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When clean air is affordable

An impact assessment of PATH's Clean Fuels pilot project in Cambodia

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DISCLOSURE

The author of this impact analysis is a former PATH employee, and was responsible project manager for the Clean Fuels pilot study in Cambodia. While every effort has been made to be fair and impartial in this impact analysis, no claims of objectivity can be made.

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ABSTRACT

From January 2015 to January 2016, the global health nonprofit PATH conducted the Clean Fuels pilot study in Cambodia, which launched an ongoing partnership between Cambodian social enterprise Made For Life and Vision Fund. The goal was to increase use of clean-burning liquid petroleum gas (LPG) for cooking as an alternative to wood, which is highly polluting and linked with numerous diseases.

Using microfinance and a direct-sales approach, the pilot resulted in a 100% increase in the number of households that used LPG as their primary fuel for cooking among the study group. Of the households that were primary wood users at baseline, 61% switched to LPG as their primary cooking fuel (defined as using LPG for 80% or more of cooking tasks) at endline. Multivariate regression analysis was also used to test for predictors of fuel switching based on published literature from other cookstove studies, but due to the small sample size few significant correlations were detected.

Using a model called the Household Air Pollution Intervention Tool, the author finds that the health impact of this intervention is comparable to what would be expected from a similar LPG intervention, but far more effective than a biomass cookstove intervention among the same population. A conservative estimate using this model predicts 86 total deaths and 3,770 DALYS are averted, including 25 childhood deaths from acute lower-respiratory infection among a target population of 25,000 households.

The most noteworthy aspect of this intervention was its cost-effectiveness. As a self-supporting social enterprise using donor capital only for startup, the cost per DALY averted was only $20 and cost per childhood death averted was $1,200 – substantially less expensive than other cooking interventions from the literature.

LIST OF ACRONYMS

ALRI	Acute lower respiratory infection
CO^2	Carbon dioxide
DALYs	Disability adjusted life years
GACC	Global Alliance for Clean Cookstoves
GDP	Gross Domestic Product
HAP	Household air pollution
IHME	Institute for Health Metrics and Evaluation
LPG	Liquid petroleum gas
NGO	Non-governmental organization
PATH	(formerly) Program for Appropriate Technology in Health
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
SNV	Netherlands Development Group
SUMs	Stove use monitors
WHO	World Health Organization

I. BACKGROUND

A. A global health crisis is in the air

When is cooking a meal dangerous? When your family must cook most of their meals on an open fire, using biomass fuel such as wood, crop residue, or charcoal. Three billion people—that is nearly half the world's population—cook and heat their homes this way. That such an everyday chore is a major health hazard makes it easy to overlook, but air pollution is the world's largest single environmental health risk and the number of deaths it causes is astounding. The World Health Organization (WHO) estimates that air pollution is responsible for 7 million *annual* deaths, and 4.3 million of these deaths are specifically linked to pollution from cooking with coal, wood, and other biomass fuels.[1] And because women and young children in developing countries often spend more time inside the home, they share a disproportionate burden of smoke-related illnesses,[2] and make up the majority (54%) of all household air pollution (HAP) related deaths.[3]

In fact, pneumonia and other acute respiratory infections are the leading killers of children under five years of age globally, with air pollution as a major contributor to these preventable childhood deaths. Burning biomass creates a lot of smoke, and inhaling the fine particulates[a] in this smoke can cause chronic inflammation of the lungs. Wood smoke contains concentrations of fine particulate matter ($PM_{2.5}$) that are well above WHO air safety guidelines.[b] Of the estimated 4.3 million annual deaths from air pollution, 12% are acute respiratory infections in children whose lungs are still forming and therefore are more susceptible to these illnesses.[4,5] In fact, children who live in households that burn biomass fuels experience approximately 80% more cases of pneumonia than children living in households which burn cleaner fuels, such as natural gas or electricity.[6]

B. Efforts and impediments to date

Along with health benefits, many environmental groups are interested in improving fuel efficiency to slow down habitat destruction and desertification in environmentally sensitive areas. In places such as Kenya and Sudan, safety is also a major concern where women and girls must travel long distances from home every day, increasing their risk of rape and sexual assault in conflict zones. There have been significant efforts among governments, international organizations, and the development community towards the worthy goal of increasing access to clean and efficient stoves and cooking fuel.

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[a] Fine particulate matter is considered most dangerous when it measures 2.5 microns or less, a size so small that coughing cannot expel it from the lungs, and therefore increasing the chance of irritation, infection, and disease.

[b] For example, an open fire can emit above 40 micrograms (µg) of fine particulates per minute, and concentrations in a poorly-ventilated room can grow to 500 µg per cubic meter or higher. The WHO clean air guidelines specify that clean air is a daily average of 10 µg per cubic meter or less of exposure to $PM_{2.5}$.

Most of these efforts have focused on introducing improved stoves that burn biomass more efficiently. For example, a recent systematic review[7] included 57 studies on improved biomass-burning cook stoves compared to just 12 on LPG and 32 on all other alternative fuels combined. These improved biomass stoves can be made from ceramic, metal, or other materials, and range widely in price and quality. The general idea is to create and introduce a stove device that retains heat and burns the fuel at a higher temperature, thereby providing both higher fuel-efficiency and less smoke. Figure A shows some examples of improved cookstoves.

Figure 1. Examples of three varieties of the many improved cookstoves currently on the market.

A. Locally-made ceramic stove B. Charcoal stove C. High-quality biomass stove

Stoves which burn biomass have several major limitations that hamper their effectiveness: inadequate reduction of emissions, high cost of manufacture and distribution, and lack of desirability by consumers. All of these factors limit a product's ability to reduce HAP—either by lacking efficacy, usability, or affordability—and therefore to prevent illness and premature death.

1. Limited health impacts

The Global Alliance for Clean Cookstoves (GACC) was launched as a global consortium under the UN Foundation to focus efforts around this issue, with the original goal to distribute 100 million clean cookstoves by 2020. As of 2015, an estimated 82 million households had gained access to stoves and fuels. However, of these only 53 million (about 66%) were actually deemed to be clean and/or efficient, meeting some minimum standard for emissions reduction or fuel efficiency.[9]

Generally speaking, you get what you pay for in the world of cookstoves. The cleanest-burning biomass stoves are highly engineered, made from expensive materials, and often contain multiple internal components, such as a fan or battery (see Figure 1.C). As a result of the high cost of manufacture, these stoves are priced from $60-120 or more[8]—well beyond the budget of poor families in developing economies. On the other end of the spectrum, locally-made ceramic stoves can be purchased for $2-4 in many countries (see Figure 1.A). While these may offer some fuel efficiency, they do not reduce emissions significantly enough to have measureable health benefits. Because of this wide disparity in emissions reductions, only a percentage of the alternatives being promoted by the public and private sector actually have the potential to significantly reduce household air pollution. According to the GACC, only about 45% of the stoves and fuels distributed by their partners in 2015 actually met the threshold for WHO indoor emissions.[9]

2. *Limited adoption*

The GACC acknowledges that distributing a stove is not enough. As their most recent annual report states, "Factors such as functionality, durability, and performance of stoves and fuels in household settings influence the adoption of clean and efficient cooking technologies."[9] In this context, "adoption" is defined as consistent and correct use of the product over a sustained period of time (usually a few months up to a year). The development literature is full of examples of households being given products they neither valued nor desired, nor knew how to use properly. Predictably, these products are rarely incorporated into daily routines or used for their intended purpose. Cookstoves are certainly no exception. Multiple studies have shown that "culturally and/or locally inappropriate stove designs hampered use, often leading to stove modifications by users".[7] Cooks often find so-called 'improved' biomass stoves more cumbersome to use compared to an open fire or traditional stove, which allows them to adjust heat easily by adding or taking away fuel, cook multiple dishes at once, and prepare staple dishes in the traditional manner. In short, they don't actually see them as an improvement in their lives.

C. The clean fuel alternative in a Cambodian context

Gas fuels such as liquid petroleum gas (LPG) are a substantial improvement to air quality as compared to traditional cooking methods or rudimentary stoves, with negligible emissions—around 1 µg/minute or less. Gas also has nearly complete combustion, which minimizes production of carbon dioxide (CO_2) and vastly improves thermal efficiency. Yet while LPG is already widely used among businesses and higher-income families in urban areas, it is not as widely used by lower-income and non-urban families.[10]

PATH's preliminary research concluded that solutions for rural settings have been over-emphasized, overlooking the fact that many low-income consumers living in urban and peri-urban areas and are already purchasing fuel (rather than gathering it freely). HAP could be dramatically reduced if more poor consumers could access clean fuels such as LPG. While it is often assumed that the cost of LPG is the primary barrier to use, there are strategies which could allow better access to affordable LPG fuel for cooking, especially as prices of LPG are anticipated to fall as supply increases globally.

Cambodia is a densely populated country in Southeast Asia with a year-round tropical climate. This means that almost all biomass fuel is burned primarily for cooking and also in preparing medicine or beverages, but not for heating the home.[10] It also has one of the highest reliance on biomass in the region, 90% of which is wood. In 1997, a locally-based NGO called Geres set up manufacturing facilities and began to sell low-cost ceramic stoves made from locally-sourced materials (see Figure 2 below). Their project was a huge success in terms of adoption, with over 3.6 million stoves sold and distributed since 1997.[11] While many tons of wood has been saved and CO^2 emissions averted, their simple cookstove design is not sufficient to make any real impact on HAP.

In Cambodia, air pollution from biomass fuels is still the second greatest risk factor contributing to the total burden of disease, and lower respiratory infection is the leading cause of premature death and disability.[12,13] In 2010, HAP was attributed as a cause of mortality for 13.82% of deaths in the country.[14] Clearly, in order to make a significant positive impact on health, Cambodian households would need the opportunity to purchase truly clean cooking technologies.

D. PATH's pilot study in Cambodia

PATH saw an opportunity to use microfinance and a direct-sales model to meet the unmet demands of peri-urban households. Market research found that most of these households were already purchasing LPG on a regular basis, although in small volumes and at a significant markup. PATH partnered with a Cambodian social enterprise called Made For Life, founded by former PATH employee Thunvuth Nop. By purchasing fuel directly from LPG wholesalers and storing it in a nearby warehouse, Made For Life was able to offer free local delivery of LPG fuel on-call, and provide stove delivery, installation, and support to all customers. All staff, with the exception of the managing director, received some commission for each stove sale or fuel delivery, which in turn was used to fund ongoing service and delivery.

Figure 2. Typical locally-made ceramic stoves in Cambodia (left); A customer with her double-burner LPG stove purchased from Made For Life with a loan from VisionFund (right)

1. Research design

The pilot site location lies approximately 35 km to the northwest of the capital city of Phnom Penh. Baseline surveys were conducted in four communes (Chhveang, Chrey Loas, Ponhea Pon, and Ponsang), all within Kandal Province.[15] The first 100 households who purchased a stove package through Made For Life were invited to participate in baseline and endline surveys. No households refused to participate. One-on-one baseline interviews were conducted between March and June 2015; endline interviews were conducted from October 2015 to January 2016. The average time elapsed between the baseline and endline survey was just over seven months

(215.8 days). The average household size of the sample population was 5.16 (s.d. 1.8) which is just slightly above the country average household size of 4.7.[10] Table 1 describes some basic characteristics of the study group that participated in baseline and endline interviews.

