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Economic Benefits of the Wonderbag Cooking Technology: An Impact Assessment

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This report is part of a series of research studies into alternative energy pathways for the global economy. In addition to disseminating original research findings, these studies are intended to contribute to policy dialogue and public awareness about environment-economy linkages and sustainable growth. All opinions expressed here are those of the authors and should not be attributed to their affiliated or supporting institutions.

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EXECUTIVE SUMMARY

The Wonderbag is an energy efficient cooking utensil designed for use with a broad spectrum of stove and other food preparation technologies. By insulating food containers have that have been pre-heated by conventional means, the Wonderbag extends the cooking process without the need for continued energy use or human supervision. Laboratory studies have demonstrated significant potential for a variety of benefits, including reduced energy use, labor saving, and a range of indirect health and environmental benefits.

To statistically ascertain Wonderbag's benefits in real world application, we conducted a detailed household survey in a Durban, South Africa, residential area where low-income households have been using Wonderbag for up to two years. Based on a sample of about 4000 households, we have econometrically validated three cardinal economic benefits of this technology:

1. Savings of cooking time per household member (8-21%)
2. Savings of money spent on fuel (10-36%)
3. Higher food spending per household member (36-60%)

This study could be extended in a variety of directions, measuring similar impacts in other communities and examining other impact in the sample community. For the present, however, our results demonstrate empirically that Wonderbag can confer significant economic benefits on low-income communities and these benefits should support voluntary adoption with more determined promotion. Promotion schemes can also increase the per household benefits, bringing them closer to their potential and liberating more financial and labor resources to improve consumption and livelihoods among the poor.

1 INTRODUCTION

Wonderbag is a cooking technology with the potential to improve household energy use efficiency, environmental and safety standards, and save labor. This appliance is largely independent of other technology choices such as stove and fuel type, applicable to the vast majority of staple food production practices, and requires only minimal training for safe and effective adoption into traditional cooking systems.

For all these reasons, Wonderbag adoption and diffusion should be promoted extensively in developing and middle-income economies, and intensively in very low-income settings where there are serious constraints on labor and fuel resources. To achieve this, we propose a two-part research program. The first component is a Prospects Assessment, evaluating necessary and sufficient conditions for successful diffusion of Wonderbag across four large emerging market economies: China, India, Brazil, and Indonesia. Together, these four countries comprise about half of humanity and a significant majority of the world's poor. Because only four national governments are represented, we believe that targeting these countries is the most effective way to promote global diffusion of Wonderbag. The Prospects assessment will include detailed analysis of customary practices among eligible households, institutional research on national policies related to Wonderbag, and two in-country pilot studies to evaluate adoption/diffusion strategies.

The second component of this research is a rigorous impact evaluation of existing Wonderbag adoption. Solid evidence of where, how, and why Wonderbag helps the poor will be essential to effectively promote its global deployment. Fortunately, Wonderbag has been very successfully deployed in Southern and Eastern Africa, with hundreds of thousands of individual adoptions and steady growth of diffusion around this region. Despite a wealth of anecdotal evidence attesting to Wonderbag's benefits, the technology remains to be validated with large scale and rigorous impact evaluation. Simply put, many thousands of early adopters know why they value the Wonderbag, but statistical research is needed to identify the particularly characteristics of both Wonderbag and households that lead to successful adoption. Moreover, a rigorous statistical analysis can elucidate larger social benefits from Wonderbag that would arouse support from public and private agencies; particularly those associated with public health, energy and environment policy, social and gender affairs, etc.

The project will yield a variety of knowledge products to support Wonderbag globalization. Two monograph-length reports will be produced, one for each main component. Each monograph will be distilled into a strategy document with roadmaps to promote Wonderbag national deployment (Prospects) and presentation to donors and policy makers (Impact Evaluation). The long reports will be disseminated as independent academic assessments, followed by Wonderbag presentation versions for media, policy dialog, and communication with donors and private stakeholders. In addition, several policy brief or brochure length reports will document the advantages of Wonderbag for a wider audience. Research staff will be available on an as-needed basis to support these communication activities.

2 EMPIRICAL RESULTS

In this section we present the most recent statistical findings of our research with the data obtained in the Durban Wonderbag Survey (DWBS). These results represent salient but focused insights regarding Wonderbag real and potential impacts on low-income communities. While they are important in themselves, and clearly demonstrate the economic value of Wonderbag, the scope of the DWBS would support more extensive assessment of cooking practices and technology choice in this community. At the end of the section, we discuss such extensions, as well as productive directions for future survey work.

2.1 Descriptive Statistics

As is customary upon completion of a large survey exercise, the first step in empirical assessment is to review general properties of the sample. This includes, but may not be limited to, tabulations of individual variables, ANOVA comparisons of variable groups, and general representation analysis. In this section, we report a sub-set of descriptive statistics on the DWBS that are of particular relevance to our main econometric findings.

When looking at Wonderbag use more closely, tabulation results already suggest the three main findings of our more intensive statistical analysis. In particular, the following tables clearly suggest that Wonderbag is associated with three cardinal economic benefits:

1. Reduced household time spent cooking

2. Reduced fuel cost

3. Higher household food expenditure

For low-income communities, the importance of these three benefits can hardly be overstated. As has been emphasized in the discussion above, reducing carbon fuel use has many health and environmental benefits, but for poor households economic benefits are an immediate and ever present priority. Even at the descriptive level, Wonderbag reveals it’s association with time and energy efficiency, as well as the primary economic benefit of both, higher potential real incomes and purchasing power that can translate into improved livelihood via increased consumption of essential commodities like food.

Table 2.1 shows that, across the DWBS sample of about 4000 households, those households that use Wonderbag report spending about 15% less time cooking per capita. While cooking is a productive activity, for most households it does not translate directly into additional income, and it also diverts adults from other household services (e.g. child and elder care, maintenance, etc.). The results indicate that Wonderbag liberates a significant amount of additional labor for households to dedicate to both these activities.

Table 2.1: Summary of Cooking Time per Household Member[1]

wbd	Mean	Std. Dev.	Freq.
0	43.34	39.18	1985
1	37.00	34.34	2012
Total	40.15	36.95	3997

The results in Table 2.2 could be considered a partial corollary of those above, i.e. reduced cooking time leads to fuel savings. Of course one could cook faster with higher heat, partially or completely offsetting this beneficial relationship. Conversely, automated appliances can consume energy cooking while freeing time for cooks. Wonderbag however, Wonderbag is designed to reduce both supervision and energy use, and the fuel efficiency benefit translates in the DWBS sample into an average of 13% lower fuel costs per household member.

Table 2.2: Summary of Household Fuel Expense per Capita

wbd	Mean	Std. Dev.	Freq.
0	150.11	221.04	1632
1	130.45	143.03	1802
Total	139.79	184.50	3434

A third and final salient descriptive result associates Wonderbag usage with nutrition. Simple tabulation across the DWBS sample suggests that households using Wonderbag report higher food expenditure levels per capita. Of course there are many possible reasons for this, including higher average income (which we do not

[1] The variable wbd denotes a dummy variable for Wonderbag use (1=users, 0=nonusers). Use statistics are on a household member basis to correct for (within and between group) size variation across households.

sample) for Wonderbag users, but the possibility of substitution between two essential commodities, food and fuel, is especially interesting in the present context. To better ascertain this kind of causal linkage requires more intensive econometric techniques, however, and we explore these in the next sub-section. For the present, we can only conclude that, on a per capita basis, Wonderbag users also spend less time cooking, less money on fuel, and more money on food than nonusers.

