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## Smoke Signals: An Investigation of the Effects of Eco-stoves on Community and the Environment

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**Smoke Signals:  
An Investigation of the Effects of Eco-stoves on Community and the Environment**

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**Abstract**

The use of solid biomass fuels and the implementation of eco-stoves to mitigate its harmful effects has become a popular topic in discussions on global development. An article published on use of traditional fuels in *The New Yorker* reports, “A map of the world’s poor is easy to make...just follow the smoke.”<sup>1</sup> Eco-stoves are now being constructed in impoverished communities around the world as an alternative to traditional stove models as a means to improve health and overall quality of life. Global Brigades, a sustainable development NGO, has been working in communities in rural Honduras to construct an eco-stove model called an *Estufa Justa*. This article pertains to a research project designed to evaluate household satisfaction with this new stove model, the stove’s efficiency, and the effect that installing these stoves has had on community dynamic. The methodology included a combination of qualitative and quantitative methods. Using the data obtained from this study, it can be concluded that the Global Brigades model is more efficient and has a higher satisfaction rate among users compared to the traditional *fogón* models currently in use and that the installation of stoves has had a positive impact on community dynamic.

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<sup>1</sup> Bilger, B. (21 Dec 2009). *Hearth surgery*. *The New Yorker*, 84-97.

## Introduction & Literature Review

### *Overview of Biomass Fuel Use and its Impacts*

Defined as “organic nonfossil material of biological origin that may be used as fuel to produce heat or generate electricity,” solid biomass most often comes in the form of wood, dung, or charcoal.<sup>i</sup> The International Energy Agency estimates that more than 2.5 billion people across the globe rely on biomass as their primary fuel, and the majority of use is concentrated in developing countries.<sup>ii</sup> Biomass fuel is most often incorporated into traditional use—for cooking and heating, mainly in domestic settings using open fires or self-constructed stoves.<sup>iii</sup>

Traditional use is strongly tied to poverty. Transition theory holds that, “households gradually ascend an 'energy ladder', which begins with traditional biomass fuels (firewood and charcoal), moves through modern commercial fuels (kerosene and liquid petroleum gas (LPG)) and culminates with the advent of electricity.”<sup>iv</sup> Progression through this energy ladder is linked to rising income and growing levels of urbanization. Given the position of biomass fuels in this model of development, their usage has become a popular topic in discussion on poverty eradication and improving quality of life.

Traditional biomass fuel use is also increasingly recognized as a contributor to indoor and outdoor air pollution in discussions on global health and climate change. Its role is evident as we see industrialized regions, such as those of the Organization for Economic Co-operation and Development (OECD), experiencing a gradual decline in emissions, while developing countries in regions such as Africa and South Asia continue to generate black-carbon emissions at high levels. In these developing regions, small-scale biomass combustion accounts for 65% of emissions.<sup>v</sup>

Such emissions have implications for human health. Wood smoke releases a number of harmful environmental toxins, including formaldehyde, dioxin, styrene, butadiene, benzene, and methylene chloride.<sup>vi</sup> These toxins are linked to numerous diseases, including pneumonia, emphysema, cancers, cardiac arrhythmias, and heart disease.<sup>vii</sup>

Emissions from solid biomass fuels are the fourth largest contributor to the disease burden of developing countries.<sup>viii</sup> Such indoor air pollution (IAP) is linked to between 1.5 and 2 million deaths annually, accounting for around 4-5% of total mortality worldwide.<sup>ix</sup> This cost to human life is significant, and could have widespread repercussions for the economies and general wellbeing of those countries most affected by indoor air pollution. Of those

experiencing premature death and disability, women and children are overwhelmingly impacted. A 2007 World Health Organization investigation into the impact of solid biomass fuels on indoor air quality and health found that exposure to IAP from biomass fuels is associated with numerous diseases, ranging from cardiovascular disease to perinatal health outcomes and acute and chronic respiratory conditions.<sup>x</sup>

Though health impacts have become the focus of solid biomass fuel use in recent years, the original focus of research and intervention on household energy in developing countries was on deforestation and desertification.<sup>xi</sup> Ethiopia, for instance, has lost more than 90% of its forests since the 1960s, a reduction attributed to the use of inefficient stoves in large-scale women's cooperatives to produce their traditional *injera* dish.<sup>xii</sup> As Cushion explains, "Increased demand for biomass could result in forest conversion, deforestation, and forest degradation, particularly where biomass waste is not readily available as an option and there is little degraded land available for planting (as is the case where population density is high)."<sup>xiii</sup> Honduras, too, has been impacted by deforestation, evident through the numerous mudslides that have occurred in the country in recent years. These repercussions, coupled with the significant impacts on human health, make solid biomass fuel use an immediately pressing topic to address.