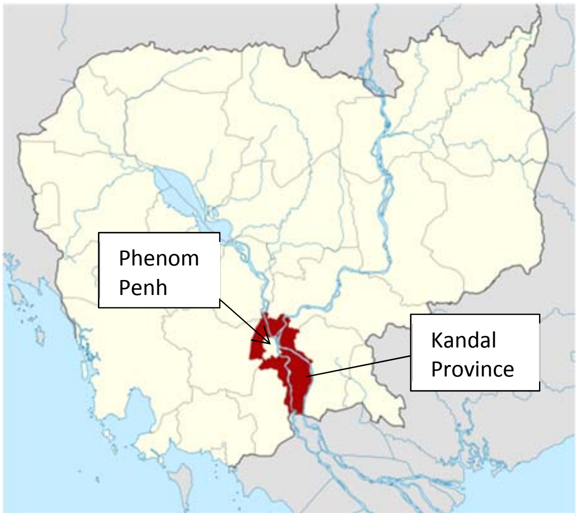

Figure 3. Map of study location in Kandal Province, Cambodia

Participants were interviewed regarding household characteristics, fuel use, stove use, cooking habits, and motivations for purchasing the stove package. Made For Life tracked the fuel consumption of each household during the duration of the pilot study. The study team used this data from the date of purchase to the date of the endline survey to compare against the self-reported LPG fuel usage for the same period. Survey data were entered into Microsoft Excel templates so that changes from baseline to endline could be analyzed. In addition to tracking the households in the baseline and endline surveys, Made For Life also reported complete monthly sales data for the duration of the pilot study.

Table 1. Characteristics of pilot study group participants.

Demographics	
Households interviewed	100
Avg. household size	5.16
Avg. number of children	1.39
Access to clean water	40%

Person responsible for:	Loan repayments	LPG fuel purchases
Self (main cook)	59%	57%
Male head of household	13%	14%
Female head of household	13%	13%
Adult son or daughter	15%	16%

2. *Study limitations*

The data gathered during this pilot study has multiple limitations. Primarily, as this was a market-based intervention and customers had to opt-in to purchase, it was not possible to randomize the survey samples. This could result in a self-selection bias, where those families who were the earliest adopters may possess unique characteristics that are not representative of the greater population. Also there is no control group to understand why some families who were exposed to the intervention (sales pitch) did not opt to purchase a stove using the offered microfinance loan. Finally, while it would have been ideal to collect actual emissions data and monitor clinical records to determine verifiable health impacts (after all, the reason for the intervention), the primary aim of the pilot was to first test if this was a viable business model. Other than a baseline and an endline survey of participants about (self-reported) health effects, there was no funding to also collect emissions data or monitor health indicators at different stages of the program implementation.

II. LITERATURE REVIEW

Many cookstove programs and interventions have been tested over decades on varying scales and with varying results, and so the significance and effectiveness of this intervention must be understood in the context of the existing literature. This literature review will first describe the key influencers of adoption of improved cooking technologies. While many common factors may influence the adoption of any cooking technology in general, there is a smaller subset which are most relevant to gas fuels such as LPG, biogas, or kerosene. After describing the influential factors relevant to adoption, I will discuss the status of the literature on indicators of adoption regarding cookstove interventions in general, LPG interventions, and microfinance programs.

A. Influencers of adoption

At one time, it was proposed that consumers in developing countries moved along an "energy ladder," meaning that as incomes rise households will move from using collected biomass such as wood and crop residue, to processed biomass such as charcoal, and finally to gas or electricity. However, multiple subsequent studies have critiqued this assumption, and it has been largely replaced by the understanding that as affluence rises, households will accumulate multiple energy options best suited to different cooking tasks.[16,17] As such, if consumers can afford to choose, they are rational in choosing what they see as the best fuel/tool for the job. This means that no LPG fuel intervention (or any cooking intervention for that matter) can assume that household income is the primary factor for adoption. Regardless of the cooking intervention, there are several factors that influence the uptake of a new technology.

In 2013, Puzzolo et al. conducted a systematic review to identify the factors associated with adoption of cleaner and/or more efficient cooking technologies.[7] The major domains identified across all studies were 1) fuel and technology characteristics, 2) household and setting characteristics, 3) knowledge and perceptions, 4) financial, tax, and subsidy aspects, 4) market development, 4) regulation, legislation, and standards, and 6) programmatic and policy mechanisms. Within each of these domains, there are multiple specific factors that have been observed to impact adoption of new cooking technologies. Some factors, such as fuel processing requirements (chopping, drying, etc.) may play a role only in the adoption biomass stoves. A smaller subset of these factors have been observed to impact the adoption of gas fuel in particular, and these have been summarized below in Table 2.

Although each of these factors have been reported to contribute to adoption of LPG in other interventions or studies, not all were addressed or accounted for within PATH's clean fuels project. Instead of describing how the project addressed each of these factors individually, Table 2 provides a graphical representation of whether or not each factor was addressed, and shows how well each domain was addressed in aggregate. Green indicates that the factor was thoroughly addressed in the project planning or assessed in the evaluation. Rows which are white indicate that this factor was not addressed. As the chart indicates, the domains most strongly addressed in this study were fuel and technology characteristics, knowledge and perceptions, and market development. Some data on demographic characteristics, such as education and household size, were collected during baseline and endline surveys but socio-economic status was not explicitly assessed.

Table 2. General factors impacting the adoption of LPG and extent to which these factors were addressed or assessed by the PATH's Clean Fuels project

Domain Addressed (Y/N)	Factors associated with adoption of LPG identified in the literature
1) Fuel and technology characteristics	
Yes	Impacts on time
Yes	Fuel savings (measured or perceived)
No	Design requirements meet users' needs
Yes	Safety (risk of explosion and quality of equipment)
2) Household and setting characteristics	
Indirectly	Socio-economic status (income, assets, expenditures)
No	House ownership and structure
Yes	Education level
Yes	Demographics (household size)
3) Knowledge and perceptions	
Yes	Awareness of smoke, health, and safety
Yes	Cleanliness and home improvement
Yes	Total perceived benefit (advantages, opportunity cost)
No	Tradition and cultural considerations (food taste, suitable to local dishes, etc.)
4) Financial, tax, and subsidy aspects	
No	Stove cost and subsidies
No	Fuel cost and subsidies
Yes	Payment modalities (loans, credit, installments, etc.)
No	Program subsidies (government support)
5) Market development	
Yes	Demand creation
Yes	Supply chain improvement
Yes	Business and sales approach (that favor expansion)
6) Regulation, legislation, and standards	
No	Regulation, certification, and standardization
No	Enforcement mechanisms
7) Programmatic and policy mechanisms	
No	Institutional coordination
Yes	User training
Yes	Monitoring and quality control

Adopted from Puzzolo et al. (2013)

The domain of financial, tax, and subsidy aspects also have a mixed emphasis in this project. While there were no subsidies or tax incentives for either the business or consumers to enjoy, a major goal of this intervention is to make the up-front cost of stoves more affordable by providing microfinance and allowing consumers to purchase their stove and first canister of fuel in installments. The cost of fuel was sold to customers at a competitive bulk market rate, however, there was no subsidy or program for providing credit for subsequent LPG refills.

In terms of government support in the form of regulation, legislation and standards, there was no meaningful coordination with or support from the government or other regulatory authorities. In Cambodia, safety is especially problematic because much of the LPG has been smuggled into the country without government control or tariffs. In this scenario, it is up to the distributor (in this case Made For Life) to ensure that the product delivered to the consumers is safe and durable. Made For Life did deliver a brief user training to each customer upon installation of the stove. They also employed quality control offers who are trained to ensure that gas refills are being handled properly in a safe manner, and to respond to customers' questions or problems with operation of their new stove.

B. Indicators of adoption

Few studies agree upon common *indicators* of adoption, i.e. to what extent the product is used consistently and correctly over a sustained period of time, compared to the relatively abundant literature on the factors influencing adoption. Meanwhile it has become very clear over the past decade that simply counting the number of stove products purchased is not enough to measure impact.

The Clean Fuels pilot study did track closing rate, which is the percentage of people who attend a sales event that actually purchase a stove. This measure is important because it describes the extent to which there is a market of consumers interested in purchasing the product. However, this measure can also be confounded by the effectiveness of an individual sales agent or the strength of the marketing strategy. For the purposes of estimating health impact, it is equally or more important to measure the continued use of the product over a sustained period of time. Below I will discuss how other similar interventions have assessed this factor, and how the results compare with the Clean Fuels project.

1. Cooking interventions

For cooking interventions, a common practice is to do a follow-up survey in conjunction with stove use monitors (SUMs), which record how often a stove is used over a period of time by recording temperature readings at regular intervals. As discussed above, many biomass stove interventions show a low level of sustained adoption, as is often verified by use of SUMs. For example, an evaluation of an improved biomass-burning stove in Kenya, a small sample of households were given a Jiko Poa stove at a discount in return for their participation in the study. The fact that they were willing to purchase the stove indicates that customers initially saw value in the product.

Ten weeks after the initial purchase, 52% (n=13) of households were still using their new stove every day, while 28% (n=7) had stopped using it altogether. The SUMs data corroborated what survey respondents reported. In addition, the SUMs data indicated that use of the Jiko Poa declined rapidly each week over a 10-week period, from 1.4 average uses per day during week 1 to 0.4 average uses per day during week 10.[18] Results such as this are not atypical for biomass cook stove evaluations.

By comparison, at 7 months post-intervention, 87% of Clean Fuels participants in Cambodia continued to use their LPG stove one or more times per day, while 13% of participants had stopped using their new stove altogether. The average household used their new LPG stove 2.3 times per day. While the Clean Fuels project did not have the benefit of SUMs data, the fuel sales data as recorded independently by Made For Life is correlated with the self-reported amount of stove uses per day. Holding household size constant, we see a 9.79 kg increase in total LPG purchased during the pilot study for each additional self-reported instance the LPG stove was used daily (adjusted $R^2 = 0.36$; $P>0.000$).

A recent study in rural Cambodia also used another improved biomass cookstove: a low-emissions, forced-air (fan) stove called the ACE-1.[19] Although the full cost of this stove is $150, control group participants were offered the stove at a subsidized price of $50 after a trial period of one month. Intervention groups could also earn additional rebates in exchange for continued usage of the stove, effectively “paying off” the full cost of the stove during the intervention. While all those who were given ongoing rebates for continued use of their ACE-1 did so, none of the control households chose to purchase the stove for a price of $50 at the end of the trial period, choosing instead to give it back. This indicates that the willingness to pay cash for even high-quality biomass stoves in rural Cambodia is effectively zero in the absence of ongoing social or financial incentives.