Table 2.3: Summary of Household Food Expense per Capita (rand/month)

wbd	Mean	Std. Dev.	Freq.
0	258.89	185.59	1822
1	312.48	167.57	1894
Total	286.20	178.63	3716

2.2 Econometric Results

While the descriptive sample relationships summarized above are suggestive, they do not rigorously establish statistical correlation, let along causal relationships between the variables of interest. In the first instance, we would like to understand if the relationships between Wonderbag use and the time and cost variables is statistically significant, i.e. can be reliably inferred from our sample to hold across a larger population. Secondly, we would like these relationships to have practical predictive power, meaning that initiatives to extend Wonderbag usage could be guided by reliable expectations regarding benefits. To do this, we need rigorous econometric models that yield not just average impacts (point estimates), but confidence intervals that accommodate reasonable levels of uncertainty. Finally, we want to elucidate the question of causality - asking not merely if Wonderbag use is associated with benefits but, when introduced/adopted by a representative household, can actually be expected to induce those benefits. In the following three sub-sections, we address these issues for each of the cardinal economic benefits, using a combination of econometric methods.

2.2.1 Savings in Cooking Time

As labor is the primary endowment of the poor, time saving has a high potential return to poor households. It might seem that low income households, particularly in areas with high and chronic unemployment, have "time on their hands," or that surplus formal sector labor implies idleness among these populations. More detailed studies of time use, particularly among adult females responsible for cooking, suggests that they can be quite time constrained, and that saving time on one task translates into higher levels of productivity in other household enterprise and service activities. Particularly for this group, such individual time benefits become are translated into benefits for the entire household.

To better understand the relationship between Wonderbag use and savings in cooking time, we begin with a standard regression model. Summarize in Table 2.4 below, we see cooking time savings associated with Wonderbag (wonderbagdummy=1) averaging 5.48 minutes per family member per week. This translates into 14.8% average time saving for Wonderbag households, almost exactly the result from the descriptive statistics (Table 2.1). This time, however, we have established a statistically significant relationship and a confidence interval. The latter means that time saving among Wonderbag users will range (95% of the time) between 8% (3 min/pc) and 22% (7.89 min/pc).

Table 2.4: Modeling Cooking Time per Capita: Linear Regression

Source	SS	df	MS
Model	219242.668	3	73080.8895
Residual	4706401.64	3544	1327.99143
Total	4925644.3	3547	1388.67897

Number of obs	3548
F(3, 3544)	55.03
Prob > F	0.0000
R-squared	0.0445
Adj R-squared	0.0437
Root MSE	36.442

ct_per_member	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
wonderbagdummy	-5.481514	1.228805	-4.46	0.000	-7.890751	-3.072277
grocer_expense	-.0059827	.0007256	-8.24	0.000	-.0074054	-.00456
hh_education_highest	-2.12283	.3450898	-6.15	0.000	-2.799425	-1.446235
_cons	78.52212	4.356687	18.02	0.000	69.98025	87.06399

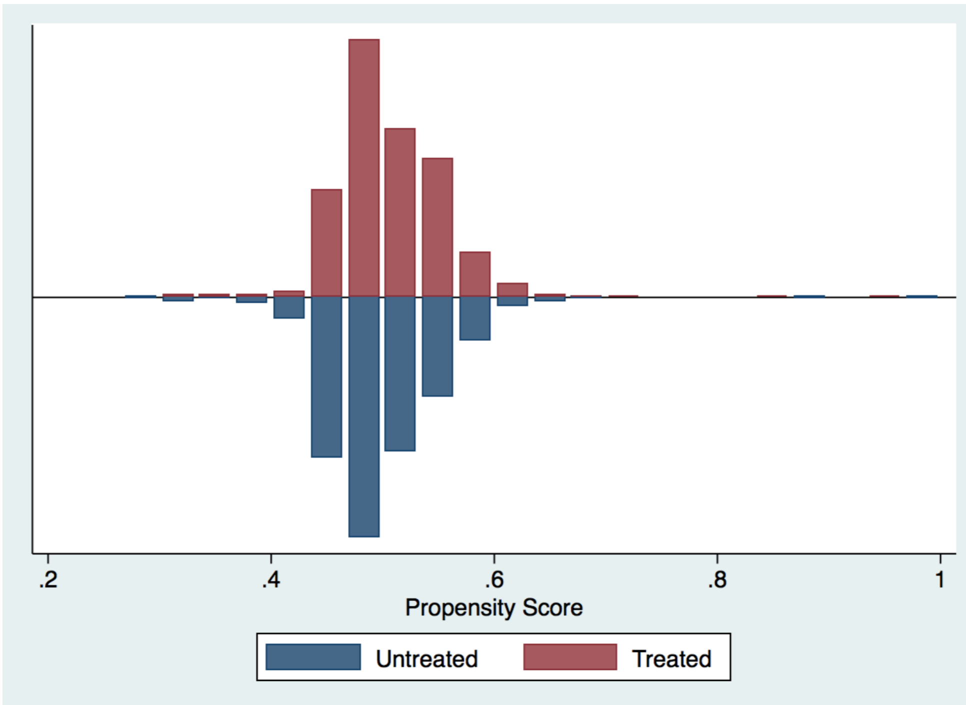
A few observations are in order for the other variables in this model. Total household food cost (grocer_expense) is negatively associated with cooking time, but has a negligibly small coefficient. While an exact interpretation of this would require more detailed analysis of the underlying data, it is most likely that higher food expenditures are associated with higher incomes and more time efficient cooking technology. The same interpretation can be given to our other income proxy variable, educational attainment (hh_education_highest). As was explained in the survey overview, we did not sample total income because of concerns about reporting bias, and did not have the time and resources for exhaustive sampling of expenditure categories. Thus we use an education proxy for income differences, which suggests that higher opportunity cost of labor is associated with less time cooking. Again, this can be the result of cultural, technological, or other choices, but we do not further identify them here.

Having firmly established a statistical link between Wonderbag use and time saving, we now examine the question of causality, i.e. would introducing Wonderbag into a representative household be expected to itself (other things equal) reduce cooking time and do so predictably? This question is typical of classical impact evaluation, where one uses statistical methods to establish and estimate the impacts of some "treatment" administered to a population. This is a higher standard of linkage assessment than regression analysis, which is more rigorous than simple tabulation but still it only establishes passive correlation. To identify a causal link, we need to carefully control for other sources of sample variation, isolating the role of the treatment to the maximum extent possible. The ideal way to accomplish this is to have two distinct samples, randomized by identical standards but differing in only one characteristics, presence or absence of treatment. With two such groups, one can fully identify the treatment effect even against stochastic within sub-sample variation.

In the DBWS, our original goal was to take this approach, sampling randomly among comparable populations with and without Wonderbag. In the event, however, resource and information constraints prevented this and we were forced to sample extensively across available neighborhoods. More details on this are presented in Section 3 above, but suffice to say for the present that we produced a sample of 4000 households, about half of which were Wonderbag users. Given that we could not achieve the ideal sampling strategy, we are instead taking advantage of non-survey causality modeling, or Propensity Score Matching (PSM) econometric methods. Like our situation, it is quite rare to have ideally segregated samples for impact evaluation. For this reason, a variety of techniques have developed second-best inferential techniques like the ones we apply here. In essence, these methods seek to identify shared characteristics across treated and untreated sample groups and, holding these constant, evaluate the outcome difference associated with the treatment. To the extent that treatment impacts are robust against (mutual) changes in other underlying sample characteristics, they can be inferred to be reliable estimates.

The efficacy of the PSM approach depends critically on the concept of sample support, meaning that the characteristics of both treated and untreated subsamples should jointly span the overall sample's set of characteristics. An example of where this might fail is eyeglass impact and incomes. If only very high-income groups have glasses and low-income groups do not, PSM cannot reliably predict the impact across both groups. For the DWBS, however, we were very fortunate in terms of sample support. As the following figure shows, both the treated (Wonderbag) and untreated groups span the sample space of other attributes (food costs and education). Not only are they highly conformal, but they follow apparent and natural exponential distributions.

