood was cut to a cross-sectional dimension of approximately 2 x 2 cm of various lengths. The cooks then chose wood pieces from the variably-sized pile as they desired to suit each stove. Table A2 below shows the approximate average wood size used for each stove type.

**Table A2. Wood sizing for each stove**

Stove	Envirofit & StoveTec	Vesto	Philips & Save80
Wood size	~2 x 2 x 40 cm	~2 x 2 x 20 cm	~2 x 2 x 15 cm
Photograph of wood sizing			

## 7.6 INSTRUMENTS & DATA MANAGEMENT

My Weigh digital scales (model 7001DX; 7 kg max and  $\pm 1$  gram accuracy) were used in this study. A multipoint calibration was performed on the scales in Berkeley, CA with the following certified weights just prior to the study: 200g, 1000 g, 1200g, 3000 g, 4000 g, 5000 g, 6000 g, and 6200 g. Table 3 below lists all instruments used in the study.

**Table A3. Instrument list**

Name	Description
My Weigh digital scales	Used to weight materials for tests
Delmorst Instrument Co. wood moisture meter	Used to measure wood moisture levels
Omega Engineering Inc. thermometer and probe (# HH11B)	Used to measure ambient air, food, and water temperature

For QA/QC purposes, the team conducted four practice CCTs, including quantitative measurements, structured observations, and user questionnaires, in Nairobi, Kenya, prior to departing for the Dadaab camp. This allowed them to check that all instruments were performing correctly and that all data collection tools were comprehensive and free of errors. The data from these tests was entered into the study database and used to check its readiness for the field. All data was entered by one member of the field team. All of the entered data was then checked by the other two field team members, where one read the entered information aloud and the other checked the accuracy of the information against the corresponding field data sheet.

**7.7 CONTROLLED COOKING TEST PLAN**

**Table A4. Summary of stove tests completed by each cook**

	Number of Tests per Cook per Stove:					
	Open fire	Envirofit	StoveTec	Philips	Vesto	Save80
<b>Dagahaley:</b>						
<b>Cook 1</b>	3	2	2	3	1	0
<b>Cook 2</b>	3	3	2	2	1	0
<b>Cook 3</b>	3	1	3	2	1	1
<b>Cook 4</b>	3	2	3	3	1	0
<b>Cook 5</b>	3	3	2	2	1	0
<b>Cook 6</b>	3	2	2	2	1	1
<b>Cook 19</b>	0	1	0	0	0	0
<b>Ifo:</b>						
<b>Cook 7</b>	3	3	1	2	1	1
<b>Cook 8</b>	3	2	3	3	1	1
<b>Cook 9</b>	3	2	2	2	1	2
<b>Cook 10</b>	3	2	2	2	1	2
<b>Cook 11</b>	3	3	2	3	1	1
<b>Cook 12</b>	3	2	3	2	1	1
<b>Hagadera:</b>						
<b>Cook 13</b>	3	2	1	2	2	2
<b>Cook 14</b>	3	2	1	2	2	2
<b>Cook 15</b>	3	2	2	1	2	2
<b>Cook 16</b>	3	1	2	2	2	2
<b>Cook 17</b>	3	2	2	1	2	2
<b>Cook 18</b>	3	1	2	2	2	2
<b>Cook 20</b>	0	0	1	0	0	0
<b>TOTAL</b>	54	38	38	38	24	22

Note: Cooks 19 and 20 were substitute cooks who only performed one stove each.

## 7.8 STRUCTURED OBSERVATION TOOL

### Structured Observation Data Sheet

This is designed to be completed 'real time' – i.e. during the observation, as the CCT progresses. Extra columns and rows are left blank in the tables to insert further issues which may arise during a particular observation.

