# Lessons Learned from a Comparison Study of Charcoal Stoves for Haiti

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**Abstract:** Biomass is the predominant cooking fuel in Haiti, where it creates burdens on both the environment and the Haitian people. Following the 2010 earthquake in Port-au-Prince, the need for fuel-efficient cookstoves was acute. Although several organizations were quite interested in dissemination of fuel-efficient stoves in the relief effort, there was little knowledge about the performance and usability of the proposed stoves. To help fill the knowledge gap, stove researchers from Lawrence Berkeley National Laboratory evaluated and compared the performance of several cookstoves intended for dissemination in Haiti. This paper discusses the decisions made throughout the course of that work, from project identification and approach through the dissemination of results. It identifies the challenges faced and how they were addressed, while briefly presenting the data from stove performance evaluated using Water Boiling and Controlled Cooking Tests. It also highlights the importance and benefits of evaluating technologies such as cookstoves prior to dissemination, even in urgent disaster relief situations.

**Keywords:** Charcoal cookstoves, Haiti, Cookstove evaluation

**Full Paper**

## 1. Introduction and Background

Most of the ten million people of Haiti use solid fuels, primarily wood and charcoal, for cooking and heating, with the combustion of biomass equaling an estimated 70% of Haiti's annual energy use (Nexant, Inc. 2010). Cooking with solid fuels has vast global consequences as approximately 3 billion people worldwide cook with such fuels (WHO 2014). Exposure to emissions from these fires causes an estimated 4.3 million premature deaths annually, primarily of female cooks and children who tend to be more often around the cooking fires (Lim et al. 2013). Besides such major human health concerns, biomass cooking contributes to environmental damages such as deforestation and global climate change. Charcoal is an especially wood-intensive fuel as wood is typically used not only as the base material for the charcoal but also is burned to produce the heat necessary to convert wood into charcoal. The unsustainable harvesting of wood and production of charcoal over several years has substantially contributed to widespread deforestation in Haiti; in 1923, 60% of Haiti was forested, but by 2009 only 2% of the forests remained (Hubbell 2013; Lim et al. 2013; Highwood and Kinnersley 2006; Nexant, Inc. 2010). Charcoal for cooking also imposes a large economic burden on Haitians with families spending a significant portion of their income on cooking fuel. For example, in Port-au-Prince, a marmite (a local definition of the amount of charcoal needed to cook roughly half a day's worth of food) costs approximately 0.50 USD in the retail market, while the gross national income per capita is only about 760 USD (UNICEF 2012).

A devastating earthquake rendered approximately 1.5 million Haitians homeless in January 2010 (Yonetani 2011). Owing to the significant economic burden on the survivors of procuring cooking fuel, many organizations, such as USAID, the Women's Refugee Committee, and the World Food Programme, called for the deployment of fuel-efficient cookstoves as an essential part of the relief efforts in Haiti (Nexant, Inc. 2010; WRC 2010).

## 2. Identification of Project Needs

Lawrence Berkeley National Lab (LBNL) had begun working with cookstoves in 2004, focusing on reducing the fuel consumption necessary for cooking in Internally Displaced Persons (IDP) camps in the Darfur region of Sudan. Using the science and engineering resources of a national laboratory and feedback and information from organizations and users in Darfur, the LBNL stove lab developed a new stove for the region that greatly reduced the fuel necessary for cooking (Jetter 2012; Preble 2014). This process required several iterations of scientifically rigorous design and testing at LBNL and feedback from trials in the Darfuri IDP camps. Even working as quickly as possible, the process from an initial field visit (2005) to the production of first 1000 stoves of fully mature design (2009) took four years.

Because of this prior experience developing a stove for a difficult relief situation, a team from LBNL responded to the call for fuel-efficient cookstoves in post-earthquake Haiti by undertaking a fact-finding mission to Haiti in April 2010 to evaluate the current stove use situation and identify what, if any, stove development project LBNL should undertake to assist the Haitian relief efforts.

The team discovered extensive interest from non-government organizations (NGOs) in stove dissemination projects and found there were already several stoves under development or available to be disseminated to Haiti. To gain more information about Haitian cooking practices and the stoves available in Port-au-Prince, the LBNL team interviewed dozens of local cooks; observed cooking in markets, homes, and IDP camps; and conducted a cook-off in which local cooks simultaneously prepared the same meal on multiple stoves, both traditional and improved. Based on observations from this cook-off and the interviews with Haitian cooks, the team determined that neither the dissemination of the Berkeley-Darfur Stove in its current form, nor its adaptation for Haiti would be the best use of LBNL's time and resources.