2. *LPG interventions*

Compared to improved biomass cookstoves, generating demand and ensuring sustained use of LPG is much less of a problem. For example, one study in Sudan that introduced LPG in Sudan concluded that, “the rapid growth in demand for LPG sets reflects the comparative ease of disseminating a technology which is highly desirable.”[20] Instead, the major challenge with LPG interventions is providing a reliable source of fuel, and helping low-income consumers overcome the initial purchase price of an LPG stove setup – the former being a much bigger challenge than the ladder. Because this fuel is often not locally produced, it is tied to global markets and distribution channels which can mean price fluctuation is a risk. Therefore the greatest successes have been in countries which have launched major government subsidy programs, such as those in India or Senegal. Such interventions commonly involve a targeted subsidy aimed at making LPG more affordable to the poor. Otherwise, relatively few LPG interventions have been launched, and are either fully funded for the purpose of demonstrating health impacts on ALRI[21], or are reliant on microfinance.[7]

3. *Microfinance interventions*

While PATH does not have other major cookstove or air quality intervention projects, it does have significant experience using microfinance and direct sales in the arena of water, sanitation, and hygiene. The Safe Water project used these methods to address deaths from diarrheal disease in India, Kenya, Vietnam and Cambodia. They developed sales strategies and distribution channels for a variety of locally developed water purification products, such as chlorination tablets and ceramic water filters. In Cambodia, rates of consistent use of water filters were at 81% eleven months after purchase among those households that received a microfinance loan, and 74% for all consumers who purchased the product.[22] This is just slightly less than the 87% of households that used their LPG stoves every day seven months after purchase in the Clean Fuels project. The results from Cambodia were significantly higher than another water filter intervention in India, however, where just 9% of purchasers were using their filter at 10 months. Clearly, context and product quality matter a great deal.

Within the context of the Clean Fuels study, there was no government subsidy or promotion of any kind. For this reason it would also be ideal to compare the results of this project to other market-based interventions that used microfinance as a tool for promoting the adoption of household products in the absence of government support (for instance, the rate at which consumers opt-in to other microloan programs). One obvious problem with this comparison, however, is that the rates of adoption will vary greatly by products sold, finance terms and mechanisms, and location. A review of the literature produced few comprehensive reports of microfinance loan uptake by the target population. As one point of reference, Crepon et al. conducted an evaluation of the impact of microcredit in Morocco, and found that 16% of surveyed households with the target area took up a microcredit loan.[23] Made For Life's average closing rate of 21% during the pilot study, however this counts only those households that were approached with a sales pitch, and not the general area population.

III. ANALYSIS

Based on the literature, the variables analyzed below are widely considered to influence the adoption and use of new technologies and innovations, and to be important indicators of potential health impacts. Before evaluating the results of PATH's clean fuels project, I will begin with a description of the data collected and project's results, and then discuss how this intervention compares with other potential HAP interventions in Cambodia in terms of health benefits and cost effectiveness.

A. Household energy use before and after intervention

1. *Baseline energy mix*

Among the one hundred households surveyed, 38 used gas as their primary source of cooking fuel at baseline, and the remaining 62 used wood as their primary cooking fuel. This mix is consistent with other studies of peri-urban households in Cambodia.[c] Within this mix, household energy supply also included charcoal and electricity. The average energy mix among these fuels was 35% gas, 8% electricity (usually in the form of an electric rice cooker), 55% wood, and 3% charcoal (commonly used for grilling meat or fish). This indicates that 58% of cooking tasks were done using highly polluting biomass fuels, and about 43% were done using clean modern fuels. These changes are summarized in Table 3 below.

However, among those households who did not own a gas stove before the intervention, the average energy consumption mix was 94% wood, 1% charcoal, and 5% electricity—meaning 95% of cooking is being done using dirty fuels. Among those households who already owned a stove and used some gas before the intervention, the average energy mix for cooking tasks was 56% gas, 9% electricity, 31% wood, and 4% charcoal. This observation is consistent with other studies and confirms that as household incomes rise, families do not just use only more modern energy sources (electricity and gas) but they also continue to use a wider variety of fuels. This is most likely because they can afford to use the preferred fuel for each cooking task.

Table 3. Average household energy mix at baseline and endline

	Gas	**Electric**	**Wood**	**Charcoal**
AVERAGE				
Baseline	35%	8%	55%	3%
Endline	77%	4%	19%	0%
PREVIOUSLY OWNED GAS STOVE				
Baseline	56%	9%	31%	4%
Endline	78%	4%	18%	0%
NO PREVIOUSLY OWNED GAS STOVE				
Baseline	0%	5%	94%	1%
Endline	76%	3%	20%	1%
	Clean burning		**Highly polluting**	

2. Endline energy mix

At the end of the pilot study, 76 households used primarily gas for cooking, and 24 still primarily used wood for cooking (although two of those 24 households now used gas for the majority [60-70%] of their cooking, but did not reach the 80% threshold which this study defined as “primary use”). This is a 100% increase in the number of households who now use gas as their primary fuel for cooking. It also means that 38 households jumped from primary wood users to using LPG as their primary cooking fuel. In theory, this should indicate a huge reduction in the amount of smoke they are exposed to on a daily basis.

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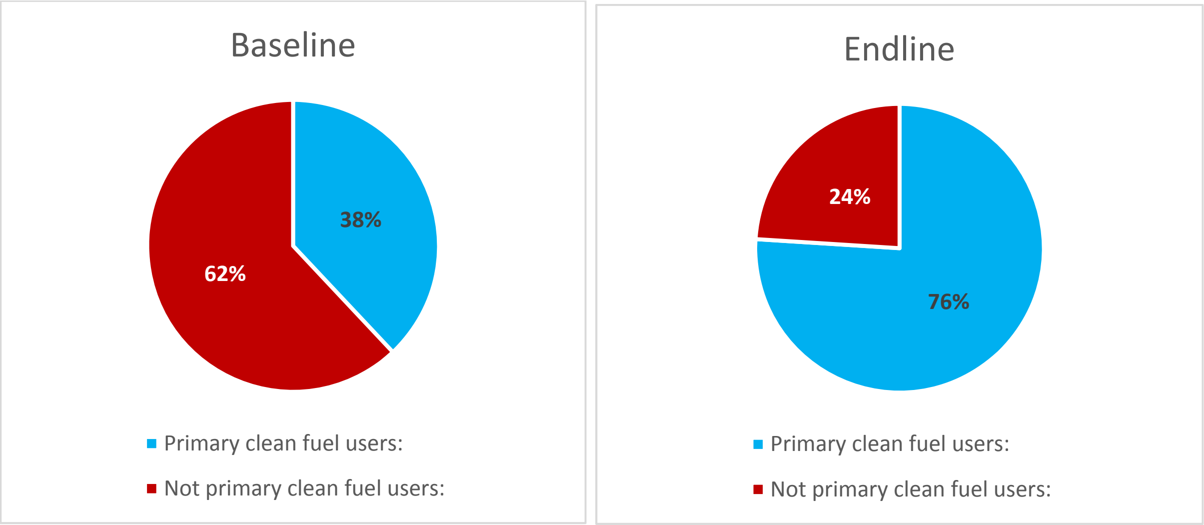
[c] A 2013 Domrei Household survey reported that 53% of peri-urban households used wood as their main fuel, and 37% used LPG. See Domrei Research and Consulting, Cambodia Market Assessment: Sector Mapping. July 2013.

At endline, the new average energy mix of all households in the sample was 77% gas, 4% electricity, 0% charcoal, and 19% wood (meaning that 81% of cooking fuel was coming from clean sources). Of the households that previously owned gas stoves and used gas for some of their cooking, the endline energy mix changed to 78% gas, 18% wood, and 4% electricity. For households that did not previously own a gas stove, the endline energy mix was now 76% gas, 20% wood, 1% charcoal, and 3% electric. Figure 3 below shows the percentages of households using primarily clean fuels (gas and electricity) at baseline and endline.

Figure 3. Households' primary fuel source at baseline and endline



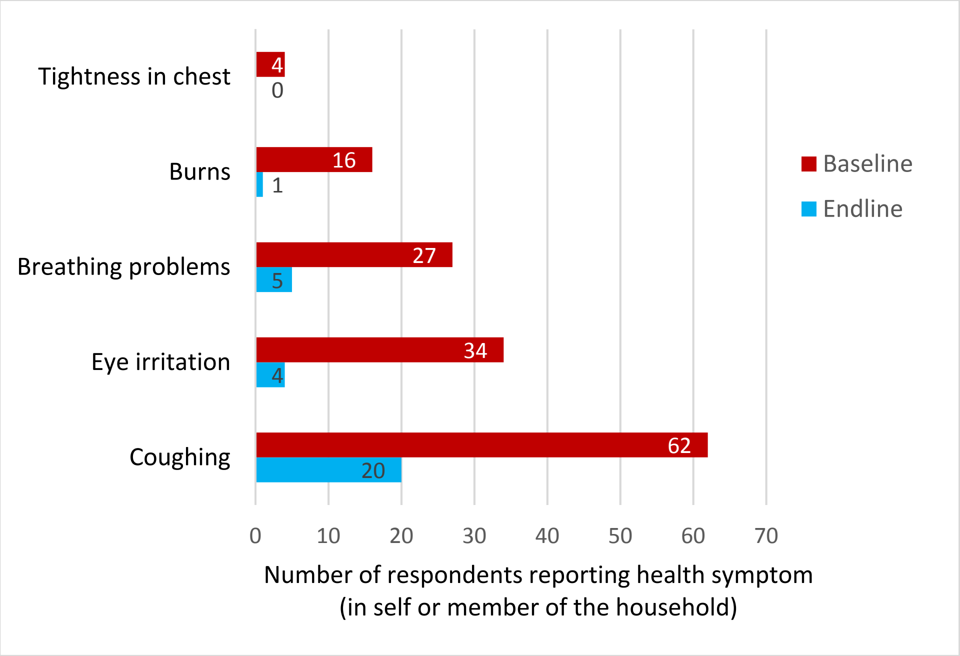
B. Health impact

1. Self-reported health indicators

The most important implication of the changes in fuel use is the impact on health. At baseline, participants were asked, "In the last six months, have you or your family experienced any of these conditions?" The conditions listed were coughing, bothered eyes, tightness in chest, breathing problems, and burns – all symptoms associated with indoor air pollution and potential indicators of diseases linked to cooking with traditional fuels. At baseline, 64% reported symptoms of coughing, 34% reported bothered eyes, 4% reported tightness in chest, 27% reported breathing problems, and 16% reported burns. The participant were then asked "Which family members experienced these problems?" Not surprisingly, 62% said that the main cook experienced at least one of these symptoms. Forty four percent said that children in the household experienced symptoms, and 28% said other adults also experienced one or more of these symptoms.

At the endline, the exact same questions were asked regarding the same conditions. Now only 20% reported coughing, 4% reported bothered eyes, 0% reported tightness in chest, 5% reported breathing problems, and 1% reported burns. Among the family members, 11% of the main cooks reported experiencing these symptoms, 7% reported that children demonstrated these symptoms, and 11% reported one or more of the symptoms in other adults. Figure 4 below shows the change from baseline to endline for each symptom, as reported by the household respondent. Overall, we see a 68% reduction in households reporting coughing, 88% reduction eye irritation, 81% reduction in breathing problems, a 94% reduction in burns, and a 100% reduction in households reporting experiencing tightness in the chest.