#### A. BASIC DATA

<b>A.1</b> Date:	<b>A.2</b> Time:	<b>A.3</b> Location:
<b>A.4</b> Stove name:		<b>A.5</b> CCT number: (1, 2 or 3):
<b>A.6</b> Cook ID:		<b>A.7</b> Fieldworker name:

#### B. EVENTS LOGGING

<b>1. Fuel use Observables</b>	<b>B1.1</b> Refuelling	<b>B1.2</b> Near extinguishing	<b>B1.3</b> Relighting with match	<b>B1.4</b> Excessive blowing required to maintain fire
<b>Events Log</b> (tally/count incidents e.g. III)				
<b>Comments</b> (e.g. typical causes of incidents observed)				

<b>2. Stability Observables</b>	<b>B2.1</b> Pot slipped - clearly unstable without being held	<b>B2.2</b> Stove unstable and required adjustment	<b>B2.3</b> Skirt slipped?	<b>B2.4</b> Other
<b>Events Log</b> (tally)				
<b>Comments</b> (typical causes)				

<b>3. Smoke Output</b>	<b>B3.1</b> Particularly smoky period (e.g. at lighting)	<b>B3.2</b> Particularly clean burning period		
<b>Events Log</b> (tally)				
<b>Comments</b> (typical causes)				

**C. IMPRESSIONS**

**1. LEVEL OF CONFIDENCE AND EASE USING THE STOVE**

This reflects the observers' impression of how confident and comfortable the cook feels using the stove. **ONE** letter and **ONE** number should be noted, to describe both the apparent nature and the physical wellbeing of the cook.

**CODING SYSTEM**

	In Control	Tentative	Confused	Physically Relaxed	Physically Awkward	Physically Straining
<b>CODE:</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>1</b>	<b>2</b>	<b>3</b>

**DATA COLLECTION TABLE**

	Rank ( <b>ONE</b> letter and <b>ONE</b> number)	Comment (any supporting information/justification)
<b>C1.1</b> During lighting		
<b>C1.2</b> During cooking (related to cooking process & utensils)		
<b>C1.3</b> Tending the fire during cooking (related to the fire alone)		
<b>C1.4</b> Adjusting heat		
<b>C1.5</b> Take pot off and putting out fire		
<b>C1.6</b> Other: _____		

**D. COMMENTS**

**1. RECORD ANY COMMENTS THE COOK MAKES DURING THE TEST HERE:**

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## 7.9 USER SURVEY

### User Questionnaire

\* Note that this questionnaire can be directly completed by the cook or administered as an interview by a field worker. This questionnaire is designed to be completed by each cook for each stove tested.

Date:	Time:	Location:
Stove name:		CCT number: (1, 2, or 3):
Cook ID:		Fieldworker name:

1. Overall, do you think this stove is better, worse or the same as the stove you use every day?

[1 - better; 2 – the same; 3 – worse]

2. What are the best two aspects of the stove?

[1 – fast cooking; 2 – convenience; 3 – appearance;  
4 – less fuel used; 5 – less smoke; 6 - other]

2.1 If other, please describe:

3. What are the worst two aspects of the stove?

[1 – slow cooking; 2 – difficult to cook on; 3 – difficult to keep alight;  
4 – difficult to refuel; 5 – appearance; 6 – too much fuel used;  
7 – too much smoke; 8 - other]

3.1 If other, please describe:

4. After training, how easy was it for you to use the stove?

[1 – Very easy; 2 - fairly easy; 3 - fairly difficult; 4 - very difficult]

4.1 If 1 or 2: How could training be improved?

5. Did you have to change the way you usually cooked food to use the stove?

[1 – *yes*; 2 – *no*]

5.1 If yes, how?

---

6. Did you have to change the way you usually used fuel to use the stove?

[1 – *yes*; 2 – *no*]

6.1 If yes, how?

---

7. Does the food you have cooked with this stove taste any different?

[1 – *yes*; 2 – *no*]

7.1 If yes, how?

---

8. Do you think the stove is particularly unsuitable for cooking any particular food?

[1 – *yes*; 2 – *no*]

8.1 If yes, which?

---

9. Is the stove the right size for cooking meals?  [1 – *yes*; 2 – *no*]

9.1 If no: is it too large or too small?  [1 - *too large*; 2 – *too small*]

9.2 Please describe why you think this: Give details:

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10. Assuming you could afford it, would you buy this stove from the market?