### *Prior Stove Intervention Studies*

Numerous strategies focused upon mitigating the negative health and environmental impacts of solid biomass fuel use have been proposed and implemented. While some exhibit great potential, others have failed as they neglect the multitudinous factors shaping and propelling the use of biomass fuel in different communities across different regions of the developing world. Thus, a purpose of this study was to better explore and gain insight into the relationship between the behavioral, cultural, and technological factors that facilitate or impede the adoption of new stove models in rural, resource-poor settings.

On the most general level is the challenge of effecting behavioral change. As Baron explains, "Reducing black carbon emissions in developing countries *relies upon the actions of millions of people* that live in poverty. Changing behavioral patterns of such a vast number of people requires policy approaches that are realistic, affordable, and sustainable."<sup>xiv</sup> When improved cook-stoves that meet the user's needs are implemented, behavioral change may remain difficult. This was found in a study conducted in San Lorenzo, Guatemala, where people saw the smoke from domestic biomass fuels as more of a bother than a threat to their health.<sup>xv</sup>

Thus, a key research question for this study was to assess to what extent health concerns motivated people to replace their traditional stove with a GB stove.

A limited understanding of the real conditions under which the stove will be used has hindered the success of projects as well. Although researchers and stovemakers work painstakingly to perfect a design that will maximize combustion efficiency while minimizing emissions, such technologies are piloted in controlled environments. Testing under conditions so drastically different to those encountered in daily life for the people who will ultimately use the stoves has meant a neglect of “the various social and physical factors that would limit the use of these stoves altogether or result in „suboptimal“ performance.”<sup>xvi</sup> It is in light of this that the protocol of this study was designed so as to observe stove use in the home setting, where it is used on a daily basis.

An especially important aspect that has challenged the acceptance of improved stoves and technologies is their ability to create the cuisine characteristic of the local area in which they have been introduced. As Baron explains, “Traditional cooking using open burning does result in some of the taste inherent in the food. A move towards other means of cooking would need to overcome any cultural barriers.”<sup>xvii</sup> This contextual importance has been observed particularly in attempts to transfer interventions that have proved successful in one setting to other regions. In Ethiopia, attempts to replace the traditional ceramic *mitad* with a steel cooking surface originally introduced in Latin America failed. The surface is unsuitable for cooking the traditional *injera* dish whose thin and watery batter cannot be moved around like a tortilla. As Bilger explains, “The Ethiopians are unbelievably particular. If the injera doesn’t have the exact size of bubble in the batter, they’ll say it’s garbage.”<sup>xviii</sup>

Although many of the same values and qualities are sought in a cook-stove that can be used across the globe, generalized interventions have met resistance. This ultimately points to the need for localized approaches or, at the very least, specific attention to conditions on the ground where interventions will be put to use. Given this insight from prior work, it was greatly important in this study to utilize local cuisine in the stove tests to most accurately gauge the extent of user satisfaction with the stove model. Specifically, an aim of the study was to assess the efficacy of GB’s metal cooking surface as a replacement to the traditional *plancha* surface by observing how it conducted heat and how this aided or impeded the preparation of tortillas and other local fare.

Numerous projects and studies have utilized such small-scale, local approaches similar to

Global Brigades and served as models for this study. Project Surya, an initiative conducted in India to provide people with energy-efficient cookers, employs innovative methods focused upon understanding and overcoming local sensitivities. To ensure continued user buy-in, Surya engages village children to partake in data collect to increase understanding of the benefits of improved cook-stoves.<sup>xix</sup>

While our study did not seek to utilize participant data collection as an indication of buy-in, we did incorporate an assessment of Global Brigades' microfinance approach to creating user buy-in. Initiatives such as Project Surya make clear how critical an aspect user buy-in is to establishing local, enduring change to traditional practices, as it recognizes that individuals can provide the information and motivation for their neighbors to instill widespread change within a community. In light of this, a key focus of our study was to examine what role social and community dynamics played in people's adoption of, and attitudes towards, the stove interventions.