Figure 4. Air pollution-related health symptoms reported at baseline and endline.



It is important to note that this study had no way of documenting or verifying the presence of these symptoms or other health indicators. This data relies only on the highly subjective memory of the respondent using self-reporting. However, this question does provide a good indicator of how the respondent feels about the product – is it improving the overall health of his or her family? As is indicated by the literature review of factors influencing adoption, awareness of health and safety is a common predictor of adoption of LPG. Accordingly, the endline survey also asked respondents a more general question to this effect: “Do you feel your family has more or less health problems since you started using Made For Life products?” Ninety-five respondents reported less health problems, and five reported it was about the same.

Another important consideration for health is the amount of time that households burn wood, because the duration of exposure (as well as dose, which in this case is the concentration of $PM_{2.5}$) are predictors of negative health impacts. At the baseline, participants reported burning a wood fire for an average of 103.3 minutes (1 hour 43 min) every day. At endline this number had decreased by 181% to 36.8 minutes per day. Next I will discuss the expected health implications that we can infer from this reduction in exposure to $PM_{2.5}$.

2. *Potential for health impact*

Although PATH was not able to monitor exposure before and after the intervention directly, we can rely on other recent studies in Cambodia to approximate the expected impact of a Cambodian household switching from primary wood burning to primary gas use. Berkeley Air Monitoring Group was commissioned by Netherlands Development Group (SNV) to conduct a controlled study in urban and peri-urban Cambodia in 2015 to determine the difference in kitchen concentrations of $PM_{2.5}$ in households using traditional wood stoves compared to two interventions: one model of improved biomass stove and one model of a biogas-burning stove. In both cases, 24 households in each intervention group and a control group were sampled over a two-week period and two robust methods of $PM_{2.5}$ measurement were used to record personal exposure over a 48 hour period.[24]

Like LPG, biogas has complete combustion and produces negligible emissions. Therefore, it can be assumed that households using the biogas stove in the SNV study would have very similar exposure to $PM_{2.5}$, if using the stove at about the same frequency as in PATH's LPG intervention. In fact, biogas users in the SNV study used biogas for 87% of their cooking events,[24] which is just slightly higher than PATH's self-reported average clean fuel use at endline of 81% (including electricity). This study also monitored households before the intervention, and a control group of other non-intervention households in the same peri-urban area. PATH's intervention also focused on peri-urban households. It is therefore possible to use the pre- and post-intervention exposure levels recorded for the SNV study as a proxy for the potential health impacts that would be expected from PATH's pilot study.

UC Berkeley's Household Energy, Climate, & Health Research Group has created a statistical model to predict the deaths and disability adjusted life years (DALYs)[25] averted by a cookstove intervention. This tool, called the household air pollution intervention tool (HAPIT), is free and publicly available online for the use of all practitioners working in the household energy, cooking, and air pollution sector.[26] The model asks the user to input number of households targeted, cost per household for intervention, fraction using intervention (adoption rate) and fuel costs per year, as well as pre- and post- intervention $PM_{2.5}$ exposure rates. Using the pre-intervention exposure levels and counterfactual exposure level from the SNV study, and the costs and

What is a Disability Adjusted Life Year?

"One DALY can be thought of as one lost year of a healthy life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability."[20]

In other words, DALYs are a way to quantify the total disease burden on a population, beyond the number of deaths. In this case we are just looking at all the lost years of health that can be specifically attributed to diseases caused by household air pollution from cooking.

WHO Metrics: Disability-Adjusted Life Year (DALY). Quantifying the burden of disease from mortality and morbidity adoption rates from the PATH project, I am able to generate a statistical model that approximates the deaths and DALYs averted from this, intervention specific to Cambodia.

Using the HAPIT tool to model the health impact of the PATH Clean Fuels project, an estimated 117 deaths and 5,200 DALYS would be averted. That would include 35 deaths among children under 5 years old from acute lower respiratory infections (ALRI), like pneumonia. The methods to derive these estimates are detailed in Appendix 3, the HAPIT report. The parameters used for the PATH study were slightly constrained by the HAPIT model. The scenario labeled Custom 1 in Table 3 assumes a target number of households of 15,000 with a .87 adoption rate. That is feasible considering that with a current staff of 132 sales agents, even achieving below average historical closing rates we would expect Made For Life to have sold an accumulative total of 15,000 stoves by March 2017. From the preliminary data we see a 13% dropout rate, so then assume adoption rate is 87%. Table 3 below contains the total deaths and DALYs averted according to the HAPIT model under this custom scenario.

Table 3. Total predicted DALYs and deaths averted from PATH intervention (Custom 1 and Custom 2 scenarios) compared to other typical interventions

Scenario	Pre-intervention exposure	Post-intervention exposure	Total DALYs averted	Total Deaths averted
Custom 1	172	35	5,200	117.5
Custom 2	172	35	3,770	86.2
LPG*	172	24	4,260	96.4
Chimney*	172	120	353	7.4
Rocket stove (biomass)	172	96	630	12.7
Advanced/fan stove (biomass)	172	80	872	17.7

*Denotes scenarios using conservative pre and post $PM_{2.5}$ exposure values from the literature.

The second scenario, Custom 2, considers the potential impact on the wider population, but counts only those households that become primary gas users. I use the model's maximum target household population of 25,000, although there are approximately ten times as many households in Kandal Province alone and Made For Life has already expanded to 10 provinces. We do not have data on the number of villages per province being reached, but 25,000 is certainly a low estimate. In this scenario I use the much more conservative adoption rate of 38%, because this is the percentage of households that switched from primary biomass to primary gas in our study sample, and hence have the most health benefits to gain. In this scenario, 86 total deaths and 3,770 DALYS are averted, including 25 childhood deaths from ALRI.

The HAPIT model also compares this to other hypothetical interventions using IHME population data specific to Cambodia. An LPG intervention with a 60% adoption rate targeting a population of 25,000 households would be expected to result in 96 deaths and 4,260 DALYS averted. By contrast, an advanced biomass stove would avert under 18 deaths and 872 DALYS. The slightly greater number of averted deaths/DALYs in the hypothetical LPG scenario is due to the fact that a lower post-intervention exposure rate of 24 $\mu g/m^3$ of $PM_{2.5}$ is assumed, compared to 35 $\mu g/m^3$ documented in the SNV study. Regardless, we see the health impact of this intervention is comparable to what would be expected from a similar LPG intervention, and performs far better on health impact than a biomass cookstove intervention.

One notable difference between the SNV and the PATH study group was minutes per day spent cooking. At baseline, PATH participants estimated burning a wood fire for approximately 1.75 hours per day, while the SNV control groups in the biogas study burned a traditional fire for an average of 3.2 hours per day – almost double. This could be due to reporting bias, because the SNV study had the benefit of using SUMs to record actual number of cooking events within a given period. It could also be due to the fact that the study sites used for the SNV study (in another region of Cambodia) relied less on small LPG stoves, with an average of only .53 cooking events with LPG daily compared to 1.6 average daily cooking events at baseline in the PATH study. It is possible, then, that the health benefits in the intervention groups of the SNV study had even greater potential for emission reductions because their baseline exposure was higher than among the PATH intervention group.

C. Cost effectiveness

Using the WHO's cost effectiveness benchmarks, the HAPIT tool considers an intervention cost-effective if the expected annual cost of the intervention per DALY averted is less than three times the per-capita GDP of the intervention country, and is considered very cost effective if it is less than or equal to the per-capita GDP. The model assumes that programs are covering the costs of fuel-based interventions, such as the monthly cost of LPG per household. In Custom 1, the first scenario, I include the start-up cost to the consumer of $120 for the double-burner stove package, and $50 per year for fuel (which is 12 times the Made For Life reported household average monthly spending on fuel of $4.17). Table 4 below shows the cost-effectiveness of the two custom PATH scenarios compared to other potential interventions.

Table 4. Cost effectiveness of PATH intervention compared to other potential cookstove interventions

Scenario	USD per averted child death	USD per averted DALY	Cost effectiveness category
Custom 1	187,000	1,220	Cost-effective
Custom 2	3,000	20	Very cost-effective
LPG*	745,000	4,720	Not cost-effective
Chimney*	320,000	2,270	Cost-effective
Rocket stove (biomass)	200,000	1,430	Cost-effective
Advanced/fan stove (biomass)	363,000	2,670	Not cost-effective

*Denotes scenarios using conservative pre and post $PM_{2.5}$ exposure values from the literature.

The annual per-capita GDP in Cambodia was estimated at $3,600 in 2016.[27] By this measure, Custom 1 is cost effective according to the HAPIT model, because it would cost $1,220 per DALY averted. However, this is somewhat misleading, because in PATH's intervention the ongoing program costs are passed on to the consumer and then transferred to local employees, thus creating jobs and bolstering the local economy. Since there is no ongoing program costs to any donor, Custom 2, the second scenario, only includes a cost of $3 per household. This is to account for the startup cost of $45,000 invested by PATH to reach the 15,000 households. Using this scenario, the intervention is very cost effective, costing just under $20 per DALY averted. Compare this to a hypothetical advanced biomass cookstove intervention, which is predicted to cost $2,670 per DALY averted.

Although in many contexts the introduction of LPG is thought to be prohibitively expensive, this intervention demonstrates that consumers find it convenient and desirable, and therefore are willing to spend their own money to adopt it. This attribute makes an LPG intervention of this kind cost effective compared to even cheap or freely available fuels because of the dramatic reductions in $PM_{2.5}$ and the fact that so much of the intervention is driven by market demand.

D. Statistical analysis

1. *LPG use and health*

As one might expect, there was a strong correlation between the self-reported health outcomes, the amount of LPG fuel used, and level of adoption, which correlated to health data both before and after the intervention. Using the data from the surveys about self-reported health indicators (coughing, tightness in chest, bothered eyes, breathing problems, and burns) I created two dummy variables for any cooking-related symptoms at baseline [healthsympt] and at endline [endhealthsympt]. Then I created a third dummy variable for those households that went from having one or more symptoms to having no symptoms at endline [healthchange].

This variable was analyzed against indicators of fuel use, including as minutes per day burning wood, amount of LPG purchased, and whether they switched primary fuel from wood to gas. Minutes of burning a wood fire per day was positively correlated with having health symptoms at endline ($P < 0.016$; 95%CI) and being a primary gas user at endline was negatively correlated with having health symptoms in the household – meaning that being a primary gas user reduced the incidence of having any health problems. While this is to be expected, it does indicate that 1) there is internal validity in the households' responses: what they reported in terms of their amount of time inhaling smoke correlates to their self-reported health impacts, and 2) that the intervention is improving the health of the participants, as expected. See Appendix 3 for the regression outputs in STATA.