[1 – yes; 2 – no]

10.1 If yes, why?

---

10.2 If no, why not?

---

11. Do you feel the stove is safe for you and your children?

[1 – yes; 2 – no]

11.1 If no, why not?

[1 – stove is unstable; 2 - risk of burn from the metal exterior; 3 - pot is loose so may spill; 4 – other]

11.2 If Other, describe:

---

12. Would you like to mention anything else like problems, concerns, benefits, difficulties etc to do with this stove?

*Give Details:*

---

13. Any other issues which the fieldworker considers require further examination not mentioned by the cook spontaneously (e.g. 'I noticed that the fire kept going out. Could you say why you think this happened?')

*Fieldworkers to use neutral language so as to minimise risk of leading questions.*

13.1.1 Question:

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13.1.2 Response:

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13.2.1 Question:

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13.2.2 Response:

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## 7.10 FOCUS GROUP DISCUSSION TEMPLATE

### Focus Group Discussions

At the end of the tests in each camp one focus group discussion will be held. The purpose of these discussions will be to invite the women to reflect on their experiences during the week and to draw some conclusions about which stoves they feel fit their needs best and least, and -- most importantly -- why.

#### KEY ROLES

##### *PARTICIPANTS*

Six is a minimum, but acceptable, number for an effective focus group discussion. Fieldworkers could consider including translators and others on a case by case basis if it was felt they would contribute to discussions (including being able to compare the range of stoves) without impeding the testers' willingness and ability to share their thoughts.

##### *FACILITATOR*

The focus group should be facilitated by an individual -- most probably a woman -- who speaks the local language and English, and has an easy relationship with the women. Ideally she should have previous experience of conducting such group discussions, and an understanding of their principles (i.e. open-ended but focused) and her role (i.e. facilitatory, not advisory). Most importantly, she should be skilled at listening, and watching the group for their reactions to various comments.

Fieldworkers will identify the facilitator for the focus group discussion during the week spent in each camp. Often someone from outside the community works best, so that any prevailing hierarchies or relationships would not impinge on the participants' freedom to speak and be honest.

If no such individual can be identified, the fieldworker will facilitate the discussion through the translator. According to prevailing cultural sensitivities, a female facilitator may be preferable.

##### *TRANSLATOR*

If necessary, the facilitator will be accompanied by a translator with a good command of the local language in which the discussions taking place, as well as English. The translator should also have a clear understanding of his/her role. Participants may be more comfortable with a female translator.

##### *FIELDWORKER*

The fieldworker present may also interject with questions, clarifications or thought-provoking questions, best addressed through the facilitator.

The fieldworker will be responsible for note taking during the focus group discussion. It is suggested that he/she take some time with the translator and/or facilitator at the end of the discussion, if possible, to ensure that all key points have been captured.

Again, to reduce the burden of note taking during discussions, the discussions could be recorded. Permission to record the conversations should be given beforehand by participants and facilitator, with a clear explanation of why recording is being requested.

## **PRACTICALITIES**

### *EXPLANATION AND INTRODUCTION*

Explain the purpose of the discussion, the roles individuals and facilitators have, and underline that there are no right or wrong answers. Put a time limit on discussions: one hour is probably reasonable.

### *STOVES*

One of each of the stoves tested during the week should be available during the discussion, to refresh users' memories, and to enable confirmation that users are referring to the correct stove, particularly in view of their diverse and unfamiliar names. In addition, it may be useful to have photos/diagrams of the stoves which could aid discussion.

### *LOCATION*

As always with a focus group, choose somewhere where discussions will remain undisturbed for the duration.

## **DISCUSSION TOPICS AND ACTIVITIES**

### *GENERAL DISCUSSIONS*

Discussions should be focused around a series of simple questions, including, for example:

- Overall, what features of the new stoves did you particularly value?
  - Why? (e.g. if time-saving was particularly valued, why is this important?)
- Overall, which features of the new stoves did you dislike?
  - Why?
- What differences if any did you experience whilst cooking on the new stoves in comparison to your traditional stove? What similarities are there, if any?
- If you could use one of these stoves in your home, would you want to? If yes, which stove and why? If yes, how would the way you prepare and cook food change? How would the way you obtain and prepare fuel change?