Figure 2.1: Propensity Score Histogram: Cooking Time with respect to Food Expenses and Education Levels



Source: Author's estimates.
Note: The y axis is proportional by group – treated and untreated scales may differ.

With a solid foundation in terms of sample support, we report the first set of PSM results in Table 2.5 below. The results are not only fully consistent with both the descriptive and regression findings, but suggest a more direct and even stronger link between Wonderbag usage and time saving. After taking account of sample differences that could undermine a causal inference, we find that Wonderbag adoption by an untreated household could be expected to reduce cooking time by 6.79 minutes per capita (18.35%) on average. Thus controlling for sample characteristics and expunging secondary sources of variation has actually strengthened the Wonderbag impact evaluation with respect to a passive correlation estimate.

Table 2.5: Propensity Score Matching Model: Cooking Time per Capita

```
Logistic regression                               Number of obs   =       3548
                                                  LR chi2(2)      =      31.85
                                                  Prob > chi2     =     0.0000
Log likelihood = -2443.2931                       Pseudo R2       =     0.0065

------------------------------------------------------------------------------
wonderbagd~y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
grocer_exp~e |   .0001907   .0000476     4.01   0.000     .0000974     .000284
hh_educati~t |   .0497419   .0195684     2.54   0.011     .0113885    .0880953
       _cons |   -.885798   .2449499    -3.62   0.000    -1.365891   -.4057049
------------------------------------------------------------------------------
There are observations with identical propensity score values.
The sort order of the data could affect your results.
Make sure that the sort order is random before calling psmatch2.
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
   ct_per_member  Unmatched | 36.9793925   43.7677629  -6.78837046   1.24623311    -5.45
                        ATT | 36.9793925   35.0646571   1.91473534   9.61908592     0.20
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

           | psmatch2:
 psmatch2: |   Common
 Treatment |  support
assignment | On suppor |     Total
-----------+-----------+----------
 Untreated |     1,763 |     1,763
   Treated |     1,785 |     1,785
-----------+-----------+----------
     Total |     3,548 |     3,548
```

A third and final approach to impact evaluation, Nearest Neighbor Matching (NNM) is a refinement of basic PSM techniques due to Abadie and Imbens (2002). In this approach, each case in the control group is matched to a treated case based on the closest propensity score. These results, summarized in Table 2.5, are fully consistent with what we have found so far, a statistically significant causal relationship between Wonderbag adoption and reduction in cooking time per capita. In the present case, we have a smaller (but still significant) estimate of average savings (4.65 min or 12.6%), but this remains within the confidence interval predicted by both the other two methods.

Table 2.6: Nearest Neighbor Matching Model: Cooking Time per Capita

```
Treatment-effects estimation                    Number of obs      =      3548
Estimator      : propensity-score matching      Matches: requested =         1
Outcome model  : matching                                      min =         1
Treatment model: logit                                         max =       185
--------------------------------------------------------------------------------
               |              AI Robust
 ct_per_member |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
ATET           |
wonderbagdummy |
     (1 vs 0)  |  -4.652215   1.167246    -3.99   0.000    -6.939975   -2.364454
--------------------------------------------------------------------------------
```

2.2.2 Savings on Fuel

For most of the world's low income households, food and fuel are essential commodities. Not only is demand for these goods inelastic, meaning they crowd out other expenditures in times of adversity (i.e. frequently), they generally command a large percentage of poor people's income, labor, and other resources. As we saw with food, labor time can be saved with the efficiency benefits conferred by Wonderbag. If Wonderbag also conserves fuel, the same should be true for time and money spent on fuel acquisition. Indeed, the financial benefit may be even more important in households with high unemployment rates.

As mentioned in Section 2.1, however, fuel efficiency and time efficiency are not synonymous across cooking technologies. As with electric vs. manual eggbeaters, some convenience technologies require more energy, while more labor-intensive ones save it. Although the salient uses of Wonderbag suggest both time and energy saving, the magnitude (if not the sign) of each is an empirical question, and thus the present section reports separate statistical analysis of fuel savings attributable to Wonderbag adoption. Because we are comparing results across a variety of fuel types (both between and within households), we assess fuel efficiency with a universal metric, fuel cost per household member.

The estimation strategy is the same three-fold approach used for cooking time. The standard regression results are summarized in Table 2.7 below, we see cooking timesavings associated with Wonderbag (wonderbagdummy=1) averaging about 23 Rand per family member per week. This translates into 17.7% average fuel savings for Wonderbag households, about half again as mush as suggested by the descriptive statistics (Table 2.2). This time, however, we have established a statistically significant relationship and a confidence interval. The latter means that time saving among Wonderbag users will range (95% of the time) between 8% (10 Rand/pc) and 28% (36 Rand/pc). Because of the low income and high unemployment in the sample community, the fact that percentage gains in money are greater than those in labor time is particularly significant. Simply put, labor may be plentiful but money is scarce. Indeed, even if family members are available for the time needed to cook by conventional means, it still makes sense to invest in Wonderbag as a means of conserving precious household financial resources.

Table 2.7: Modeling Fuel Cost per Household Member: Linear Regression

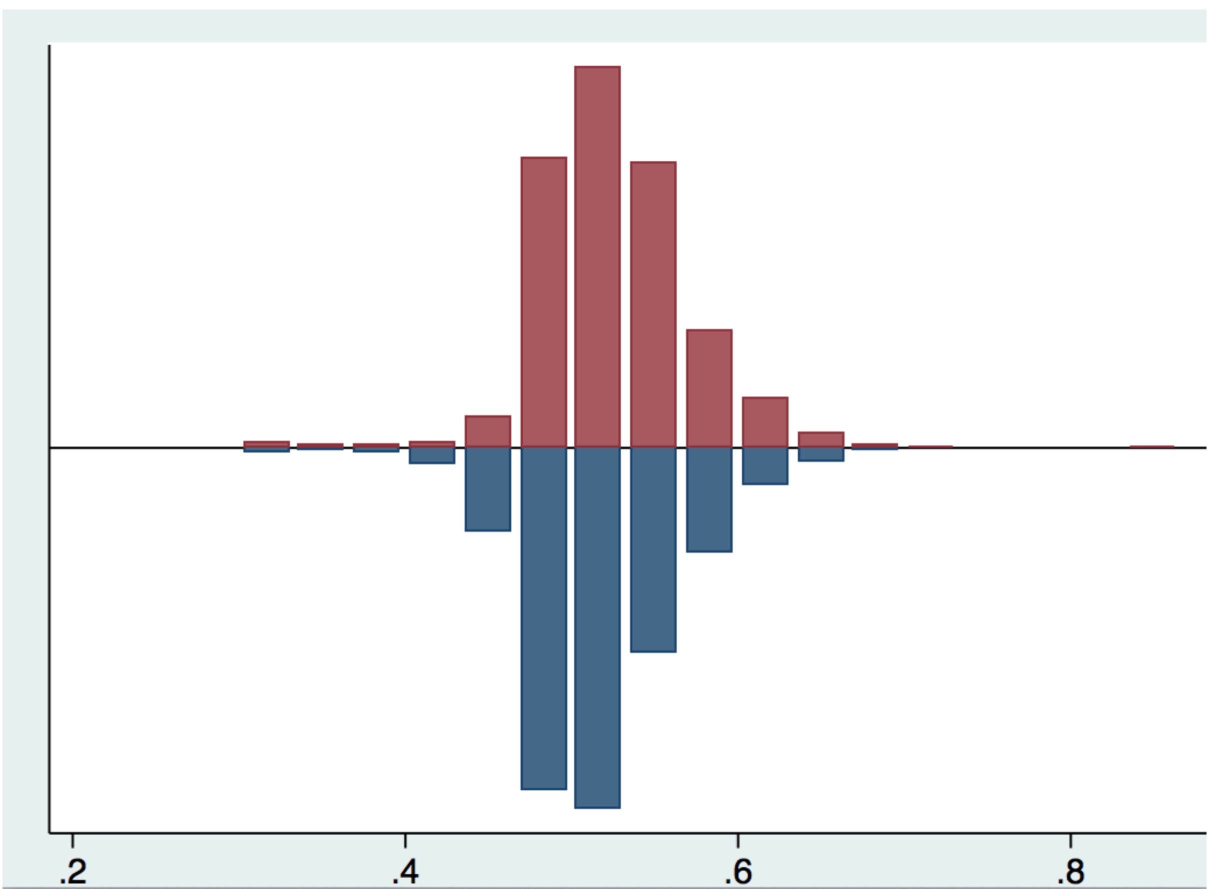
Source	SS	df	MS
Model	1625136.35	3	541712.117
Residual	108107123	3137	34461.9455
Total	109732259	3140	34946.5794