However, it was apparent to the team that there was reason to question whether the models of improved stoves intended for distribution in Haiti would actually operate efficiently and meet the needs of Haitian cooks. Cookstove distributors and NGOs had little or no data on the performance of most of the stoves and had neither the time nor the expertise and instrumentation to conduct experiments to determine the most appropriate stoves. This meant that relief organizations were distributing cookstoves without knowledge of their effectiveness or potential impact.

Without this information, there was a strong risk that the cookstoves intended for distribution by NGOs would not produce the desired economic and environmental benefits due to either rejection by the local populace or inability to reduce emissions and fuel consumption. Cookstove adoption is notoriously tricky because cuisine, equipment, and cooking methods tend to be both highly localized and culturally significant; the history of cookstove intervention projects is rife with failure. Perhaps because they appear to be simple or "mundane" technologies (Kammen 1997), it is common to underestimate the difficulty in developing biomass cookstoves that are culturally appropriate and high-performing from the perspectives of both NGOs and local users. As with many technologies, if a cookstove is not adapted for local customs and does not offer clear improvements over familiar, traditional stoves in the metrics important to local cooks, it is unlikely to be adopted and used.

Due to LBNL's background in rigorously testing cookstoves for Darfur, the LBNL stove lab was well-positioned to fill this information gap by providing unbiased evaluations of the performance and usability of various proposed stoves so distributing organizations could make well-informed decisions about which technologies to deploy. The evaluations would characterize the performance of the stoves in terms of efficiency, emissions, and cultural appropriateness. Given the critical situation in Haiti, however, the evaluations had to be completed under the pressure of time, so results could be communicated rapidly to stove distributors and enable them to procure and disseminate the stoves of their choice in a timely manner.

## 3. Cookstove Evaluation

To meet this timeframe and to provide information that could inform the decisions being made by the NGOs operating in Haiti, compromises had to be made when selecting stoves and choosing metrics to measure and report. Concurrently, new protocols had to be developed to ensure results were applicable to the Haitian stove situation.

### 3.1 Stoves Evaluated

NGOs were organizing both short-term relief and long-term rebuilding dissemination efforts. We decided to focus on stoves intended for short-term relief efforts, limiting the choice to models that were already available in Port-au-Prince or being considered for relief-operations distribution in Haiti. There would be time and opportunity to assess stoves under development for long-term dissemination at a later date. The final stoves were chosen based on their timely availability and included a traditional Haitian stove for comparison.

### 3.2 Measurement Criteria

Only attributes expected to have the largest impact on cookstove adoption and environmental and economic benefits were chosen for evaluating the stoves. This enabled results to be collected quickly, while still being meaningful. To ensure that the results would accurately portray the stoves' usability and be useful for organizations on the ground in Haiti, the stove team solicited input from Haitian cooks and distributing NGOs on which metrics were most important to them and incorporated those into the testing. The LBNL observation team had learned that the largest concerns for Haitian users were the amount of fuel and time required to complete a cooking task. Distributing NGOs were also interested to know the fuel consumption as well as other indicators of performance such as efficiency and emissions to understand the environmental impacts of the stoves.

Therefore, the metrics chosen for evaluation included the amount of fuel and time required to complete a cooking task, thermal efficiency, and the emission of carbon monoxide (CO). CO is a known major pollutant emitted from charcoal fires; other emissions, such as soot, were not chosen because charcoal fires produce relatively few particles compared to CO emissions and neither the NGOs nor users expressed concern with those pollutants.

**3.3 Protocol Development**

The standard international test for cookstove comparisons is the Water Boiling Test (WBT), which centers on boiling and simmering water (Bailis 2007; GACC 2013). The WBT was used for the first round of stove testing, primarily to evaluate differences in cooking times and efficiencies. Often a WBT is not representative of local cooking practices, however, so results can be quite different when cooking real food, both in terms of performance and usability.

Cooking an actual meal typically requires different cooking styles than those outlined by the WBT, which can lead to errors in the WBT estimates of thermal efficiency; for example, frying food requires much higher temperatures and thermal power than would be estimated by the WBT. In addition, the WBT does not take into consideration if a stove is even capable of cooking the desired meals; for example, if the cultural cooking style requires using large pots, a stove intended for the region should be able to support a large pot and produce enough heat to evenly warm the contents, a characteristic that cannot be captured by boiling water with temperature measured at a single point as is done in the WBT.