## **Preparation of Study**

The project began when a research team consisting of Claire Hennigan and Amy Rogers, two students studying Global Public Health at the University of Virginia, collaborated with Global Brigades to apply for the Community Based Undergraduate Research Grant. Upon securing the grant, coordinators from Global Brigades, the research team, and outside experts began designing the project.

In preparation for the project, Hennigan and Rogers met with their advisor Dr. Rebecca Dillingham, Co-Director of the Center for Global Health. Dr. Dillingham has background knowledge in epidemiology with her Masters in Public Health and also research experience working in countries such as South Africa. The research team also received support and guidance from Lydia Abebe, a graduate student in the Civil Engineering Department, on the study design as well as the creation of the survey. Another major collaborator on the project was Dr. Kyle Enfield. Dr. Enfield is a Pulmonologist with his Masters in Epidemiology who had previously completed stove evaluations in Guatemala. Dr. Enfield was able to provide valuable insight regarding the feasibility of stove research in a global setting, as well as encouraging a focus on community dynamics that was later incorporated into the project.

In-country support for the project was primarily received from Johanna Chapin, Director of Research & Evaluation for Global Brigades. Chapin assisted the research team in designing the project, selecting the Joyas de Carballo community as the population for study, coordinating in-country logistics, and initiating community contact. Chapin's selected of Joyas de Carballo due to the long-standing relationship that Global Brigades has maintained with this community. Global Brigades was in the process of constructing stoves in this community, giving a diversified sample of homes with the Global Brigades model stove and many homes that still used the traditional *Fogon Normal*.

Additional in-country support was also received from Lauryn Linsell and Orlando Osorto, who offered extensive knowledge about Global Brigades's Public Health Program. Linsell is the Director of the Public Health Brigades and was able to provide maps and provide the research team the particulate detector used during the project. Osorto, a native to Honduras, has worked for organizations such as ADESA installing eco stoves and is now responsible for constructing all of Global Brigades' stoves. Besides providing suggestions to improve our methodology, Osorto was able to provide cultural insight and background knowledge of the community.

By collaborating with those listed above, as well as conducting a literature review on eco stoves<sup>2</sup> and global stove research,<sup>3</sup> Hennigan and Rogers received a great deal of insight in shaping a protocol for the stove evaluations and creating a survey to be performed in each home. After securing IRB approval, Hennigan and Rogers traveled to Honduras on June 2, 2010 to begin in-country work on the project.

The initial in-country necessities included purchasing a cell-phone compatible with



EpiSurveyor through Tigo, a common cell phone carrier. The model selected was the Nokia e63. Chapin then brought the research team to the community to make the initial contact. With a local guide, the first few days were spent assessing the accuracy of a current community map and determining the number of occupied homes. During these days the research team also attended community meetings to introduce the project and piloted the stove evaluation in two homes.

<sup>2</sup> Bilger, B. (21 Dec 2009). Hearth surgery. *The New Yorker*, 84-97.

<sup>3</sup> Mandzuk, C & Schrowe, L. (2007). Honduras stove project: phase 2. Unpublished manuscript, Public Health Program, Indiana University, Retrieved from

<http://www.medicine.iu.edu/documents/DPHDocuments/InternationalHealth/Phase%20II%20%20AMT%20Version.pdf>

The community was receptive to the project, and all families were given a handout with the date and time that the research team would arrive at their house should they choose to participate. The handout included instructions specific to the protocol; it requested each home to have their stove off, masa for tortillas, and two kilos of ocote wood upon the arrival of the research team.

After the first three days of community engagement, the research team began surveying. At this point Claudio Paz, a Honduran University student, joined the research team. Paz assisted the research team in maintaining cultural sensitivity and interpreting when necessary. The research team planned on visiting three to five homes each day by traveling on foot.



## Protocol

The protocol in each home remained consistent regardless of the type of stove the family possessed. The research team greeted each household, entered the home, and began by receiving informed consent from the adult resident of the home who chose to participate. After receiving verbal consent to take part in the study, as well as a verbal consent allowing photographs to be taken, the stove evaluation began.

The first action performed during the stove test was an initial particulate detector reading. The machine used for evaluation was a Kanomax Model 3887 Handheld Laser Particle Counter<sup>2</sup>.