Number of obs	= 3141
F(3, 3137)	= 15.72
Prob > F	= 0.0000
R-squared	= 0.0148
Adj R-squared	= 0.0139
Root MSE	= 185.64

fuel_expense_per_m~r	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
wonderbagdummy	-23.13195	6.659163	-3.47	0.001	-36.18871	-10.07519
grocer_expense	.0162462	.00391	4.16	0.000	.0085799	.0239126
hh_education_highest	6.548153	1.83908	3.56	0.000	2.942231	10.15408
_cons	46.70149	23.127	2.02	0.044	1.355909	92.04708

Both the other explanatory variables behave in ways that are consistent with economic intuition. The amount of fuel is positively correlated with the amount spent on food (in these communities, differences in food expenses have more to do with quantity than quality). As energy is a normal good (more income means more purchased), the income proxy (hh_education_highest) is also positively correlated with fuel expense per household member.

Figure 2.2: Propensity Score Histogram: Cooking Time with respect to Food Expenses and Education Levels



Source: Author's estimates.
Note: The y axis is proportional by group – treated and untreated scales may differ.

Looking beyond simple correlation to the more important policy question of causality, we apply the PSM estimation technique as before. Doing so in the present case is strongly supported by our sample characteristics, as illustrated in the treatment/control histogram of Figure 2.2. The PSM results, summarized in Table 2.8, are fully consistent with both the descriptive and regression findings, suggesting a more direct link between Wonderbag usage and fuel savings. Unlike time savings, the fuel cost PSM result is smaller than the regression estimate, while still larger than the descriptive (sample mean) statistics would suggest. After taking account of sample differences that could undermine a causal inference, we find that Wonderbag adoption by an untreated household could be expected to reduce average fuel cost per household member by 19.32 Rand per month per capita (14.81%). Thus controlling for sample characteristics and expunging secondary sources of variation sustains the inference that Wonderbag adoption would significantly reduce fuel costs.

Table 2.8: Propensity Score Matching Model:
Fuel Cost per Household Member

```
Logistic regression                                 Number of obs   =       3141
                                                    LR chi2(2)      =      28.42
                                                    Prob > chi2     =     0.0000
Log likelihood = -2160.0648                         Pseudo R2       =     0.0065

------------------------------------------------------------------------------
wonderbagd~y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
grocer_exp~e |   .0001857   .0000506     3.67   0.000     .0000865     .000285
hh_educati~t |   .0514354   .0204593     2.51   0.012     .0113359     .091535
       _cons |  -.8274687   .2545852    -3.25   0.001    -1.326447   -.3284909
------------------------------------------------------------------------------
There are observations with identical propensity score values.
The sort order of the data could affect your results.
Make sure that the sort order is random before calling psmatch2.
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
fuel_expense_p~r  Unmatched | 131.603266   150.925248  -19.3219822   6.66943727    -2.90
                        ATT | 131.603266   107.183157   24.4201089   40.1609585     0.61
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

           | psmatch2:
 psmatch2: |   Common
 Treatment |  support
assignment | On suppor |     Total
-----------+-----------+----------
 Untreated |     1,503 |     1,503
   Treated |     1,638 |     1,638
-----------+-----------+----------
     Total |     3,141 |     3,141
```

Our third impact estimation, using the NNM technique, suggests an average impact even higher than the two previous methods. These results, summarized in Table 2.9, are fully consistent with what we have found so far - a statistically significant causal relationship between Wonderbag adoption and reduction in household fuel expenses. In the present case, our estimate of average savings (30.47 min or 23%), is at the higher end of the confidence interval predicted by the regression model.

Table 2.9: Nearest Neighbor Matching Model: Fuel Cost per Household Member

```
Treatment-effects estimation                    Number of obs      =      3141
Estimator      : propensity-score matching      Matches: requested =         1
Outcome model  : matching                                      min =         1
Treatment model: logit                                         max =     174
--------------------------------------------------------------------------------
               |              AI Robust
fuel_expense~r |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
ATET           |
wonderbagdummy |
     (1 vs 0)  |     -30.47   9.507569    -3.20   0.001    -49.10449    -11.8355
--------------------------------------------------------------------------------
```

2.2.3 Fuel and Food

As mentioned above, fuel and food share the characteristic of being essential commodities. It is also the nature of the modern diet that the two are consumed together. While energy provides a broad spectrum of important services such as transportation and electrification, food preparation is arguably the most essential and universal one. In this section, we examine how Wonderbag influences their relationship in the expenditure patterns of low-income households. For developing countries in particular, better understanding of this relationship can support more effective policies toward both nutrition and energy. Indeed, many such countries have historically subsidized energy with the intention to improve nutritional outcomes. Our results suggest that promoting cooking efficiency technologies can serve similar purposes in a more (environmentally and fiscally) sustainable manner.

Using the same three-part estimation strategy, we present the linear regression results in Table 2.10. These suggest that households who use Wonderbag also spend more money per capita on food, averaging an additional 49.09 Rand per month per member. This translates into 15.7% higher food expenditure for Wonderbag households, smaller than the descriptive statistics suggest (Table 2.3) but still substantial. On average, additional food expenditures among Wonderbag users will range (95% of the time) between 12% (37.7 Rand/mo/pc) and 19% (60.5 Rand/mo/pc).

Table 2.10: Modeling Food Cost per Capita: Linear Regression

Source	SS	df	MS
Model	300139869	2	150069935
Residual	106698201	3550	30055.8314
Total	406838071	3552	114537.745

Number of obs =	3552
F(2, 3550) =	4993.04
Prob > F =	0.0000
R-squared =	0.7377
Adj R-squared =	0.7376
Root MSE =	173.37