### *SEASONALITY*

The focus group discussion could also be a useful opportunity to discuss whether and how their cooking habits, location, fuels and diets vary during the year according to availability of foods and fuel, changes in the weather, and so on. In line with the overall objective of the study, it is important to keep discussions as focused as possible on if/ how these issues may affect their stove preferences.

- What has been your experience of using different stoves during this week?
- Does your cooking or wood use change over the course of the year?
  - If yes to either:
    - How?
    - Why?

- How do the seasons affect cooking?
  - specific questions on how for aspects affected
  - possibly prompt for other impacts (e.g. if they just say it affects food, ask if it also affects fuel and cooking location if you think this is likely to be relevant).

*[Fieldworker note: During the course of the week, it is likely that other prevailing issues will emerge which could also be introduced to this discussion.]*

#### ACTIVITY 1: RANKING THE STOVES

Using stoves themselves, or pictures of the stoves, invite participants to rank the stoves according to a number of criteria, including for example:

- overall performance
- most desired
- most convenient
- most fuel efficient

This can be done by giving each participant labels with the numbers 1 to 6 (1 for each stove, including traditional), and inviting them to place the 1 at the 'most' or 'best' (e.g. performance, desired, convenient etc.), down to 5 for the least. Stoves could be arranged in a line and participants be asked to stand in front of their top ranked stove according to various criteria.

The above variations will give a mix of resolutions of data (i.e. most favoured only, or ranked 1 to 5), but will also lend themselves either to enabling participants to give their individual opinions versus the group's opinion. Both have value.

*Going deeper:* Once the stoves are ranked, the facilitator can then question participants about choices, for example 'Why is this one better than this, why is this one worst of all, what makes this one particularly convenient/inconvenient, why do you rate that stove better overall than this despite worse efficiency?', and so on.

#### ACTIVITY 2: RANKING STOVE ATTRIBUTES

Using a set of clearly drawn/labelled cards (appropriate for literacy level of participants) participants will be requested to rank the following stove attributes according to their priorities:

- Uses less wood
- appearance
- speed of cooking
- ease of cooking
- safety
- less smoke
- others added during the week if appropriate

Participants will be invited to discuss their choices and decisions, and particular note should be made of any pertinent disagreements between participants.

*ACTIVITY 3: STOVE AWARDS*

Participants are invited to vote for the best stove with three labels/ribbons:

- Overall winner (e.g. gold label)
- \* Silver
- \* Bronze

\* The second and third awards will be decided after completing the previous activity, inviting participants to award stoves according to the top two ranked attributes.

Note, this will be an opportunity for women to express personal preferences, rather than reaching consensus.