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<sup>2</sup> For more information visit <http://www.breathepureair.com/kanomax3887.html>





*(L) Rogers taking a particulate reading for an unlit stove. (R) Hennigan and Paz conducting a survey.*

This reading was taken with the particulate detector facing upward and held at shoulder height, two feet from the cooking surface of the cold stove. After obtaining this reading, two kilos (4.4 lbs) of ocote wood were precisely measured using a scale carried by the research team. This wood was then used to ignite the stove. Pieces were added as needed by the owner of the stove until all of the two kilos had been consumed and a flame was no longer visible in the stove's chamber. The time for two kilos of wood to burn was measured and used as part of the data collection and assessment of stove efficiency.

Upon lighting the stove, the research team measured two cups of purified water into a pot and placed it on hottest part of the cooking surface, as suggested by the owner. The same pot and lid were used during each trial and time for this water to reach a rolling boil was recorded. The

research team chose to cover the water with a clear, glass lid, seeing that this is the typical practice of the stove users in Joyas de Carballo.

While one member of the research team waited for the stove to heat to a temperature suitable for cooking and monitored the wood to ensure that the flame did not extinguish, the other research team member began the survey with the owner of the stove. This survey consisted of four parts: demographics, stove efficiency, effects on daily life (health and social), and effects on community dynamics. Each survey was completed in Spanish. The survey was completed through a program called Episurveyor.<sup>3</sup> This program allowed all responses to the survey to be collected and stored on a Smartphone and then uploaded to an online database for analysis.

During the survey, the stove was monitored with a simple oven thermometer. When the increase in temperature appeared to be stagnant, the research team began the kitchen tests. These kitchen tests were created to reflect the times necessary to cook typical foods eaten in the community. The first test was the time required to cook a tortilla.

Five tortillas were cooked during this test and the average of these five trials was taken as the final time for each stove. The tortillas were prepared by the owner of the stove, and the research team allowed owners to prepare the tortillas as they would see fit for a normal meal in order to obtain an accurate reflection of each owner's use and time spent cooking on his/her stove. The manner in which each participant prepared tortillas was nearly identical except for the variation in masa used. Several participants used homemade masa prepared directly for grinding corn while others used Maseca, which is a prepared mix requiring the addition of water.

The second kitchen test was time needed to prepare one scrambled egg. The research team provided two eggs to each family and measured the time required to cook each one individually.



The average for these preparations was taken as the final time for each stove. The egg protocol was similar to the tortilla protocol in that it allowed each participant the liberty to perform this task in the manner that it is typically done in each home. Like the tortillas, the preparation style was nearly identical in each home. Each participant first set a pan to heat

<sup>3</sup> More information can be found at <http://www.datadyne.org/episurveyor>

on the stove surface. After several minutes, the participant deposited about a tablespoon of shortening into the pan. After the shortening had liquefied, the participant added the egg, scrambling it as it cooked. The participant notified the research team when the egg was prepared.

During the kitchen tests and the survey, the research team was also conscious to take another particulate detector reading 30 minutes after the stove had been lit. This reading was done in same fashion as the initial reading and recorded. The research team also made sure to record the location of the stove through use of GPS, as well as to document the condition of the stove through photographs.

After the survey and kitchen tests were completed, the research team waited for the two kilos of wood to finish burning. At this point, the research team graciously thanked the family for their participation and provided the owner of the stove with a 1 lb bag of rice as compensation for his/her participation.

By July 13, 2010, the research team had completed stove evaluations of every willing home in the Joyas de Carballo community. This community has been naturally divided by its members into three smaller communities. The three subsections include El Junco, Joyas, and El Encinal. In El Junco, 26 of the 26 inhabited homes (100%) chose to participate in the survey, and 22 of the 26 inhabited homes (85%) chose to participate in the kitchen tests. In Joyas, 7 of the 7 homes (100%) chose to participate in both the kitchen tests and the survey. In El Encinal, 41 of the 43 occupied homes (95%) chose to participate in the survey and 35 of the 43 homes (81%) chose to participate in the kitchen tests.