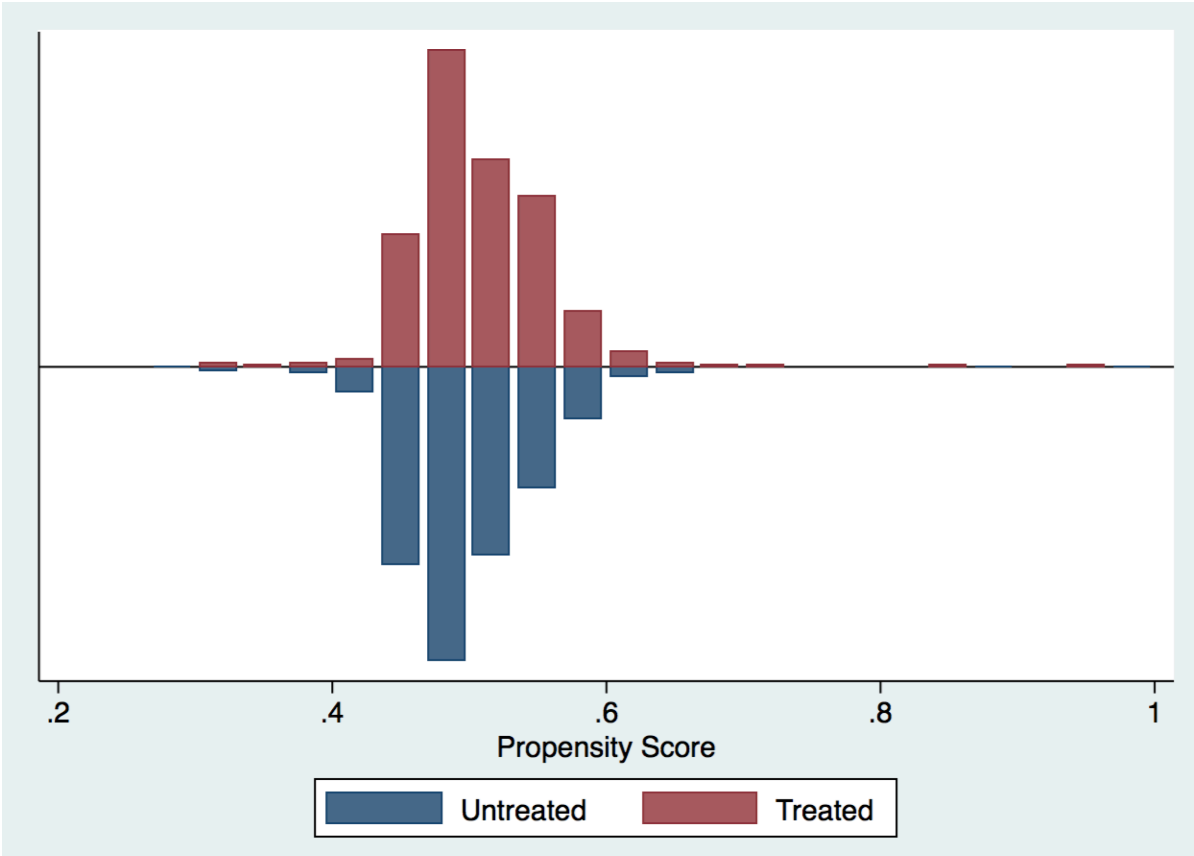
fc_pc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
wonderbagdummy	49.08622	5.810571	8.45	0.000	37.69382	60.47861
hh_education_highest	20.50966	.3189971	64.29	0.000	19.88422	21.13509

As expected (food being a normal good) the income proxy variable (hh_education_highest) is positive and statistically significant. The observed correlation between Wonderbag use and higher food cost can be explained in a variety of ways, most of which are none-exclusionary.[2] Income differences would not appear to explain higher food expenses, since we control for the former with a (significant) proxy and in any case the control and treatment groups have about the same sample income statistics. More interesting for the present assessment would be an indirect linkage, where Wonderbag households are reallocating fuel savings to achieve higher food consumption. If true, the argument for complementarity between energy efficiency and nutrition policies takes on greater significance, as do Wonderbag benefits generally.

Alternative behavioral theories, for example, might suggest that Wonderbag users may simply be more "food conscious" or technology receptive associating new technologies with a commodity (food) to which they commit more resources. While interesting in their own right, these conjectures could best be elucidated by more intensive data development and analysis. In any case, a robust finding that Wonderbag households have higher food expenditure is of practical significance in itself, and particularly so would causal, i.e. an inference that Wonderbag adoption actually supports higher outlays on food for low-income households.

Figure 2.3: Propensity Score Histogram: Food Cost per Capita with respect to Education Levels

[2] In other words, several alternative reasons for the Wonderbag food correlation probably apply the most households simultaneously.



Source: Author's estimates.
Note: The y axis is proportional by group – treated and untreated scales may differ.

The sample support histogram in Figure 2.3 suggests that we can proceed toward exactly such an inference with the PSM estimation method. Applying it to food costs yields the results in Table 2.11, where we that Wonderbag adoption is associated even more strongly with higher food expenditure per household member. After controlling for PSM factors, Wonderbag households can be expected to spend and average of 54.22 Rand/mo/pc (17%) more on food than non-Wonderbag households, at the high end of what the passive correlation (regression) model would predict. Since this amount is substantially more than our estimate of fuel saving, other forces must also be at work.

Table 2.11: Propensity Score Matching Model: Food Cost per Capita

```
Logistic regression                                 Number of obs   =       3552
                                                    LR chi2(1)      =      13.93
                                                    Prob > chi2     =     0.0002
Log likelihood =  -2455.025                         Pseudo R2       =     0.0028

------------------------------------------------------------------------------
wonderbagd~y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
hh_educati~t |   .0699585   .0190412     3.67   0.000     .0326385    .1072786
       _cons |  -.8827716    .246121    -3.59   0.000     -1.36516   -.4003832
------------------------------------------------------------------------------
There are observations with identical propensity score values.
The sort order of the data could affect your results.
Make sure that the sort order is random before calling psmatch2.
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
           fc_pc  Unmatched | 313.737703   259.520265   54.2174384    5.9624786     9.09
                        ATT | 313.737703   306.127311   7.61039222   75.8319281     0.10
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

           | psmatch2:
 psmatch2: |   Common
 Treatment |  support
assignment | On suppor |     Total
-----------+-----------+----------
 Untreated |     1,765 |     1,765
   Treated |     1,787 |     1,787
-----------+-----------+----------
     Total |     3,552 |     3,552
```

The same conclusions arise from NNM estimation, as can be seen tin the results of Table 2.12. The estimated average Wonderbag “impact” on food expenditure is more moderate, but still quite significant and wholly consistent with the other estimation approaches.

Table 2.12: Nearest Neighbor Matching Model: Food Cost per Capita

```
Treatment-effects estimation                    Number of obs      =      3552
Estimator      : nearest-neighbor matching      Matches: requested =         1
Outcome model  : matching                                      min =         1
Distance metric: Mahalanobis                                   max =       785
--------------------------------------------------------------------------------
              |              AI Robust
        fc_pc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
--------------+-----------------------------------------------------------------
ATE           |
wonderbagdummy |
     (1 vs 0)  |   48.80959   5.728304     8.52   0.000     37.58232    60.03686
```

Thus we see that Wonderbag adoption is empirically linked to higher food spending per capita in low-income households. Explicating more detailed aspects of this relationship would be very interesting, but are beyond the scope of the present study.

In practical terms, however, the fuel cost savings already attributed to Wonderbag adoption are likely play a role, as they liberate financial resources from one essential commodity to another one that, for low income households, usually comprises the largest budget share.

An essential caveat to the results for food is that we only evaluate expenditure, not nutritional values. This could mean that Wonderbag households are spending more, but in nutritionally neutral or even adverse ways. These qualitative characteristics of food spending are quite difficult to measure, especially in ways that predict health outcomes, but in any case doing so would be a much more ambitious empirical exercise than the present one. Suffice to this study to observe that, again the control and treatment groups exhibit a high degree of congruence in terms of other observed characteristics. This makes it likely that, at the margin, food is relatively homogeneous in quality characteristics, and increased spending is more likely to represent increased food values.

2.3 Extensions of the Present Analysis

The objectives of this report were twofold, to report on the DWBS survey activity and assess the most salient economic benefits of Wonderbag. The results of the previous section clearly attest to Wonderbag's potential to improve livelihoods and environmental sustainability, and we believe these findings will be robust across a broad spectrum of low-income communities around the world. Doing so can be expected to confer at least the same three cardinal economic benefits, saving households time, fuel, and enabling higher food consumption. In addition to these core findings, future research is recommended in several directions.

2.3.1 Secondary Benefits

Each of the three core benefits of Wonderbag adoption have implications for many indirect impacts. Time saving opens new opportunities for labor re-allocation, depending on competing claims for the time of those who were cooking. Fuel efficiency has a variety of indirect environmental and health impacts, including lower resource depletion and incidence of respiratory illness. Higher food expenditure can have important positive or even negative health impacts, depending upon how food consumption patterns actually change across households. All these indirect impacts are worthy of more detailed study, but outside the scope of the present activity. Some would be supported by the DWBS dataset, while others will require new sampling.