Therefore, the development of a second protocol, the Controlled Cooking Test (CCT), was necessary to simulate a more realistic cooking cycle for testing. A CCT mimics the cooking of specific cultural dishes using a scientifically-repeatable protocol. No CCT protocol existed for Haitian cooking prior to these trials, so an entirely new CCT had to be developed. From the field visit and detailed discussions with organizations that had worked extensively with the Haitian population, it was apparent that a meal of rice and beans, called *diri kole ak pwa*, was prepared regularly throughout Port-au-Prince so would serve as a good example of the Haitian cooking style on which to center the CCT. Based on observational notes and conversations with Haitian cooks and organizations working in the field, the observed cooking methods for *diri kole ak pwa* were turned into a scientifically-rigorous, repeatable, lab-based test protocol used for the second round of testing.

For both the WBT and CCT, the cooking pots used were common, traditional Haitian pots purchased in Port-au-Prince, as those would be the same pots used by cooks in the field and they could easily be transported back to LBNL. Importing adequate quantities of Haitian charcoal, however, was deemed impractical, especially under the time constraints. Therefore, the charcoal used for testing was an all-natural lump charcoal, locally-acquired in Northern California, which was produced in a similar fashion to Haitian charcoal and broken to a similar size and shape.

**4. Results of the Case Study**

Clear differences in performance and usability, both positive and negative, were seen between the stoves in the results of the WBT, CCT, and the in-country cook-off.

**4.1 Performance and Emissions Results**

Results of the evaluations found that all of the potential stoves to be disseminated that were tested did, to varying degrees, consume less fuel, improve thermal efficiency, and emit less CO than the traditional stove, on average. This made them look advantageous for the distributing NGOs. However, the improved stoves boiled water much more slowly than the traditional stove, which could be problematic for their adoption because cooking time is a stove characteristic that was observed to be equally or more important to users than fuel efficiency.

To illustrate the disparity between cooking time performance and the other evaluated metrics, results from the traditional stove are shown in Table 4.1.1 along with results from the second fastest stove. Note, as the CCT is a time-constrained test, values for thermal efficiency and cooking time were calculated using the WBT results. In the cold start phase of the WBT, the cooking time is estimated using the time to boil, which is the amount of time necessary to bring room temperature water to a boil using a pot and stove that are initially at room temperature as well. Specific fuel consumption (calculated as grams of fuel used per kilogram of food cooked) and CO emissions are reported from the CCT results as that protocol better represents Haitian cooking practices.

In Table 4.1.1, it can be seen that across all metrics of thermal efficiency, specific fuel consumption, and total emitted CO, the proposed stove is indeed an improvement over the traditional stove, reducing fuel consumption and CO emissions by roughly 50% and increasing efficiency by 1/3, on average. However, the traditional stove brings water to boil 15 minutes faster, on average, than the next fastest stove – a result that would definitely be noticeable to and disliked by a stove user that primarily values time savings. These results highlight the fact that although the improved stove meets all of the NGO expectations for an improved stove, further consideration needs to be taken to provide the users with a stove that will cook at least as quickly as the traditional and therefore have a better likelihood of adoption.

*Table 4.1.1: Example results from the WBT and CCT trials for the traditional stove and an improved stove. Although the improved stove outperforms the traditional stove in fuel consumption, efficiency, and emissions, the traditional stove boils water much faster, which could lead to user adoption issues. Estimated error represents a 95% confidence interval.*

| | Traditional Stove | Improved Stove |
|---|---|---|
| Time to Boil (min) – WBT | 32.4 ± 10.8 | 47.4 ± 9.4 |
| Thermal Efficiency (%) – WBT | 23.7 ± 4.2 | 37.8 ± 5.9 |
| Specific Fuel Consumption (g/kg) – CCT | 144.8 ± 19.1 | 77.4 ± 10.9 |
| CO Emissions (g) – CCT | 127.6 ± 15.5 | 69.0 ± 20.4 |

For in-depth descriptions and values of all of the performance and emissions results, kindly refer to Booker et al. (2011), Lask et al. (2011), and Lask et al. (2015).

**4.2 Usability Results**

Another important result of this study was the assessment of the stoves' usability for Haitian cooking, both by lab testers and local cooks.

The usability results show that some of the cookstoves intended for distribution were not well-suited for making the sample dish of *diri kole ak pwa,* especially for evenly cooking the rice portion of the meal. This indicated that while all of the improved stoves that were tested had the technical capability to meet the NGO goals regarding environmental and human health, the improved stoves had usability issues that posed potential barriers to adoption. In order to achieve the wide-spread acceptance and daily use necessary to actually produce impact, these barriers would have to be overcome, either by redesigning some aspects of the stoves or through efforts to change local cooking styles or behavior.