## **Challenges and Success of Protocol**

Common technical problems encountered during research mainly included participants not having ocote wood in their home, having wet wood, or not having their stove off, resulting in the stove not being cold to the touch upon the research team's arrival. The short battery life of the particulate detector also resulted in several days or half days, in which this device could not be used. These problems were troubleshot in several ways. When the household did not have the appropriate type of wood, the research team would perform the test but disregard the time for burning two kilos of wood. If the wood were wet,

the research team would often use the driest pieces of wood to light the stove and then dry on the other pieces of wood using the heat produced by the stove. When the stove was not completely cool upon arrival, the research team asked the family to turn off the stove. The team would then return at least thirty minutes later, after the stove surface had had sufficient time to cool. The short battery life prevented the team from taking particulate readings in some homes. The research team was then careful to fully charge the device every night.

The research team also encountered several problems with igniting stoves. In several cases, the participants would light a stove and, after burning for several minutes, the fire in the chamber of the stove would extinguish. The participant would often have some difficulty relighting the stove. This created the technical issue of determining whether to measure the time frame of burning two kilos of wood from the initial lighting or from the secondary ignition. In most cases, the research team elected to use the initial time in the recorded data with a small intermission, in which the stopwatch was paused until the flame appeared again in the stove. Only in a few instances was the stopwatch completely reset for difficulties in the lighting the stove. In these special cases, the team decided to restart the stopwatch because the extended period from the time of lighting the stove to the disappearance of the flame. In these instances the fire had taken to the wood but not enough to burn a notable amount, thus leaving an almost equal amount of wood as the initial conditions. This issue could be eliminated if future protocols chose to standardize the procedure for starting a fire. The practices the team found were most effective for starting a fire in the chamber of the stove include using small pieces of wood also referred to as *ocote*,<sup>4</sup> and owners using a pipe to blow oxygen into the chamber. Although there was debate about allowing participants to demonstrate how the stove meets their specific need through permitting them to operate the stove as they do on a regular basis, a required procedure for lighting be more beneficial for data collection on efficiency. This required procedure would create a standard that eliminates the minor discrepancies that can occur in measuring each stove's ability to conserve energy.

Another technical issue encountered with the protocol potentially revolved around the gender and cultural influences of the community. In a house in which the female was

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<sup>4</sup> This is not to be confused with the type of wood used to in the fire. Both these items go by the same name.

not home or in the home of a single male, the men would not consent to performing the cooking tasks necessary for the kitchen tests. There were five homes in which this was the case. In all but one, the male opted to complete only the survey portion of the evaluation. In the one home that did participate in the kitchen test, the male had his daughter perform the cooking necessary for this evaluation.

The greatest success in the protocol was the use of Episurveyor. This technology greatly increased the fluidity and ease of the project. It facilitated easy movement in the community because the research team could travel without any paperwork or binders for storing information by keeping all data on the smartphone. It also ensured that information was not damaged or lost due to unforeseen circumstances, such as rain. Researchers were able to frequently upload the data to the Episurveyor webpage for safekeeping. The use of Episurveyor also allowed the team to quickly analyze the data without the numerous hours spent doing data input. Episurveyor also assisted in the analysis of the data by providing several tools online for synthesis as well as statistical calculations. Through this edition to the protocol, the process of collecting and reviewing data was greatly simplified.

Another highly effective component of the protocol was the handouts distributed before visits to participants' homes. For most surveys, the family was completely prepared for the arrival of the research team. This ensured minimal issues with stoves already being lit. It also allowed the research team to control important variables such as type of wood, since most families were prepared with the ocote wood necessary for the stove evaluation. Overall, these handouts served as an effective tool for engaging participants in the project and ensured that the research team had the conditions necessary to perform a stove evaluation upon arrival at each house.

## Findings



*Global Brigades Estufa Justa*



*Fogon Normal*

### *Quantitative Stove Test Portion:*

Quantitative questions regarding stove use consisted of two types; those self-reported by households and those recorded during the kitchen tests. 44% of participating households (31 out of 71) had a Global Brigades stove. 97% of households with a Non-GB stove had a *fogon normal* (traditional “normal stove”). Households with Global Brigades stoves reported their stoves were lit for an average of 10.03 hours per day, with the maximum reported at 19 hours and the minimum at 2 hours. Households with Non-GB stoves (*fogones*) reported their stoves being on for a mean value of 9.65 hours per day, with the maximum reported at 17 hours and the minimum at 2 hours. A minimal difference was found between GB and Non-GB stoves in the amount of time needed for the stove to heat to a temperature adequate for use. Households with GB Stoves reported waiting a mean value of 17.73 minutes until the stove was hot enough to cook, while households with *fogones normales* reported waiting a mean value of 15.32 minutes.