2.3.2 Adoption and Diffusion

Despite its demonstrable benefits, it is apparent that both Wonderbag adoption rates and perhaps Wonderbag performance with existing adopters are below their potential. To confer this innovation's benefits on a larger population, while increasing individual benefits to adopters, more detailed research is needed on actual patterns of Wonderbag adoption and use, as well as how this technology diffuses (or can be diffused) across society. Our PSM data analysis suggests strong demographic congruence between Wonderbag user and nonuser populations (see the PSM histograms in the last sub-section). This implies that many eligible users have yet to adopt Wonderbag and enjoy its benefits, even in a population with several years of exposure. More detailed marketing research and outreach would seem to be needed to overcome this apparent barrier to spontaneous diffusion. For the existing Wonderbag user population, average efficiency gains appear well below the potential demonstrated in Wonderbag trials. Thus it appears that fuel and time savings might be even higher if training were implemented to promote more intensive Wonderbag use. In fact, a large proportion of Wonderbag owners asked our enumerators for this kind of information.

2.3.3 Promotion Strategies

As a household technology generally and a cooking technology in particular, Wonderbag exhibits remarkable versatility and ease of use. For these reasons, as well as its demonstrable economic benefits, it has bright prospects for global deployment. In the four largest emerging markets, China, India, Brazil, and Indonesia, all have large eligible populations for Wonderbag adoption. This could be promoted by identifying most important national characteristics of demand, supply, and institutional environment, and synthesizing them into a coherent strategy to bring Wonderbag's benefits to the majority of the world's poor people.

2.3.3.1 Demand Side Analysis

To be most effective, Wonderbag globalization needs to be supported by a clear understanding of the diversity of local needs and exactly the kind of solution it represents in each market. For example, African deployment mitigates a critical local/regional issue of biomass scarcity, as it can in India and arid parts of China. In Brazil and Indonesia, by contrast, biomass is abundant and the public health, labor, and energy efficiency characteristics of Wonderbag will be more salient.

When considering global diffusion potential, there are many reasons for optimism. Most of the world’s low-income societies rely on staple dishes with longer cooking starch and carbohydrate products, such as rice, beans, etc. All these are ideal entry-point dishes for Wonderbag adoption, and the same cardinal benefits can be expected to accrue regardless of country or culture. Moreover, because Wonderbag is largely independent of (and complementary to) other cooking technologies, its diffusion will be easier to promote than specific stoves, energy use technologies, etc.

2.3.3.2 Supply Side Analysis

Given the sheer magnitude of the markets being considered, Wonderbag production and supply chain strategies will also need to be reviewed for extension into different local/national/regional contexts. Generally, each of the large markets will probably need it's own supply chain architecture, partnerships, and marketing strategies. This promotional component can build on Wonderbag's past experience with production and partnership, extending it to specific strategies for each of the four markets.

2.3.3.3 Institutional Setting

In these very large low-income economies, governments have in place a broad array of policies relevant to Wonderbag, including policies and entire ministries dealing with energy, food security, public health, labor, and household political economy. With this in mind, it is obvious that Wonderbag deployment there can be most effective if we take account of these public sector interests and engage them proactively.

An important example of is energy subsidies, politically expedient but inconsistent with environmental and fiscal sustainability. All four of the countries under consideration have policies to subsidize energy use for the poor. Because these policies encourage energy waste at public expense, Wonderbag will not only save households money, but also (relatively scarce) public funds that could be used for other important priorities. Raising this issue directly in dialog with governments will facilitate Wonderbag deployment; indeed we might be able to justify (short term) Wonderbag adoption subsidies to reduce (long term) energy subsidies.

Wonderbag also has a variety of other benefits which aggregate to benefit society, including reduced public health costs, resource conservation, labor productivity, etc. In combination, the Prospects Assessment and Impact Evaluation will elucidate these and exploit them in our strategic dialog with governments, donors, and complementary NGOs. To make this effort more effective, the Prospects Study will thoroughly research national policies and experience with related technology deployment.

2.3.3.4 Commercial Promotion

Given the evidence we have developed on economic benefits, it is clear that Wonderbag diffusion could be promoted with economic incentives, especially those related to food products. Since the economic savings of adoption appear significant, agrifood partners may want to promote the product with subsidies that can be recouped through sales of companion products. Our results suggest that such subsidy mechanisms, if carefully designed and promoted, have the potential to be self-financing.

3 OVERVIEW OF COOKING TECHNOLOGY INNOVATION IN LOW INCOME COUNTRIES

In developing countries, especially in rural areas, 2.5 billion people rely on biomass, such as fuel wood, charcoal, agricultural waste and animal dung; to meet their energy needs for cooking. In many countries, these resources account for over 90% of household energy consumption. In the absence of new policies, the number of people relying on biomass will increase to over 2.6 billion by 2015 and to 2.7 billion by 2030 because of population growth. That is, one-third of the world's population will still be relying on these fuels.[3] There is evidence that, in areas where local prices have adjusted to recent high international energy prices, the shift to cleaner, more efficient use of energy for cooking has actually slowed and even reversed. Two main approaches can improve this situation: promoting efficient and sustainable use of traditional biomass; and encouraging people to switch to modern cooking fuels and technologies.[4] The appropriate mix depends on local circumstances such as per-capita incomes and the available supply of sustainable biomass. Improved cook stoves have long been identified as a promising option to reduce the detrimental impacts of cooking with traditional cook stoves. Although the term ''improved'' possesses varying significance as to the stove's technology, and is often loosely applied by promoters to quite different devices in different regions, we will continue to use it in this report for simplicity.

In its latest study, "The Energy Access Situation in Developing Countries", the World Health Organization (WHO) and the United Nations Development Program (UNDP) raised various observations regarding the ubiquity of improved cook stoves in developing countries.[5] Currently, three billion people rely on solid fuels such as traditional biomass and coal. Most of these people reside in Less Developed Countries (LDCs) and in SSA (Sub-Saharan Africa) where more than 80 percent primarily rely on solid fuels for cooking, compared to 56 percent of people in developing countries as a whole. Moreover, the report indicated that developing areas are deprived of proper access to improved cooking stoves; merely 7 percent of people in LDCs and SSA who rely on solid fuels use improved cooking stoves compared to 27 percent of people in developing countries as a whole.[6]

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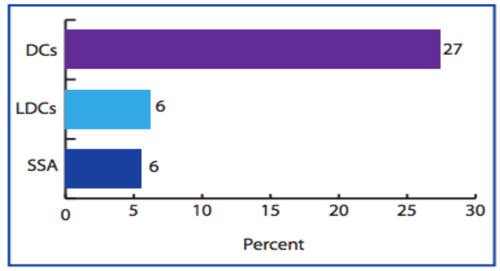
[3] IEA. *World Energy Outlook*. Paris: OECD/IEA, 2006. Print.
[4] Ibid.
[5] UNDP-WHO Report on Energy Access in Developing Countries: Review of LDCs & SSAs." *UNDP*. Nov.-Dec. 2009.
[6] Ibid.