When looking at all members of the household individually (elderly, adults, children, infants, main cook), and the extent to which there was a correlation with fuel switching, the only member whose experience of health problems is significantly correlated is the main cook. This is perhaps not surprising because the cook is the one most acutely impacted by and therefore aware of the negative health impacts of cooking with wood, and in most cases she was also the survey respondent. Additionally, it indicates a level of influence of the main cook over household energy use decisions, and that the main cook is motivated by protecting her own health.

2. *Indicators of wealth*

As discussed above, household income or assets is generally thought to be an important predictor of adoption of LPG. The participant survey did not explicitly record any variable for household income. However, there are several variables from the baseline/endline surveys that may be indicators of household income, such as education level of the main cook, the amount spent on energy monthly at baseline, and whether a family previously owned a gas stove or has a home business. There was a wide variation in all of these factors, suggesting heterogeneity of household incomes in the sample. See Table 5 for a summary of the data for wealth indicators.

For example, the endline survey asked the level of education of the main cook on a scale of 1 to 6 with 1 being illiterate and 6 being a university education. Forty-nine percent of main cooks had completed primary school and 37% had some secondary education, but no cooks in our sample had a university education. This is very similar to the Cambodian population as a whole, where 49.6% of adults have completed primary education.[10] The mean amount spent per month on all energy costs (wood, charcoal, electric, and gas) at baseline was $21.95, however there was a large standard deviation of $17.51. This indicates a wide variety of household incomes and socioeconomic status in the sample. Household size was included to control for the difference in expenditures on energy costs, and also because smaller households are reportedly associated with LPG adoption.

Table 5. Summary of indicators of houshold wealth

Variable	Obs.	Mean	Std. Dev.	Min	Max
Education level of main cook	100	3.36	0.847	1	5
Total monthly energy costs	100	21.95	17.511	1.5	109.88
Electricity in household	100	0.59	0.494	0	1
Business in household	100	0.42	0.496	0	1
Household size (# of people)	100	5.08	1.661	2	10

I ran a separate multivariate regression on each of the following dependent variables, using all of the indicators of wealth in listed in Table 5 as the independent variables.

a) Self-reported percentage of meals cooked with gas is 80% or more (primary gas user)
b) Self-reported amount of gas purchased during pilot study
c) Made for Life reported gas sales to household
d) Households who switched from primary wood to primary gas (80% or more) during the pilot study

None of these regressions resulted in an adjusted R-squared value of greater than 0.1, which denotes an extremely low explanatory power of this combination of independent variables on any of the dependent variables tested. The only variable that was statistically significant at a 95%CI was total monthly energy costs at baseline, which had a significance of P>.037 for self-reported LPG use and P>.001 for Made For Life reported LPG sales. This may indicate that families who were already spending a relatively high sum on energy costs before the intervention were more likely to continue spending relatively more than other households on LPG. This may also suggest that within this pilot study, wealth was somewhat correlated with adoption of LPG. However, with a small sample size of only 100 households and just two time-point observations, it is unlikely that any model will be robust enough to demonstrate strong correlations.

3. *Other factors tested*

Behavior change can be slow, and much experience on the subject of cooking technology has proven that getting a household to switch its principal energy source is difficult – even with support. The analysis of this project's outcomes looked at the predictors of adoption that were commonly referenced in the literature. The goal was to detect if there were any factors (or combination of factors) from the literature that predict the likelihood for a household to switch primary fuels, consume more LPG fuel than at baseline, or drop out of the intervention – a sign that there were too many barriers in place for them to adopt LPG.

After reviewing the literature, there were several factors that were reported to either enable or discourage adoption of LPG. Some enablers, such as "convenience/time savings" given as the main reason for purchase, were left out because virtually all respondents listed this as a reason for participating in the program (n=96). Because cost savings was also an important influencer of adoption in the literature, I created a dummy variable for whether or not a household saw a decrease in their total self-reported energy costs from baseline to endline to indicate if there was in fact a monetary savings from switching to gas. Most families (n=86) did in fact reduce their monthly energy expenditure, although this does not account for the cost of loan repayment.

The enablers of adoption included from the literature were:

1) Small household size
2) Education level of main cook or head of household
3) Having electricity in the household (possibly an indicator of wealth)
4) Having prior experience with LPG (previously owning an LPG stove)
5) Energy cost savings from baseline to endline

The barriers to adoption included in from the literature were:

6) Large household size
7) Fear of gas explosion
8) Some dishes are traditionally cooked outside (grilled meat, fish)

As above, the dependent variables tested using a multivariate regression model were:

a) Self-reported percentage of meals cooked with gas is 80% or more
b) Self-reported amount of gas purchased during pilot study
c) Made for Life reported total gas sales to household
d) Households who switched from primary wood to primary gas (80% or more) during the pilot study

In addition to the variables above, I also tested to see if any of the independent variables were factors in predicting:

e) Whether or not a household dropped out (i.e., stopped using the new gas stove they purchased) within the period from baseline to endline.

I ran a multivariate regression model to test each of the dependent variables listed in a through e above, using a model that included all of the pertinent factors (barriers and enablers) from the literature listed in 1 through 8 above. Just as with the regression analysis on wealth, the majority of these models had very little explanatory power. The strongest model was in predicting dropouts, with an Adjusted R-squared value of .2575. In this model, however, only cooking some dishes outside was statistically significant at a 95%CI (P>0.000) with a positive coefficient. In the model for predicting self-reported primary gas use, the same variable was also statistically significant at a 95%CI (P>0.000), this time with a negative coefficient, which is logical. Appendix 3 includes the complete regression outputs from STATA for each dependent variable tested.

There were a few other exceptions that did have some statistical significance. Most interestingly, instead of being a predictor of adoption, previously owning an LPG stove made it less likely that a household switch to LPG. In the multivariate regression model predicting fuel switching, this variable had a coefficient of -.59, meaning that if a household previously owned their own stove it lowered the household's likelihood of switching from primary wood to primary gas by .59 (P>0.001), which is substantial considering the variable for switching was 0 or 1. Keep in mind this factor is only relevant for those families who already had a gas stove *and* were primary wood users at baseline. This finding is contrary to other published studies, where previous experience with gas as a predictor of adoption.

On reflection, it is reasonable that this would be the case; when these households were not able to afford a full refill of LPG for their double-burner stove from MFL, they could easily revert to using their small LPG stove, purchasing smaller amounts of fuel on an as-needed basis. In this scenario, even though a household is still using some gas it is more likely that they would be using a wood-burning stove concurrently since all households who previously owned gas stoves used the small single-burner stove, not sufficient for cooking a complete family meal. They are also not benefitting from the lower cost of LPG enjoyed through purchasing in bulk from Made For Life. This observation does indicate that the price of refilling a 10 kg tank of fuel at once (for approximately $10) is a barrier for some households, even if they have already purchased a stove, and continue to make loan payments.

II. CONCLUSION AND RECOMMENDATIONS

Cooking routines are personally and culturally entrenched, and often resistant to change. The percentage of Made For Life customers surveyed who switched their primary source of fuel from wood to gas in just seven months is a promising result in the face of a global health problem that is as serious as it is difficult to solve. The self-reported reduction in HAP-related symptoms offer encouraging results, which hopefully indicate real health benefits of this intervention for those households that participated in the pilot study.

The key distinguishing factor of PATH's Clean Fuel project is that this intervention is self-sufficient, neither relying on donors or carbon credits to support its existence. This makes it an extremely cost-effective approach to addressing household air pollution from cooking. With little seed funding (under $45,000 from PATH directly to Made For Life for start-up, marketing, and operations costs), an estimated 86 to 118 premature deaths prevented is surely a sound return on investment by any measure. And the cost-per-death averted will continue to decline as Made For Life's operations expand with no external funding.

In terms of household size, education, and baseline fuel usage, the Clean Fuels study group was consistent with wider surveys and country-level demographic data. This suggests that the study group population was not unrepresentative of peri-urban households in Cambodia, which gives credit to the assertion that such an intervention could be effective on a much wider scale. It also somewhat diminishes the concern that the intervention group was comprised of households that are unrepresentative of the population as a whole.

Still, the biggest obstacle in making any conclusive assertions about the health impact of this study is that the data is limited, and from a unique subset of early adopters. We cannot be sure that the trends observed (13% dropout rate, 38% switch rate, endline energy mix, etc.) have been sustained in the customer population as a whole. We also cannot conclusively state the actual health benefits without having monitored emissions and personal exposure or clinical records. The top recommendation for this study would simply be to do a follow-up study with a representative sample of households targeted by this intervention in order to gather data and verify these trends. This should also include households in the intervention area who did *not* opt to purchase from Made For Life, to identify weaknesses or gaps in this approach.

Pre- and post-intervention exposure monitoring would also be a worthwhile endeavor. It might indicate that for maximum health benefits and economies of scale, it would be most effective for Made For Life or other social enterprises of this type to concentrate their sales efforts heavily in one geographic area at a time – and even subsidize the poorest families – to maximize the social return on investment. This is because clean air is a public good, and with low saturation rate in a community even those households switching to LPG will still sustain harmful health impacts if most of their neighbors continue to burn biomass.

Though this intervention may not be feasible or suitable in all scenarios, the characteristics of the population targeted within this study could be used as a guide to identify populations with similar characteristics for expansion and scale-up of such an intervention, even in other countries. Future research could also guide programmatic changes that would make households even less likely to drop out. For example, households that use wood for most of their cooking but also use small canisters of LPG on portable stoves may need further support – such as education about the dangers of reusing old LPG canisters and/or access to more frequent, smaller volume refills or longer loan repayment terms that make monthly stove payments less burdensome.

Even though a robust level of evaluation is not possible with the information and resources available, we can look to this pilot as a promising opportunity to reduce exposure to harmful emissions from cooking in a very cost-effective manner. Obviously, in order to realize the potential health benefits, families will have to continue to purchase LPG fuel and use it regularly for cooking. While we cannot verify this on a per-household basis, with Made For Life's continued success and expansion, there is little reason to suspect that this would not be the case. Cooking interventions have proven difficult to scale up for numerous reasons. It seems worthwhile to prioritize one solution that consumers are eager to take up.

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APPENDIX 1. Survey questions

QUESTION	SUB-QUESTION OR ANSWER CHOICES
General Information	
	Date of Baseline survey
	Date of Endline survey
	Days elapsed
	Village
	Commune
	Number of Key Opinion Leaders
1.5 Which budle/package did the consumer select?	1) Single Burner: Namilux or Green Star
	2) Double Burner: Molux + fuel
	3) No stove: Fuel only
	Fuel Volume (kg)
	Fuel Cost per tank ($)
	Number of people living in house-hold
	Number of Adults (age 18 and older)
	Number of Young Children (age 12 and younger)
Fuel Use	
2.1 Please list all the fuels used in your home for cooking in the last month	Gas (LPG)
	Wood
	Charcoal
	Electricity (such as electric rice cooker)
Which fuel do you usually use the MOST for cooking? 1) Gas (LPG)	
	BIOMASS: Wood + Charcoal
	NON-BIOMASS: Gas + electric
2.3) Please estimate what percentage of your cooking is done with the following fuels:	Gas (LPG)
	Wood
	Charcoal
	Electricity
	How many MIN per day do you usually burn a wood stove or cooking fire?
[If 2.1b or 2.1c are selected] 2.5) What do you use your wood fire for?	Stir fry
	Grill meat or fish
	Soup
	Rice
	Boil water
	Prepare medicine
	How much money ($) did your family spend last month on wood and charcoal?
	How much money ($) did your family spend last month on electricity?
	How much money ($) did your family spend last month on LPG fuel?
	Have you ever run out of LPG (from MFL)?
[If yes to 2.9] How long was you canister empty before you filled up?	Why did you wait to fill up?