**Table 1: Stove Test Results**

	<b>GB Estufa Justa</b>	<b>Fogon normal</b>
<b>Mean time to cook (seconds):</b>		
<b>Tortilla</b>	117.8	108.9
<b>Egg scrambled</b>	101	99.3
<b>Boil 2 cups water (minutes)</b>	29.7	24.4
<b>Burn 2 kilos of wood (minutes)</b>	87.7	64.1

In the stove test portion of the study, it was found that GB Stoves, on average, took longer to complete each cooking task (Table 1). *Fogones normales* took an average of 108.9 seconds to cook a tortilla, with the maximum time at 249 seconds and the minimum at 25 seconds. GB stoves took an average of 117.8 seconds to cook a tortilla, with the maximum time at 240 seconds and the minimum at 54 seconds. *Fogones normales* took a mean value of 99.3 seconds to cook an egg, with the

maximum time at 200 seconds and the minimum at 52 seconds. GB stoves cooked an egg in a mean time of 101 seconds, with the maximum time at 241 seconds and the minimum at 54 seconds. For the water-boiling portion, *fogones normales* boiled water in a mean time of 24.4 minutes, with a maximum time of 49 minutes and a minimum time of 11 minutes. GB stoves took a mean value of 29.7 minutes to bring water to a boil, with a maximum time of 48 minutes and a minimum time of 8 minutes.

Apart from cooking times, it was also observed that eco-stoves reduced energy consumption (Table 2). GB stoves were found to be more economical in the wood-burning component of the test. GB stoves burned two kilos of wood (4.4 lbs) in a mean time of 87.07 minutes, with a maximum time of 135 minutes and a minimum time of 51 minutes. *Fogones normales* consumed two kilos of wood in a mean time of 64.07 minutes, with a maximum time of 100 minutes and a minimum time of 44 minutes. This difference in average time needed to burn 2 kilos of wood was found to be statistically significant ( $p=2.46215 \times 10^{-6}$ ).

By taking a longer amount of time to burn a specified amount of wood, the eco-stoves consume less wood on average, allowing families to expend less time collecting the wood necessary to cook meals. This economic advantage of the Global Brigades *Estufa Justa* was confirmed in the data about wood gathering. Households with a *fogon normal* reported spending a mean value of 210.14 minutes collecting wood per week, or 14.01 hours per month and 182.12 hours per year. Households with GB stoves reported spending a mean value of 183.45 minutes collecting wood per week, or 12.23 hours per week and 158.99 hours per year. When asked how many kilos of wood they collect per week, it was found that households with a GB stoves use significantly less fuel wood than households with traditional stoves. On a weekly basis, eco-stove households collected an average of 26.81 kilos compared to traditional stove households with 38.72 kilos ( $p=0.01842461$ ), leading to a savings of over 600 kilos of fuel wood over the course of a year.<sup>xx</sup>

	GB “Estufa Justa”	Fogon normal
<b>Needed Repairs</b>	7%	67%
<b>Mean time spent gathering wood:</b>		
<b>Per week (minutes)</b>	183.45	219.05
<b>Per year (hours)</b>	158	181
<b>Kilos of wood gathered:</b>		
<b>Per week</b>	26.81	38.72
<b>Per year</b>	1,394	2,013

**Table 2: Quantitative Efficiency Comparison of Global Brigades' Estufa Justa and Traditional Fogon Normal**

*Qualitative Portion:*

Open-ended and other qualitative questions generated information helpful to understanding stove use and community members' opinions on the Global Brigades stoves. 100% of respondents with a GB stove reported being satisfied with their stove, while 79% of respondents with a NonGB stove reported being satisfied. It was also found that 68% of households with *fogones normales* reported having to repair their stove at some point. Differences in cooking method were found between GB stoves and *fogones normales* as households with GB Stoves reported using the whole surface to cook,

while those with *fogones normales* reported only to be able to cook in a certain spot that became sufficiently hot.