	No. of people with access to ICS (in millions)
Developing countries	828
LDCs	44
Sub-Saharan Africa	34

Source: WHO/UNDP 2009

Figure 1. Number of People relying on solid fuels with access to ICS

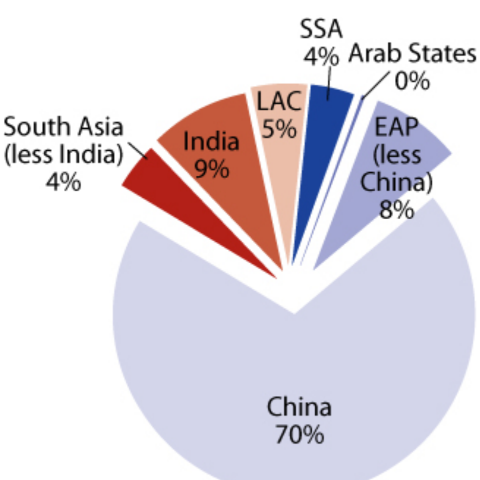


Source: WHO/UNDP 2009

Figure 2. Share of Population relying on solid fuels with access of ICS

Figure 1 indicates that only a small portion of the total population in developing countries who rely on solid fuels for cooking, use improved cooking stoves. Almost 830 million people in developing countries use improved cooking stoves to meet their cooking needs. Of these, merely 44 million live in LDCs and 34 million in sub-Saharan Africa (the area most heavily dependent on traditional biomass fuels for cooking). Fewer than 30 percent of people in developing countries who rely on solid fuels for cooking (traditional biomass and coal) use improved cooking stoves (Figure 2). Access to ICSs is even more limited in LDCs and sub-Saharan Africa, where only 6 percent of people who use traditional biomass and coal for cooking have access to improved stoves (Figure 2). These are also countries where access to modern fuels for cooking is most limited.

Interestingly, more than two-thirds of improved cook stove (ICS) users live in China (Figure 3, below). Other Asian and Pacific countries account for about another 20 percent of ICS users, while sub-Saharan Africa (where more than 80 percent of people rely on solid fuels for cooking) merely accounts for 4 percent of people currently using ICSs.



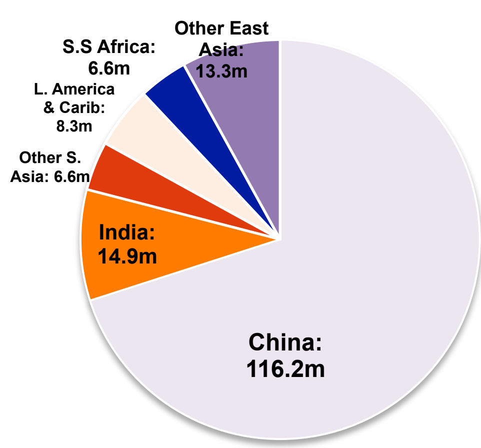


Figure 3. Distribution of People with access to ICS by developing regions

Figure 2. Number of Improved Stoves in developing countries (millions)

From figure 4 there are approximately 828 million people using improved stoves in developing countries out of a total solid fuel population (which includes coal and charcoal use) of approximately 3 billion people. This equates to approximately 166 million households using these relatively inexpensive improved stoves with 116 million users residing in China, over 13 million in the rest of East Asia, 20 million in South Asia, 7 million in Sub-Saharan Africa, and over 8 million in Latin America and the Caribbean.[7] Hence, one in four developing country households who are dependent on solid fuels for cooking use a stove with either a chimney or a smoke hood.

Complementary to the aforementioned statistics, this report is followed by a background review of the various improved cook stove programs employed in various developing countries thus far. There have been a plethora of cook stove programs conducted all over the world by governments and NGOs in various countries like China, India, Guatemala, Mexico, Haiti, Afghanistan, Sub-Saharan Africa, Bangladesh, Mongolia, etc. Objectives of these programs were to reduce fuel consumption for cooking and to improve indoor air quality. The drop in fuel consumption not only helps to impede the rate of deforestation, it also provides economic benefits for people living in rural regions by reducing fuel costs, which typically accounts for 36 percent of their annual income. Given that mostly women and children are involved in biomass collection, the reduction in fuel consumption also helps them save time incurred during the tedious collection process. Furthermore, improved indoor air quality reduces the exposure to chronic respiratory disease, eye irritation, and cardiovascular diseases.

A. China - Chinese National Improved Stove Program (1980-2000)

In the early 1980s, the Chinese National Improved Stove Program (CNISP) and its provincial counterparts were initiated and have been credited with introducing nearly 200 million improved stoves by the end of the 1990s. The focus of such programs was on increasing biomass fuel efficiency to assist rural welfare, extending fuel availability to villages and helping to protect forests. Secondary objective was the reduction of household smoke exposure through the employment of chimneys. By

[7] Barnes, Douglas. "Energy for Development and Poverty Reduction." *Improved Stoves in Developing Countries by the Numbers*. Douglas Barnes, 16 Apr. 2010. Web. 08 Jan. 2014.

the early 1990s, 130 million improved stoves had been installed, reducing the use of biomass in most parts of the country. Although most biomass stoves now in use have flues, grates, and other “improved” aspects, most coal stoves, even those using improved fuel (briquettes) lack flues and cannot be considered improved from the standpoint of Indoor Air Quality (IAQ). Currently, the NISP has been wound down, and the Ministry of Agriculture (MOA) has turned its attention towards supporting stove manufacturers and energy service companies. Support for the stove industry has been replaced with an extension of services and the certification systems to standardize stove systems. The development and distribution of improved stoves is now left mainly to market actors, with moderate local government oversight. In 1998 the MOA stated that 185 million of China’s 236 million rural households had access to improved biomass or coal stoves. In recent years, MOA has focused on integrated household welfare programs.[8]

The CNISP introduced approximately 10 different types of improved cook stoves that were suitable for users in different regions of China. Most improved cook stoves are made of ceramic, concrete slabs, prefabricated cast iron. These stove models were primarily of three types: cooking only, cooking and space heating, and crop processing or other process heat generation. See Figure 5, 6 and 7 below for examples of models distributed. In 2002, the price of each improved biomass cook stove was around 45 *yuan* or $12 dollars. However, depending on the capabilities and materials used for construction, prices could go up to 100 *yuan*. The amount of direct government subsidy for each cook stove was approximately 10 percent of the cost of each average stove, and most government subsidies went to producers.[9]

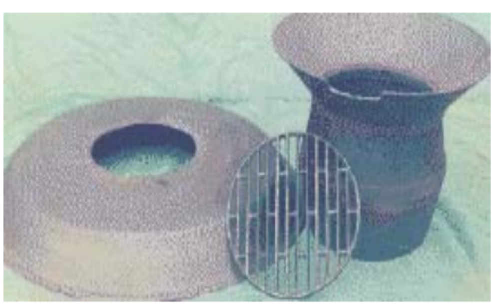


Figure 2. Cast Iron components of the domestic fuel saving heat stove

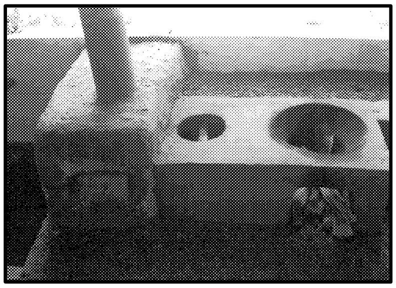
Figure 6. Model FL-CCS

Figure 7. Model FL-PCS

B. India - National Program on Improved Chulhas (1985-2001)

[8] Sinton, J., K. Smith, J. Peabody, L. Yaping, Z. Xiliang, R. Edwards, and G. Quan. "An Assessment of Programs to Promote Improved Household Stoves in China."*Energy for Sustainable Development* 8.3 (2004): 33-52. Print.
[9] Ergeneman, Ayca*. Dissemination of Improved Cookstoves in Rural Areas of the Developing World: Recommendations for the Eritrea Dissemination of Improved Stoves Program*. Rep. N.p.: Eritrea Energy Research and Training Center, n.d. Print.

Wood and biomass are used as domestic fuel even today in a majority of households in India. With its wide cultural diversity, a vast range of traditional cooking devices and practices are prevalent in different parts of the country. These include the horseshoe-shaped



chulhas, chulhas with one or more pot-holes, sawdust stoves, three-stone fire, special stoves for burning coal or charcoal, etc. The Government established the National Programme on Improved Chulha (NPIC) in 1985, with the main objective of reducing the demand for fuel-wood. This was expected to temper deforestation, and provide economic gains for the fuel-wood user (in terms time and monetary savings). The programme concentrated on increasing the fuel-use efficiency of wood-burning stoves. In addition, two secondary objectives include: (1) to alleviate the drudgery of wood collection for rural women, and (2) to create income-generating opportunities within these developing areas.