7.11 FUEL EFFICIENCY RESULTS BY COOK AND STOVE FOR EACH CAMP

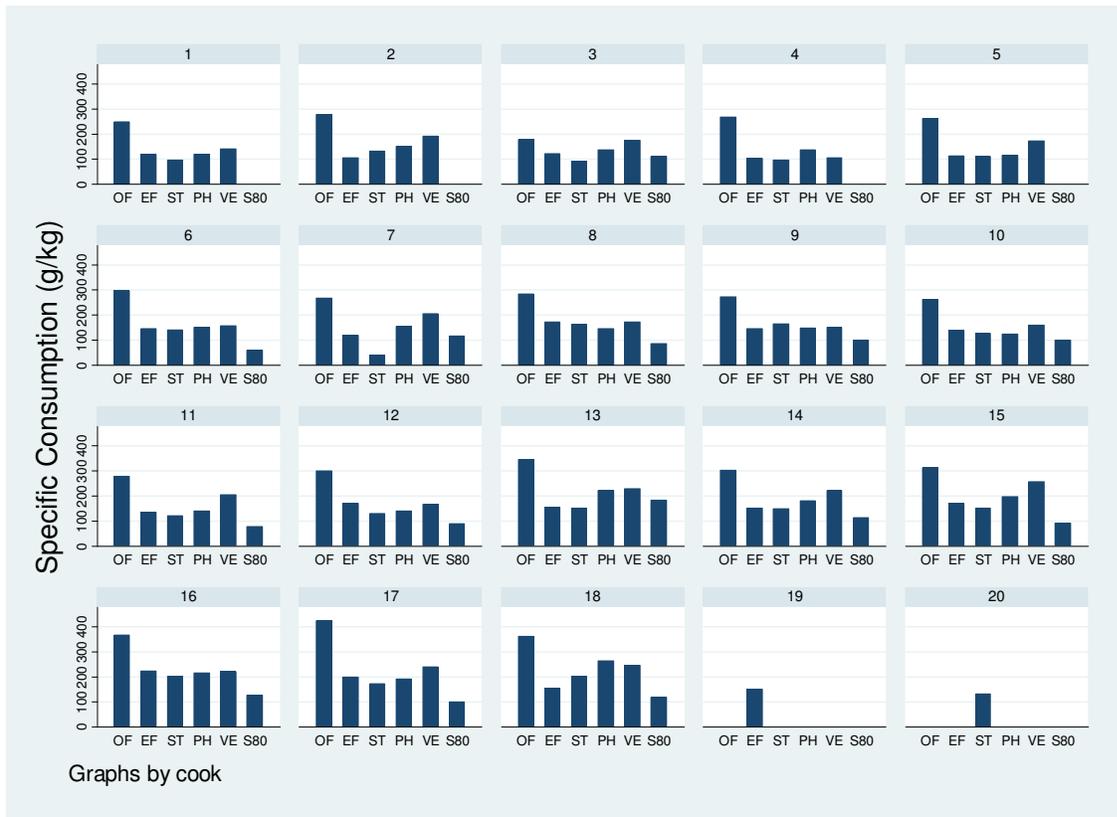


Figure A1. Average specific consumption (g/kg) for each stove type for each of the cooks.