When asked how they thought their lifestyle differed from someone with a GB stove, respondents with *fogones normales* commonly reported using more wood and spending more time collecting wood. Many also commented that they had more smoke in their homes and linked its presence to health problems.<sup>5</sup> Respondents with GB stoves echoed this difference by noting the presence of less smoke in their homes. 65 of 69 participants, or 94%, reported that the community had changed since Global Brigades had begun constructing stoves. When asked for specifics, respondents commonly cited that people now spend less time collecting wood, there is better health, and that the quality of life and homes is improved. One respondent explained that, “the forest is now being cut down less. In the past people needed many palos (load of wood) for stoves and now they need much less.”<sup>6</sup>

## Conclusions and Recommendations

As seen in the quantitative results, there were only small differences in cooking time. These times were not significantly different; justifying that there is essentially little variation between stoves when it comes to timing in food preparation. The research team observed that since GB stoves often are more evenly heated, there is less of a tendency to burn items such as tortillas.

Despite performing similarly on cooking tests, the stoves varied significantly in terms of efficiency; GB stoves offer a notable benefit. Over the course of a year, households with GB stoves gather an average of 1,394 kilos compared to 2,013 kilos in households with *fogones normales*. This efficiency not only saves time collecting wood but also eliminates 619.32 kilos per family from being destroyed in the Honduran forests. When multiplied by the 76 homes in the community this results in 47,068 kilos of wood being preserved each year. In terms of time spent collecting wood, households with GB stoves save about 35.6 minutes per week collecting wood which results in 23 hours per year of additional free time

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<sup>5</sup> A response along these lines was given by Participant 59, Participant 39, Participant 34, Participant 21, Participant 14 and Participant 10

<sup>6</sup> Participant 64

for households with these stoves. Therefore, it can be concluded that GB stoves are able to perform within the same cooking standard as *fogones normales* at much lower energy expenditure. When viewed on the scale of a year, or even a month, the time, energy, and wood saved by the GB *Estufa Justa* is notable and the success of this eco-stove intervention is an encouraging area to further explore as a solution to improving quality of life around the globe.

From the qualitative data, it can be inferred that those with GB stove have an improved quality of life compared to those using the typical *fogones normales*.<sup>7</sup> Because its surface heats evenly, those using the GB stoves are able to utilize the entire surface of the stove. This allows households to cook more items at one time, minimizing the need to spend more time cooking individual items separately. Effects of this benefit are seen by GB stove users who have used this efficiency for their own economic advantage. For example, one of the households with a GB stove is able to prepare donuts to sell throughout the community for a profit. The ability to utilize the entire “plancha” (cooking surface) allows the user the additional space to for this business endeavor.

This larger cooking surface, which in most cases is significantly larger than the plancha of *fogones normales*, can also be linked increase in free time or time to perform other domestic and/or agricultural activities. This ability to prepare several items simultaneously saves users time. It also saves them additional fuel since many users with *fogones normales* had an additional stove outside the home used to prepare items such as corn and beans when space was limited on their internal stove.

A better quality of life can be further inferred from the data on stove repairs. GB stoves show a significantly lower need for repairs. This data indicates that users are less inconvenienced by periods in which their stove cannot be in use. It also benefits the owner, fiscally and otherwise, to invest fewer resources to repair their stoves.

Participant feedback also indicates that Global Brigades stoves, or more importantly their presence in the community, are having a beneficial impact on community dynamic. According to one participant, “There is much more help now. It also seems to have people

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<sup>7</sup> Specifically stated in interview with Participant 22. Implied and stated in various other interviews as well.

working together since the various projects have arrived.”<sup>8</sup> Similarly another community member reported, “When they have projects they work together, but when they don’t have projects coming into the community people work by themselves.”<sup>11</sup>

Besides referencing a direct change in community dynamic, a majority of the interviews referred to a more cohesive community dynamic through collaboration on the water project and the community run sanitation committee created by Global Brigades. Our research team witnessed the effectiveness of the sanitation committee through their help in distributing handouts to the households prior to the research team’s arrival. With the sanitation committee’s ability to communicate with and unite the community, the stove study was greatly aided. This is indicative of strong, internal community coordination, which made it easier to distribute information and promote participation.

### *Recommendations*

Based on the study’s findings, and recognizing that the continued use of biomass fuels is the most practical approach to fulfilling energy needs in developing countries, it is strongly recommended that traditional cooking practices be replaced with stove projects that integrate improved design as a solution to improving quality of life. Households with the current GB stove model have shown a high level of satisfaction and report changes in many areas of their individual lives. They also report beneficial changes that have occurred on a community wide scale. Thus, stove construction as carried out by Global Brigades offers an important example from which to continue successful intervention, both through the continued implementation in the community of Joyas de Carballo and extending the intervention to other communities in the surrounding region and on a global scale.