During the locally-conducted cook-off, the Haitian cooks reported sometimes significant difficulties with the improved stoves including an inability to manipulate the charcoal to adjust the heat (i.e., thermal power), the difficulty of balancing large pots used in Haitian cooking on the stoves, and an uneven cooking of the rice such that the middle burned and the edges were left uncooked. One stove, for example, required users to remove the pot and turn the stove upside-down to shake out burning charcoal in order to lower the heat enough to simmer the rice, a major inconvenience and potential danger (Booker et al. 2010).

Feedback from the cook-off as well as interviews with Haitian cooks produced a list of several key physical attributes desired in a good Haitian cookstove, including: an ash pan that could be easily emptied either by removal or by picking up the stove and shaking out ashes, the capacity to stably support large pots and cook contents evenly, an accessible charcoal bed so coals could be easily rearranged or removed to adjust heat, the capacity to hold enough charcoal to cook for an extended period without refueling, and a cost comparable to current stoves in the field (cooks estimated they would pay 250 gourdes, or approximately 4.25 USD).

After using the stoves for several months, laboratory stove testers further evaluated the usability of the improved stoves, focusing on the traits identified by the Haitian cooks as well as generally accepted traits such as mechanical stability and durability. These evaluations supported the results from the in-country cook-off, pointing out several weaknesses in the improved stoves in comparison to the traditional stove. These included the inability to cook in large pots and ease of adjusting the charcoal bed while cooking. Such weaknesses could make the improved stoves less desirable and useful to Haitian cooks, as compared to the traditional stoves, indicating adoption of the improved stoves would be unlikely.

**4.3 Filling the Gap: Communicating results to stakeholders and increasing likelihood of success**
The usability observations, along with the WBT and CCT results, were quickly reported to stakeholders, such as stove manufacturers and distributing organizations. We hoped that rapidly disseminating the evaluations directly to stakeholders would increase the likelihood that stoves intended for Haitians would be well-chosen in terms of performance and cultural acceptability and also enable stove producers to adjust their designs, improving future stove acceptability and reducing the long-term economic, environmental, and health-related burdens of biomass cooking in Haiti.

At the same time, while the differences found in performance and usability between the evaluated stoves provided crucial information to stakeholders to guide their distribution efforts, they also illuminated the necessity of testing stoves and collecting user feedback, even in disaster relief situations, to ensure that the technologies to be disseminated are both high-performing and likely to be adopted by the local population. A coordinating body or institution which dedicates itself to technology evaluation, rather than deployment, in such situations provides a valuable and essential service for relief organizations. Without testing and user feedback to guide their choices, relief NGOs were distributing cookstoves blindly. While that may have seemed optimal or necessary at the time, given the scope of the disaster, deploying technologies that will never be used or adopted is a waste of valuable relief dollars and effort.

In this particular disaster relief case, LBNL researchers identified the information gap and need for stove evaluation, and thus pivoted from technology development and deployment to technology evaluation in order to fill the role where they could provide the most beneficial service. The results from the WBT, CCT, and in-country observations and interviews show that testing priorities can be identified and protocols outlined to ensure that evaluations are completed rapidly and results are disseminated quickly to stakeholders so NGOs and government actors can ensure deployed technologies are useful to the population they are trying to assist.

**5. Development Impact**
Although this study is specific to Haitian stoves, the challenges faced are universal across humanitarian technology projects, especially in disaster relief scenarios. Such complexities include:

- Quickly assessing a disaster relief situation and identifying the most useful contribution from an organization, which might not be providing a hard technology but providing other services necessary to ensuring the technologies are useful and likely to be adopted
- Deciding what to prioritize when choosing metrics and experimental parameters to rapidly meet goals
- Evaluating a technology when there is no culturally-relevant, standard methodology and producing practically useful outputs

By discussing the methods and logic used in this project to address these complications, it is hoped the experience can inspire and enable others to readily face technological project challenges for disaster relief situations. In particular, this case study demonstrates the importance of technology evaluation, even in time-constrained, disaster relief situations; the need to incorporate and prioritize the desires of technology disseminators and users; and the potentially critical role for institutions to play in filling gaps related to the “soft” sides of technologies.