APPENDIX 1. Survey questions

Stove Use	
How many times per day do you use the LPG stove that you purchased from MFL?	
	Dropout? 0=No 1=Yes
3.2) What foods do you cook with your LPG stove from MadeForLife (MFL)?	Stir fry Grill meat or fish Soup or poridge Rice Boil Water Warm up leftovers
	What do you like about using your LPG stove ? Have you had any problems with your LPG stove? How many times have you refilled your gas through MFL? Verified fuel purchased through MFL
Did you already own an LPG stove before you purchased one from MFL?	
	[If yes to 3.6] Do you still use your old LPG stove?
[If Yes to 3.7] 3.3) What do you use your other LPG stove for?	Stir fry Grill meat or fish Soup or poridge Rice Boil Water Warm up leftovers
[If Yes to 3.7] [If non-MFL cylinder used]	What size of LPG canister or cylinders do you use? How many times per month do you exchange or refill your LPG cylinder?
Health	
4.1) In the last six months, have you or your family experienced any of these conditions?	Coughing Bothers eyes Tightness in chest Breathing problems Burns Other problems - please specify
4.2) Which family members experienced these problems?	Infants Children Main cook Other adults Elderly
	Do you feel your family has more or less health problems since you started using MFL products?
Other Factors	
	Are you the main cook of the household? What is the age of the main cook? What is the highest level of education of the main cook? Who is the person responsible for making the loan payments? Who is ther person responsible for purchasing gas (LPG)?

	Think about how much time you spend cooking and gathering wood. Is it more, less, or about the same as before?
	[If 5.6 is Less] How much time do you think you save? (in minutes)
[If 5.6 is Less]	What do you do with the extra time? (OPEN ENDED)
	[If 5.6 is Less] What do you do with the extra time? Childcare Housework Home business Agriculture Work outside of home Other (relax, school, etc)
	Where does your household get your drinking water Does your family own a water filter or other water treatment system? Access to Safe drinking water Yes = 1 No = 0
Calculated variables	
	Total montly energy costs Total LPG used (self report) Total LPG costs (self-report) Montly energy cost per person (self-report) Above average? Decrease pp energy costs from baseline? Total LPG used (MFL verified) Monthly LPG cost (MFL verified)

HAPIT Results: Health Benefits of Stove Interventions in Cambodia

Generated by HAPIT 2 on 2017-04-30

This document contains output from HAPIT, the Household Air Pollution Intervention Tool. Based on user's inputs of information in their own setting, HAPIT estimates and compares health benefits attributable to stove and/or fuel programs that reduce exposure to household air pollution (HAP) resulting from solid fuel use in traditional stoves in developing countries. As each country's health and HAP situation is different, HAPIT currently contains the background data necessary to conduct the analysis in 55 countries – those with more than half of households using solid fuels for cooking and a small number of additional countries of interest.

HAPIT also estimates program cost-effectiveness in US dollars per averted DALY (disability-adjusted life year) based on the World Health Organization's CHOICE methodology (see Info tab for more detail).

This report focuses on Cambodia. It is tailored to the national average conditions (household size, background disease rates, GDP per capita, etc). Estimates derived from HAPIT are based on methods and databases developed during the Comparative Risk Assessment, a component of the IHME Global Burden of Disease project (GBD-2010). It includes exposure-response information for each of the major disease categories that have been accepted as being due to HAP as well as background health, demographic, energy, and economic conditions for an additional 54 countries. Throughout this report, an * indicates that pre and post intervention PM exposures are conservative default values estimated from the literature and not empirical, country-specific measurements, which are recommended in actual use.

For countries with large demographic, geographic, or economic heterogeneity, estimates generated by HAPIT must be used with caution. In these areas, sub-national scenarios and input data are strongly recommended.

Overview

This document is split into two sections. The first contains a text-based overview of HAPIT and output from the model. The second contains a number of relevant tables and graphs.

Scenarios Modeled

Burden of disease estimates and health benefits estimated by HAPIT require definition of an 'ideal' counterfactual exposure, below which there is no risk to health. In the 2010 Burden of Disease, this value was set at 7.3 µg/m3 for annual average PM2.5 exposure. In HAPIT, the default value is 10 µg/m3, which is the official Air Quality Guideline of WHO. HAPIT offers a third choice as well – 35 µg/m3, which is the Interim Target-1 in the WHO AQG document.

The creator of this report set the counterfactual to 35 µg/m3 and the pre-intervention PM2.5 exposure to 172 µg/m3. HAPIT is designed to accept information derived from each user's own setting for cost, pre- and post- intervention exposures, etc. * denotes scenarios using default exposure values from the literature.

Custom Scenarios

Scenario	Post PM2.5	Targeted Households	Frac Using	Useful Life	$ per Intvn	$/Year per HH
Custom 1	35	15000	0.87	5	120	50
Custom 2	35	25000	0.38	5	3	0

Default Scenarios

Scenario	Post PM2.5	Targeted Households	Frac Using	Useful Life	$ per Intvn	$/Year per HH
LPG*	24	25000	0.6	3	85	240.0
Chimney*	120	25000	0.6	2	20	5.0
Rocket*	96	25000	0.6	2	30	2.5
Advanced/Fan*	80	25000	0.6	2	75	7.5

Deaths and DALYs averted over the Intervention Lifetime

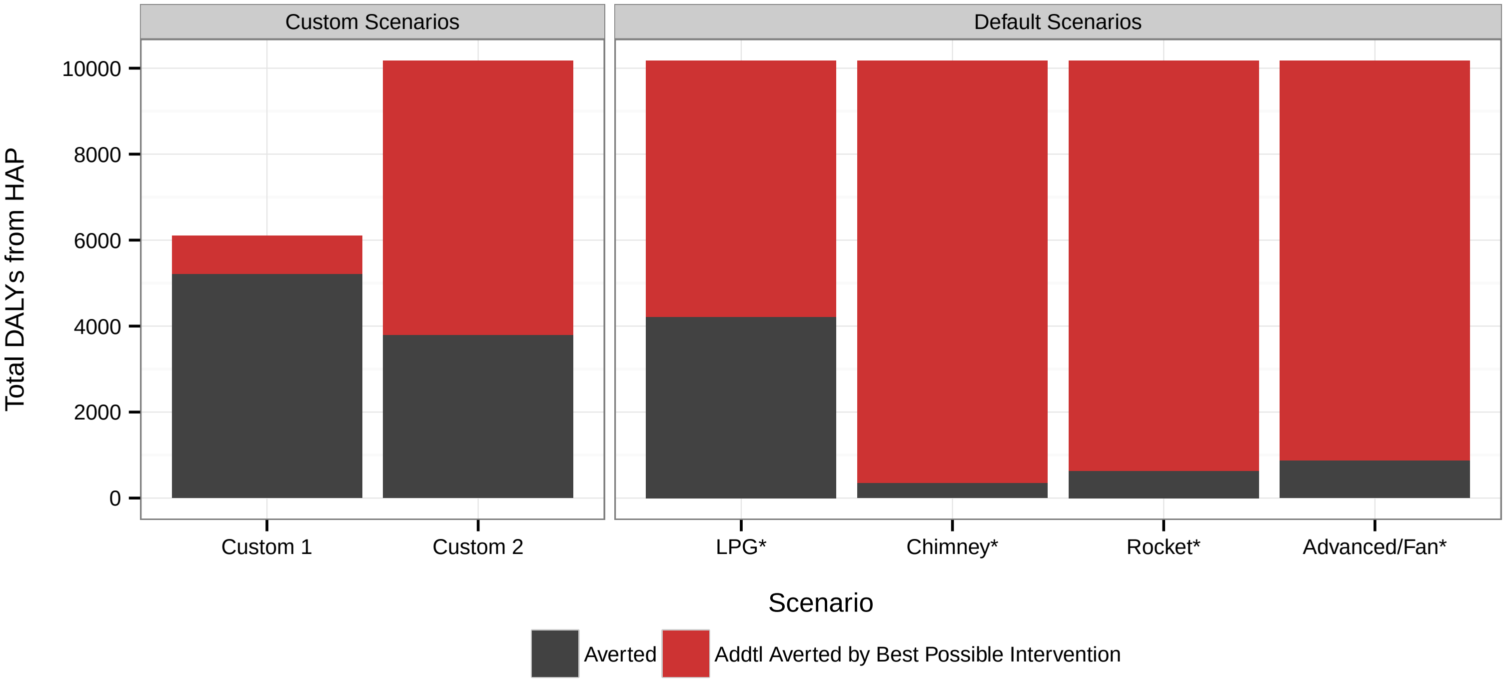
HAPIT reports values for chronic diseases adjusted using the EPA 20 year Cessation lag. Deaths and DALYs in children (due to acute lower respiratory infection, ALRI) are unadjusted and are assumed to accrue quickly after intervention deployment. Averted deaths and DALYs are reported in Table 2. DALYs averted by the interventions, summed across all disease categories, are presented in dark grey in Figure 1. Red indicates unaverted DALYs still remaining in the target population from HAP. Table 4 contains averted Deaths and DALYs by disease category for each scenario.

WHO CHOICE Cost Effectiveness Analysis

Cost-effectiveness is determined by comparing the expected annual cost of the intervention per DALY averted to the GDP/Capita in international dollars. The World Health Organization's CHOosing Interventions that are Cost-Effective (WHO CHOICE) effort advises that interventions costing less than the GDP/capita are very cost-effective, those costing one to three times the GDP/capita are cost-effective, and those costing more than three times the GDP/capita are not cost-effective.