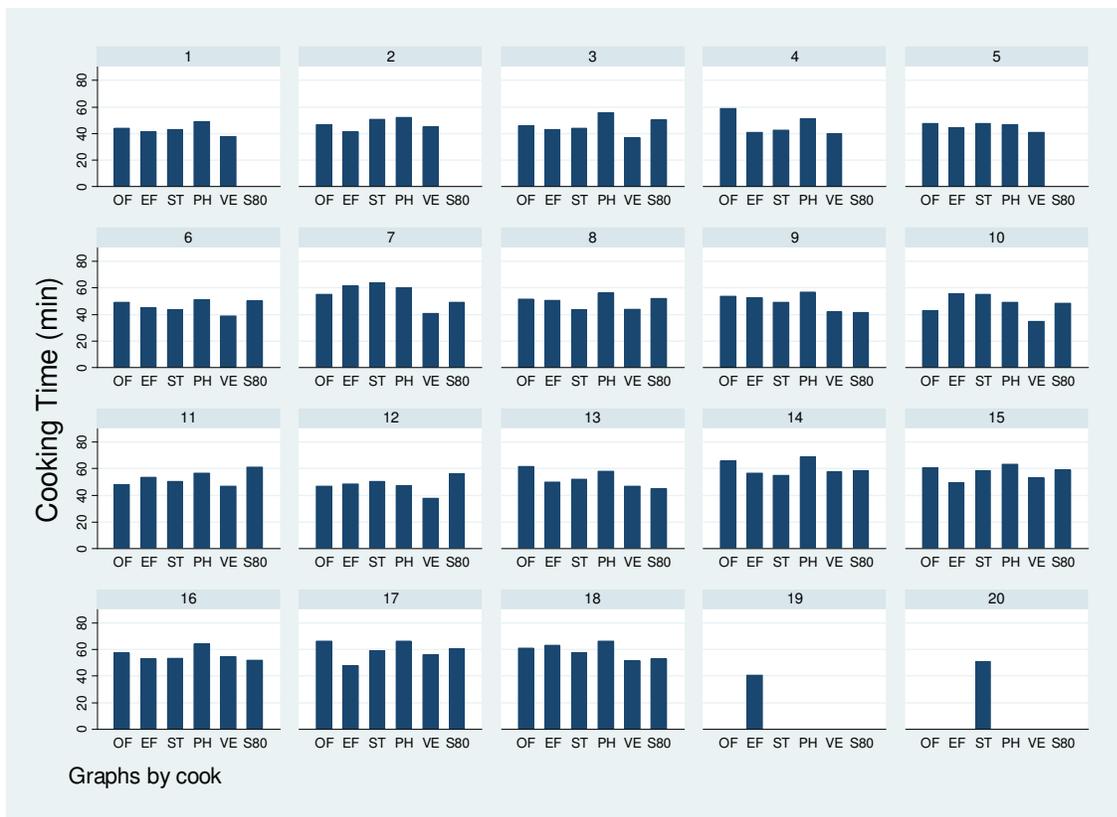
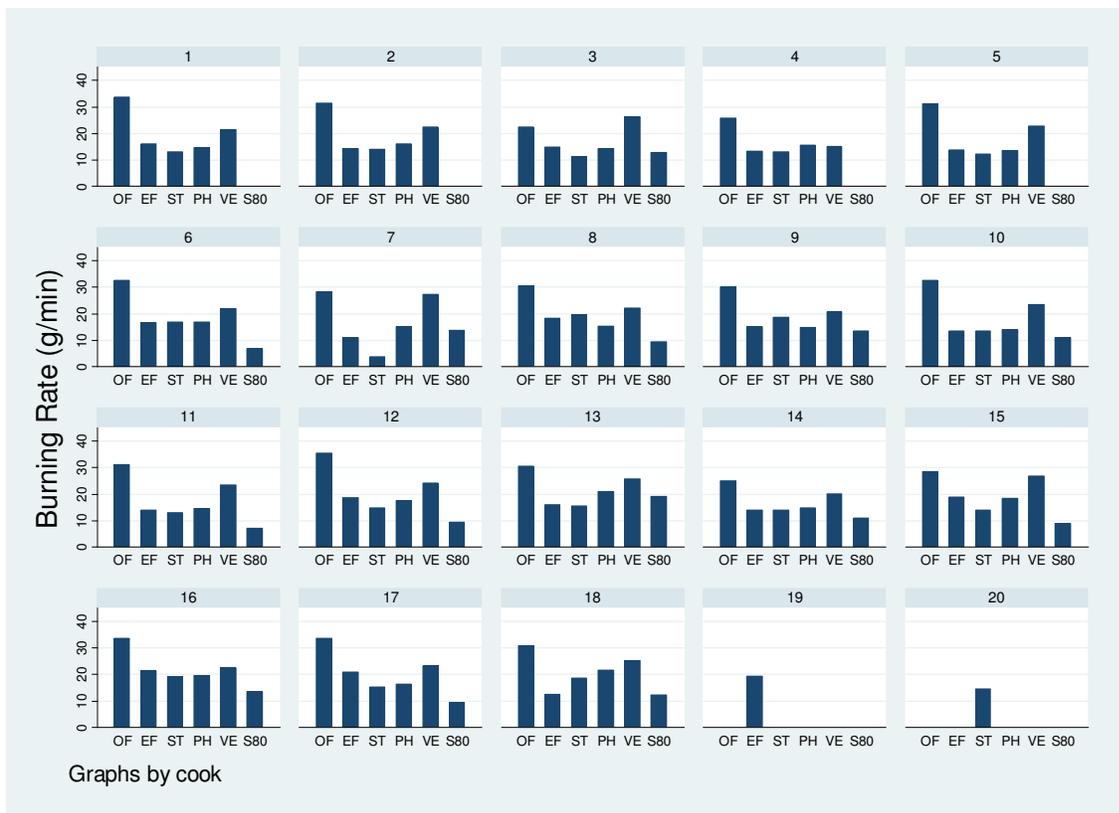


Figure A2. Average cooking time (minutes) for each stove type for each of the cooks.



**Figure A3. Average burning rate (g wood used per minute) for each stove type for each of the cooks.**