**5.1 The Need for Technology Evaluation in Disaster Relief**
The lessons from this case study argue for the need to evaluate the performance and cultural acceptability of technologies known to have high rates of non-adoption prior to dissemination, even in time-constrained, disaster relief situations. While the immediacy and enormity of the work to be done post-disaster may lead NGOs to prioritize rapid dissemination, it was found, at least in the case of cookstoves, that impulse appears to be misguided. Improved cookstoves have the potential to reduce the negative effects of cooking on human health and the environment and save users money that can be applied to other critical needs; however, all of these benefits are contingent upon actual use of the stove. The most beneficial technology will still have no impact if the intended community does not use it. While a few interventions exist that are universal or simple enough to be adopted by those in need without modification, most require evaluation and adaptation to the culture in order to be successful. Because the histories of many disseminated technologies, including cookstoves, provide ample evidence that adoption is complicated and cannot be assumed, the need for this kind of evaluation is generally accepted by the development community for long-term projects. This case study, however, indicates the need for evaluation goes a step further and remains necessary, at least for some technologies, even in critical disaster situations.

**5.2 Prioritization of Performance Metrics**
In order to evaluate a technology in disaster relief situations, it is important to first identify the key parameters valued by both the organizations disseminating the technology and the users who must adopt it. Often, the desired characteristics by disseminators and users do not overlap perfectly. In this case, the NGOs valued fuel

consumption, emissions reductions, and efficiency gains, while users valued speed of cooking, fuel consumption, and the ability to cook the desired foods to the standards they were used to. A stove that did not meet the NGOs' requirements would not be chosen for dissemination; a stove that did not meet the Haitian cooks' requirements would not be adopted and used. At the same time, the evaluations needed to be done quickly to be beneficial for the short-term relief efforts. Therefore, in prioritizing the parameters measured in a rapid evaluation, the protocols and metrics needed to reflect only the most important parameters to those groups in the immediate time frame.

This prioritization meant doing away with testing for other emissions, such as soot and methane, even though those results would be helpful to the broader development and scientific communities. Similarly, the LBNL team did not test for durability, which would matter to users over the course of years but requires either highly specific facilities or an extended period of time and was not identified by users as a critical feature. In a rapid assessment for a disaster relief situation, all aspects of a technology simply cannot be evaluated – it is therefore extremely important to gain feedback from the stakeholders to identify the key, necessary parameters that are required for the technology to be successful. Other parameters can then be evaluated once the time constraints of the disaster situation have dissipated.

### 5.3 Institutions to Fill Gaps Related to the "Soft" Side of Technologies

Finally, this case points to the importance of institutional actors who are focused on "softer" aspects of technology development and distribution, such as unbiased lab testing, field evaluation, supply chains, and user engagement and education that help ensure technologies produce the intended impact. Realizing that relief NGOs would benefit from an unbiased assessment of potential stoves, instead of producing another stove, provided LBNL with an excellent opportunity to contribute this critical service, outside of its normal realm of technology development. Recognizing the numerous aspects of technology development, distribution, and adoption that are required for a technology to be successful, this work highlights a useful contribution that organizations can provide to relief efforts besides solely creating technologies and suggests the need for institutional actors to either be ready to step into this role when needed or to specialize in providing these services in disaster relief situations.

## 6. Future Work

Because this study was conducted under the pressure of time in order to quickly provide useful results to stakeholders prior to planned disseminations, there is still much future work to be conducted. Several more stoves are available in Haiti and should be evaluated for their performance and emissions outputs. Although the time is beyond short-term relief efforts, long-term dissemination efforts are ongoing and could benefit from such knowledge. Also, the stoves deployed for short-term relief efforts should be examined to evaluate durability and signs of continued use (such as discoloration and ashes) in order to evaluate long-term effects and practicality in the field before the deployment of stoves intended for long-term relief and rebuilding efforts.

Additional evaluation parameters, such as particulate matter emissions, should be explored to provide a complete view of stove performance and its impacts on human health and the environment. Although CO is emitted in much larger quantities from charcoal fires than soot and other emissions, particulate matter has been found to be extremely detrimental to human health so would be a useful metric in future stove evaluation (Peters et al. 1997; MacNee and Donaldson 2003).

Finally, a searchable database of cookstoves with pertinent performance information has been created by the Global Alliance for Clean Cookstoves and is a huge step forward in filling the information gap in this field. However, despite the large numbers and variety of cookstoves being designed and disseminated throughout the world, many stove evaluations have yet to be conducted and shared through this resource. As this database grows, a better understanding and characterization of which technologies have and can be successfully disseminated worldwide will form and provide useful guidance for NGOs operating in both relief and rebuilding situations. Along this line, additional work outside of Haiti could include assessing regional cuisines and proactively creating CCTs for areas that are known to have high biomass use so if such a disaster or similar situation occurs in those areas, assessments can begin more quickly.

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