Tables and Figures

Averted and Unaverted DALYs by Scenario



Total Averted Deaths and DALYs

Scenario	Pre-Intervention	Post-Intervention	Total DALYs	Total Deaths
Custom 1	172	35	5200	117.50
Custom 2	172	35	3770	86.20
LPG*	172	24	4260	96.40
Chimney*	172	120	353	7.37
Rocket*	172	96	630	12.70
Advanced/Fan*	172	80	872	17.70

Children's Health: Averted Deaths and DALYs due to ALRI

Scenario	Pre-Intervention	Post-Intervention	ALRI DALYs <5	ALRI Deaths <5
Custom 1	172	35	2900	34.0
Custom 2	172	35	2100	25.0
LPG*	172	24	2400	27.0
Chimney*	172	120	210	2.5
Rocket*	172	96	390	4.5
Advanced/Fan*	172	80	550	6.4

Averted Deaths and DALYs due to Chronic Diseases in Adults

Scenario	Pre-Intervention	Post-Intervention	COPD DALYs	COPD Deaths	IHD DALYs	IHD Deaths
Custom 1	172	35	440	8.60	800	32.0
Custom 2	172	35	320	6.20	580	24.0
LPG*	172	24	300	5.80	600	24.0
Chimney*	172	120	42	0.82	54	2.2
Rocket*	172	96	67	1.30	91	3.7
Advanced/Fan*	172	80	86	1.70	120	5.0

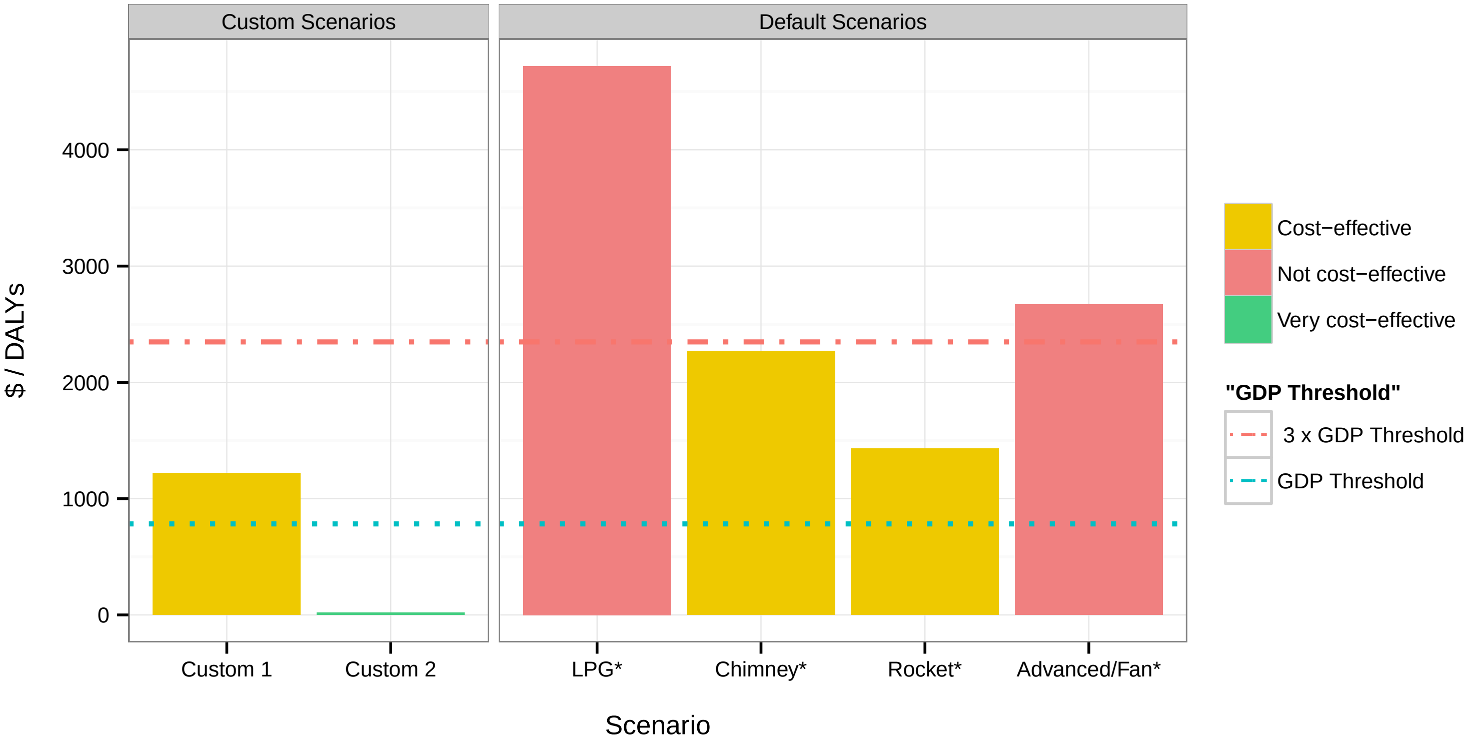
Scenario	Pre-Intervention	Post-Intervention	Lung Cancer DALYs	Lung Cancer Deaths	Stroke DALYs	Stroke Deaths
Custom 1	172	35	190	6.90	870	36.0
Custom 2	172	35	140	5.00	630	26.0
LPG*	172	24	130	4.60	830	35.0
Chimney*	172	120	18	0.65	29	1.2
Rocket*	172	96	28	1.00	54	2.2
Advanced/Fan*	172	80	36	1.30	80	3.3

Based on published health literature, HAPIT reports impacts for four chronic diseases in adults caused by air pollution. These impacts decline over a 20-year period after reductions in air pollution exposure (according to USEPA analyses): Chronic Obstructive Pulmonary Disease (COPD), Ischaemic Heart Disease (IHD), Lung Cancer, and Stroke. HAPIT also reports impacts for one acute disease in children under five years caused by air pollution that is thought to decline within a few weeks of exposure reduction: Acute Lower Respiratory Infections (ALRI, often simply called pneumonia).

Unlike ALRI, the chronic diseases caused by air pollution do not appear immediately with pollution exposure, as they are due to past exposures. Consequently, the risk of disease also does not immediately disappear with exposure reductions, but trends downward over time eventually reaching background levels if the exposure has been eliminated. Put another way, a household intervention that instantly eliminates all exposure will create some immediate benefit in terms of lower disease rates, but cannot eliminate all disease risk immediately. HAPIT takes this into account in the figure above by comparing the performance of the intervention being proposed with a hypothetical best possible intervention that 1) instantly reduces exposures to the counterfactual level; 2) works for 5 years; 3) and is used by 100% of the population. It is important to point out, however, that there is an additional residual chronic health burden not shown, which is essentially "unavertable", i.e., not possible to avert because it is already built into the physiology of the population due to the past exposures they have experienced.

In HAPIT, health benefits for chronic diseases are accrued for 2 years beyond the intervention's useful lifetime for each scenario. In the fifth year of an intervention with a 5-year lifetime, about 80% of the benefits for that year will be accrued. The remaining 20%, however, will not appear unless 20 total years with sustained exposure reductions have passed. Averted ALRI deaths & DALYs are assumed to accrue quickly after intervention deployment and cease quickly when the useful intervention lifetime is exceeded.

WHO CHOICE Cost-Effectiveness by Scenario



Scenario	1st Yr Cost	Maintenance Cost	Annualized Cost	ALRI Deaths Averted	DALYs Averted
Custom 1	1800000	652500	909642.86	34.0	5200
Custom 2	75000	0	10714.29	25.0	3770
LPG*	2125000	3600000	4025000.00	27.0	4260
Chimney*	500000	75000	200000.00	2.5	353
Rocket*	750000	37500	225000.00	4.5	630
Advanced/Fan*	1875000	112500	581250.00	6.4	872

Scenario	USD per Averted Child Death	USD per Averted DALY	CHOICE Category
Custom 1	187000	1220.0	Cost-effective
Custom 2	3000	19.9	Very cost-effective
LPG*	745000	4720.0	Not cost-effective
Chimney*	320000	2270.0	Cost-effective
Rocket*	200000	1430.0	Cost-effective
Advanced/Fan*	363000	2670.0	Not cost-effective

HAPIT estimates program cost-effectiveness based on WHO CHOICE. It takes a financial accounting approach. In doing so, it does (1) not take into account the household costs due to medical expenditure or the time or money spent acquiring fuel and (2) assumes that programs are covering the cost of fuel-based interventions (such as monthly LPG costs per household). For custom scenarios, users can adjust the per-household maintenance or fuel cost based on the characteristics of their programs on the settings tab.

*Strickly speaking, deaths cannot be averted, but only postponed. Thus, the correct term is averted premature deaths, but for conciseness, we use deaths here.

Visit HAPIT on the web for information on the methods used to generate the results outlined in this document. Click the “Documentation & Background” tab for detailed descriptions of data sources and methodologies.

HAPIT was created by Ajay Pillarisetti and Kirk R. Smith of the Household Energy, Climate, and Health Research Group at University of California, Berkeley with support from the Global Alliance for Clean Cookstoves.

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                                                      ___/   /   /___/   /   /___/
                                                        Statistics/Data Analysis


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Notes:
      1.  Unicode is supported; see help unicode_advice.
      2.  Maximum number of variables is set to 5000; see help set_maxvar.

running C:\Program Files (x86)\Stata14\profile.do ...

1 . use "E:\Clean Fuels\Survey results_in Stata v2.dta", clear

2 . summarize endcookage

    Variable |        Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
  endcookage |        100       37.91    12.13401         14         70

3 .
4 . summarize hhsize

    Variable |        Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
      hhsize |        100        5.08     1.66169          2         10

5 .
6 . regress healthchange minuteswoodburn endprimarygas

      Source |       SS           df       MS      Number of obs   =        95
-------------+----------------------------------   F(2, 92)        =      5.89
       Model |  2.47737908         2  1.23868954   Prob > F        =    0.0039
    Residual |  19.3541999        92  .210371738   R-squared       =    0.1135
-------------+----------------------------------   Adj R-squared   =    0.0942
       Total |  21.8315789        94   .23225084   Root MSE        =    .45866

------------------------------------------------------------------------------
healthchange |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
minuteswood~n |   .0016156   .0005377     3.00   0.003     .0005477    .0026835
endprimarygas |   .2920787   .1171146     2.49   0.014     .0594791    .5246784
       _cons |    .248112   .1288032     1.93   0.057    -.0077022    .5039262
------------------------------------------------------------------------------
```

```
  7 .
  8 . regress switch healthcook healthchild healthadult

      Source |       SS           df       MS      Number of obs   =       100
-------------+----------------------------------   F(3, 96)        =      4.31
       Model |  2.91117436         3  .970391455   Prob > F        =    0.0067
    Residual |  21.5988256        96  .224987767   R-squared       =    0.1188
-------------+----------------------------------   Adj R-squared   =    0.0912
       Total |       24.51        99  .247575758   Root MSE        =    .47433

------------------------------------------------------------------------------
      switch |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  healthcook |   .3120108   .0997113     3.13   0.002     .1140854    .5099361
 healthchild |   .0483393   .0984095     0.49   0.624    -.1470021    .2436806
 healthadult |   .1758344   .1068961     1.64   0.103    -.0363527    .3880214
       _cons |   .1660504   .0912093     1.82   0.072    -.0149985    .3470994
------------------------------------------------------------------------------

  9 . summarize endcookedu totalcost fuelelec endtimebiz hhsize

    Variable |        Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
  endcookedu |        100        3.36    .8470984          1          5
   totalcost |        100     21.9583    17.51169        1.5     109.88
    fuelelec |        100         .59    .4943111          0          1
  endtimebiz |        100         .42     .496045          0          1
      hhsize |        100        5.08     1.66169          2         10