It is urged that projects utilize an interdisciplinary approach. Considering the complex interaction of housing, fuel use, and daily household activities, as well as their role in determining exposure to IAP, the planning and creation of successful projects, “can

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<sup>8</sup> Translated originally from interview in Spanish by Hennigan and Rogers <sup>11</sup> Translated originally from interview in Spanish by Hennigan and Rogers

benefit tremendously from integration of methods and analysis tools from a range of disciplines in the physical, social, and health sciences.”<sup>xxi</sup>

Furthermore, a multifaceted approach can offer unique insight into the behavior and practices of those that will be using the stoves. As was touched upon previously in the *Challenges* section, ignorance of cultural practices and the conditions of daily life “can result in well-intended programs that may either face resistance during implementation or not achieve their intended goals.”<sup>xxii</sup> Finally, it is recommended that projects be implemented using smallscale and localized approaches, as was found/used in the Global Brigades *Estufa Justa* initiative. Such methods mitigate risk and reduce losses should a particular intervention fail in its design or implementation. Particularly important during this period of exploration into biomass energy use, the interventions that may be piloted through the encouragement of small-scale ventures will enable a diversity of methods to be tested, thereby increasing understanding of which are most effective. Small-scale projects will also ensure that stoves are tailored to the local community’s needs and user preferences.

In order to implement stove projects, finances must also be made available. Not only will fiscal resources enable stove construction and maintenance but, more importantly, they will also allow people to purchase the technologies themselves and maintain a sense of ownership. Microfinance is particularly recommended for this task due to its strength in distribution channels that connect people at the grassroots levels to resources for capital investment. As Baron explains, “Microfinance can either lend directly to households so that they can buy or repair these cook stoves, or develop a network of supporting businesses to provide finance, maintenance, and repair”<sup>xxiii</sup>. The stove projects conducted by Global Brigades have utilized this microfinance approach and met with success, as the study found. Providing financial resources and technical support, Global Brigades establishes and maintains community banks from which households may apply for loans to purchase an eco-stove<sup>xxiv</sup>. This is a model that simultaneously fosters user buy-in of the eco-stove and provides sustainable, community-borne funding for the projects.

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### *Future Research*

Although there is a reported health benefit associated with the GB stoves, further research is needed to see if there is indeed a clinical correlation between increased respiratory capabilities and long-term asthma reduction, particularly in children, with the use of GB stoves. It is recommended that research continue to examine the relationship between exposure amounts and health outcomes. As Ezzati et al. explains, prior programs “although lowering average emissions, may not have reduced exposure below the 2,000 ug/m<sup>3</sup> level (let alone to several hundreds of micrograms per cubic meter) that may provide important health benefits.”<sup>xxv</sup> An enhanced understanding of the link between the emissions released from a stove located immediately near a person or a distance away and their relative exposure, as well as how emissions and exposure vary depending on how a stove is used, is essential. With such comprehension, stoves can be designed more appropriately so as to minimize human exposure.

As improved designs are introduced and piloted, research must also continue to monitor the success of stove interventions. Evaluating the long-term durability and performance of the interventions will be essential to understanding both their efficacy in exposure reduction and the necessary maintenance practices.<sup>xxvi</sup> In addition, social and economic components must also be included in follow-up monitoring to gain a clearer understanding of what motivates households to adopt new stoves (i.e. for economic and time reasons, or health). Follow-up research and evaluation should seek to examine several specific questions:

- The long-term technical performance of the stove or related intervention.
- Beyond its ability to reduce emissions and exposure, the economic and social repercussions of each intervention.
- A longitudinal understanding of adoption practices. Specifically, what role do community networks play in aiding or obstructing stove adoption?
- The dynamics that facilitate or hinder the creation of commercial networks for designing and promoting locally manufactured energy technology.

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vi Bilger, 86.

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xi Ezzati 2002, 1063.

xii Bilger, 88.

xiii Cushion, 41.

xiv Baron, 152.

xv Bilger, 94.

xvi Ezzati 2002, 1064.

xvii Baron, 147.

xviii Bilger, 88.

xix Baron, 153.