 10 .
 11 . regress endprimarygas endcookedu totalcost fuelelec endtimebiz hhsize

      Source |       SS           df       MS      Number of obs   =       100
-------------+----------------------------------   F(5, 94)        =      1.14
       Model |  1.04304979         5  .208609958   Prob > F        =    0.3447
    Residual |  17.1969502        94  .182946279   R-squared       =    0.0572
-------------+----------------------------------   Adj R-squared   =    0.0070
       Total |       18.24        99  .184242424   Root MSE        =    .42772

------------------------------------------------------------------------------
endprimary~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  endcookedu |  -.0086787   .0518474    -0.17   0.867    -.1116229    .0942655
   totalcost |     .00107   .0026708     0.40   0.690     -.004233    .0063729
    fuelelec |   .1795042   .0880176     2.04   0.044     .0047432    .3542651
  endtimebiz |   .0482366   .0902413     0.53   0.594    -.1309397    .2274129
      hhsize |  -.0311388   .0269121    -1.16   0.250    -.0845733    .0222957
       _cons |   .7976836   .2354076     3.39   0.001     .3302764    1.265091
------------------------------------------------------------------------------

 12 .
 13 . regress endLPGself endcookedu totalcost fuelelec endtimebiz hhsize

      Source |       SS           df       MS      Number of obs   =       100
-------------+----------------------------------   F(5, 94)        =      2.05
       Model |  3639.14096         5  727.828192   Prob > F        =    0.0780
    Residual |  33292.5659        94  354.176233   R-squared       =    0.0985
-------------+----------------------------------   Adj R-squared   =    0.0506
       Total |  36931.7069        99  373.047544   Root MSE        =     18.82
```

```
------------------------------------------------------------------------------
  endLPGself |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  endcookedu |  -.3363052    2.28126    -0.15   0.883    -4.865801     4.19319
   totalcost |   .2486042   .1175143     2.12   0.037     .0152768    .4819315
   fuelelec  |  -5.485557    3.87273    -1.42   0.160    -13.17495    2.203839
  endtimebiz |   2.148834   3.970576     0.54   0.590    -5.734837     10.0325
      hhsize |   .9714861   1.184117     0.82   0.414    -1.379607    3.322579
       _cons |   26.97738   10.35782     2.60   0.011     6.411686    47.54307
------------------------------------------------------------------------------

14 .
15 . regress switch endcookedu totalcost fuelelec endtimebiz hhsize

      Source |       SS           df       MS      Number of obs   =       100
-------------+----------------------------------   F(5, 94)        =      0.50
       Model |  .634695834         5  .126939167   Prob > F        =    0.7757
    Residual |  23.8753042        94  .253992598   R-squared       =    0.0259
-------------+----------------------------------   Adj R-squared   =   -0.0259
       Total |       24.51        99  .247575758   Root MSE        =    .50398

------------------------------------------------------------------------------
      switch |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  endcookedu |    .007276   .0610908     0.12   0.905    -.1140211    .1285732
   totalcost |  -.0042453    .003147    -1.35   0.181    -.0104937    .0020031
    fuelelec |   .0164533   .1037094     0.16   0.874    -.1894641    .2223707
  endtimebiz |  -.0045905   .1063296    -0.04   0.966    -.2157105    .2065294
      hhsize |   .0318577   .0317099     1.00   0.318    -.0311032    .0948185
       _cons |   .3291555   .2773762     1.19   0.238    -.2215814    .8798924
------------------------------------------------------------------------------

16 . regress endprimarygas hhsize endcookedu fuelelec ownedstove base_fear endfoodg
   > rill end_decreasecost

      Source |       SS           df       MS      Number of obs   =       100
-------------+----------------------------------   F(7, 92)        =      5.69
       Model |  5.51070157         7  .787243082   Prob > F        =    0.0000
    Residual |  12.7292984        92  .138361939   R-squared       =    0.3021
-------------+----------------------------------   Adj R-squared   =    0.2490
       Total |       18.24        99  .184242424   Root MSE        =    .37197

-------------------------------------------------------------------------------
endprimarygas |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
       hhsize |  -.0297874   .0225414    -1.32   0.190    -.0745566    .0149817
   endcookedu |  -.0006297   .0450894    -0.01   0.989    -.0901811    .0889216
     fuelelec |   .1294207   .0807025     1.60   0.112    -.0308615    .2897028
   ownedstove |  -.1851947   .1436447    -1.29   0.201    -.4704854     .100096
    base_fear |   .1476027   .1347586     1.10   0.276    -.1200396     .415245
 endfoodgrill |  -.5354164   .1022379    -5.24   0.000    -.7384697   -.3323631
end_decreas~t |   .0613926   .1069602     0.57   0.567    -.1510397    .2738248
        _cons |   .9250563   .2192944     4.22   0.000     .4895187    1.360594
-------------------------------------------------------------------------------
```

```
17 .
18 . regress endLPGself hhsize endcookedu fuelelec ownedstove base_fear endfoodgril
   > l end_decreasecost

         Source |       SS           df       MS      Number of obs   =       100
   -------------+----------------------------------   F(7, 92)        =      2.42
          Model |  5737.60607         7  819.658011   Prob > F        =    0.0256
       Residual |  31194.1008        92  339.066313   R-squared       =    0.1554
   -------------+----------------------------------   Adj R-squared   =    0.0911
          Total |  36931.7069        99  373.047544   Root MSE        =    18.414

   ------------------------------------------------------------------------------
      endLPGself |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
   -------------+----------------------------------------------------------------
          hhsize |   1.645096   1.115873     1.47   0.144    -.5711236    3.861315
      endcookedu |  -.5763502   2.232072    -0.26   0.797    -5.009437    3.856737
        fuelelec |  -7.581678    3.99504    -1.90   0.061    -15.51617    .3528154
      ownedstove |   20.92943   7.110883     2.94   0.004     6.806606    35.05226
       base_fear |  -20.76291   6.670995    -3.11   0.002    -34.01209   -7.513743
     endfoodgrill |  -4.967523   5.061112    -0.98   0.329    -15.01933    5.084283
   end_decreas~t |   1.692344   5.294882     0.32   0.750    -8.823749    12.20844
           _cons |   29.54435   10.85579     2.72   0.008     7.983803    51.10489
   ------------------------------------------------------------------------------

19 .
20 . regress endtotLPG_mfl hhsize endcookedu fuelelec ownedstove base_fear endfoodg
   > rill end_decreasecost

         Source |       SS           df       MS      Number of obs   =       100
   -------------+----------------------------------   F(7, 92)        =      2.08
          Model |  4816.03307         7  688.004724   Prob > F        =    0.0535
       Residual |  30441.4069        92  330.884858   R-squared       =    0.1366
   -------------+----------------------------------   Adj R-squared   =    0.0709
          Total |    35257.44        99  356.135758   Root MSE        =     18.19

   ------------------------------------------------------------------------------
   endtotLPG_mfl |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
   -------------+----------------------------------------------------------------
          hhsize |   .6918642   1.102328     0.63   0.532    -1.497454    2.881182
      endcookedu |   -.246668   2.204978    -0.11   0.911    -4.625945    4.132609
        fuelelec |    .278774   3.946546     0.07   0.944    -7.559408    8.116956
      ownedstove |   5.352907   7.024568     0.76   0.448    -8.598492    19.30431
       base_fear |   -7.37609    6.59002    -1.12   0.266    -20.46444    5.712258
     endfoodgrill |  -12.36936   4.999678    -2.47   0.015    -22.29916    -2.43957
   end_decreas~t |   8.809015   5.230611     1.68   0.096     -1.57943    19.19746
           _cons |   33.70697   10.72402     3.14   0.002     12.40814     55.0058
   ------------------------------------------------------------------------------

21 .
22 . regress switch hhsize endcookedu fuelelec ownedstove base_fear endfoodgrill en
   > d_decreasecost

         Source |       SS           df       MS      Number of obs   =       100
   -------------+----------------------------------   F(7, 92)        =      4.38
          Model |  6.1237056          7  .874815085   Prob > F        =    0.0003
       Residual |  18.3862944        92  .199851026   R-squared       =    0.2498
   -------------+----------------------------------   Adj R-squared   =    0.1928
          Total |       24.51        99  .247575758   Root MSE        =    .44705
```

```
------------------------------------------------------------------------------
      switch |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      hhsize |   .0197252    .027091     0.73   0.468    -.0340799    .0735303
  endcookedu |   .0347372     .05419     0.64   0.523    -.0728888    .1423632
    fuelelec |   .1330653   .0969911     1.37   0.173    -.0595674     .325698
  ownedstove |  -.5975332   .1726372    -3.46   0.001    -.9404056   -.2546608
   base_fear |   .0591646   .1619577     0.37   0.716    -.2624973    .3808265
 endfoodgrill |  -.3021814   .1228731    -2.46   0.016     -.546218   -.0581449
end_decreas~t |   .0774468   .1285485     0.60   0.548    -.1778617    .3327553
       _cons |   .4675918   .2635557     1.77   0.079    -.0558526    .9910361
------------------------------------------------------------------------------

23 .
24 . regress enddropout hhsize endcookedu fuelelec ownedstove base_fear endfoodgril
   > l end_decreasecost

      Source |       SS           df       MS      Number of obs   =       100
-------------+----------------------------------   F(7, 92)        =      5.91
       Model |  3.50634847         7  .500906925   Prob > F        =    0.0000
    Residual |  7.80365153        92  .084822299   R-squared       =    0.3100
-------------+----------------------------------   Adj R-squared   =    0.2575
       Total |       11.31        99  .114242424   Root MSE        =    .29124

------------------------------------------------------------------------------
  enddropout |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      hhsize |    .008003   .0176493     0.45   0.651      -.02705     .043056
  endcookedu |   .0537536   .0353037     1.52   0.131    -.0163627    .1238699
    fuelelec |   .0304401   .0631879     0.48   0.631    -.0950565    .1559367
  ownedstove |   .1663222   .1124699     1.48   0.143    -.0570527     .389697
   base_fear |  -.1005992   .1055124    -0.95   0.343    -.3101558    .1089575
 endfoodgrill |   .4109419   .0800495     5.13   0.000     .2519567    .5699272
end_decreas~t |  -.1588962   .0837469    -1.90   0.061    -.3252249    .0074325
       _cons |  -.1068132   .1717016    -0.62   0.535    -.4478274    .2342009
------------------------------------------------------------------------------

25 .
26 .
27 .
28 . regress endusetimes endtotLPG_mfl endHHsize

      Source |       SS           df       MS      Number of obs   =       100
-------------+----------------------------------   F(2, 97)        =     29.01
       Model |  50.5288806         2  25.2644403   Prob > F        =    0.0000
    Residual |  84.4711194        97  .870836283   R-squared       =    0.3743
-------------+----------------------------------   Adj R-squared   =    0.3614
       Total |         135        99  1.36363636   Root MSE        =    .93319

------------------------------------------------------------------------------
 endusetimes |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
endtotLPG_mfl |   .0378866    .004983     7.60   0.000     .0279967    .0477766
   endHHsize |  -.0528798   .0520263    -1.02   0.312    -.1561375     .050378
       _cons |    1.02557   .3380037     3.03   0.003     .3547264    1.696414
------------------------------------------------------------------------------

29 .
```