These objectives were to be achieved by providing one improved stove, at a subsidised price, to every rural household. It was anticipated that the user would appreciate the benefits of the improved stove and be motivated to continue with its use in lieu of traditional cooking methods. Before the launch of the programme, 120 million households were estimated to be utilising biomass fuels and traditional stoves. By the end of the programme in 2001, statistics provided by the Ministry of Non-conventional Energy Sources (MNES) in its annual report claimed a 27% success rate; where its programme reached 32.77 million out of the total 120 million households.[10]

Close to 80 stove variations were disseminated, and these stoves can be grouped into 6 main categories:

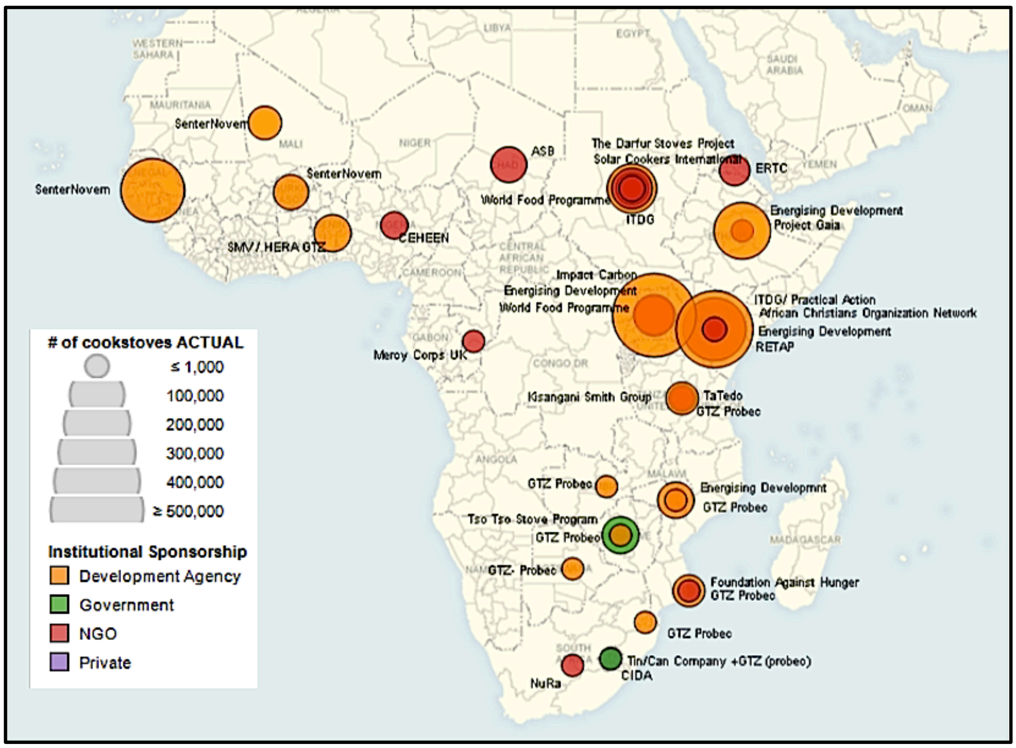
(i) Mud-built, fixed chulha with or without chimney
(ii) Mud-clad, pottery-lined fixed chulha with or without chimney
(iii) Portable metallic chulha without chimney
(iv) Portable metal-clad, ceramic-lined chulha without chimney
(v) Portable chulha with a separate hood chimney system.

The cost of each cook stove was approximately \$9, with some variation depending on the economic performance of the region, and the social status of each household. Support for households came in the form of direct cash subsidies, ranging from 50-75 percent of the cost of each cook stove. Given that rural per capita income for 'target' states was approximately \$370 and \$510, the price of the stove was approximately one to two percent of average annual rural income for households within these states.[11]

[10] Karve, Hanbar, and Priyadarshini Karve. *National Programme on Improved Chulha (NPIC) of the Government of India: An Overview*. Rep. 2nd ed. Vol. 6. N.p.: Energy for Sustainable Development, 2002. Print.
[11] Ergeneman, Ayca. *Dissemination of Improved Cookstoves in Rural Areas of the Developing World: Recommendations for the Eritrea Dissemination of Improved Stoves Program.* Rep. N.p.: Eritrea Energy Research and Training Center, n.d. Print.

Figure 9. Selected Cook stoves Disseminated in Andhra Pradesh and Maharashtra (India)
Source: Ayça Ergeneman, RWEDP 41

C. Africa - Energy advisory project



Source: A Global Review of Cookstove Programs, Mary Louise Gifford

Illustrated in the diagram above, the implementation of 'improved' stove programs has been sporadically established by development agencies, NGOs, governments, and private-business entities in various areas of the continent. Common initiatives include: the Zimbabwe *Tso Tso Stove* Program, the Darfur Stoves Project, Eritrea Dissemination of Improved Stoves Program, and Ethiopia Mirt Improved Biomass Stoves Program.

Established in 1986, the **Zimbabwe Tso Tso Stove Program** is one of the longest running cook stove programs in Africa. From the beginning, careful attention was vested into a stove design that was consistent with local cooking customs and the materials used in its construction (as many Zimbabweans perceived a metal stove a status symbol). The *Tso Tso Stove* was initially manufactured by the informal sector, but was soon mass-produced with quality control measures by the formal manufacturing sector.[12] The price of each *Tso Tso Stove* was comparable to the pre-existing ‘metal grate’ stove. Sales of the *Tso Tso Stove* were initially slow, amounting to merely 400 units in the first four months. However, breakthrough sales occurred once commercial farmers and mine managers realized substantial cost savings to supply wood for their laborers.

The Eritrea Dissemination of Improved Stoves Program was initiated in 1996, with the Ministry of Energy (in collaboration with the Eritrean Energy Research and Training Center (ERTC)) coordinating the entire program.[13] The ‘improved’ *mogogo stoves* introduced in Eritrea were in-built stoves with ceramic grates, made mainly with metal parts and brick. The non-local inputs for the stoves were subsidized; making village households liable only for costs in the construction phase of the project. Thus, close to 85 percent of one improved stove (typically $20) is subsidized. Given that Eritrea’s rural income per capita is $200, this means that the cost of each *mogogo* stove is approximately 10 percent of annual income per capita.

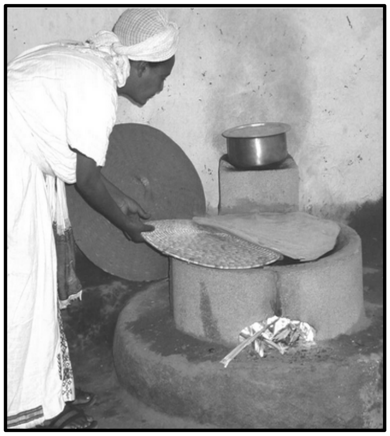

Outdoor Mogogo Stove
Source: Claudia Hudson

The program has been successful in reaching low-income households in areas it has been active in. As of 2003, 7000 ‘improved’ *mogogo* stoves have been disseminated, reaching about one percent of traditional stove users. Since the program has been active in rural areas and almost all households in rural areas use traditional stoves, it is believed that the stoves have reached approximately one percent of rural households. The project evaluation report for the energy-efficient stoves program states that acceptance of the new stoves is “wide-spread but not universal”. The annual growth in the dissemination rate of

The Ethiopia Improved Biomass Stoves Program (also known as *Mirt*) originated in 1991 and has continued under various programs since its inception. The Ethiopian program has been coordinated by several international development agencies, the Ministry of Agriculture (MoA), and Rural Energy Technology Centers. Since introduction of *Mirt* stoves in 1995, over 400,000 stoves have been disseminated mostly in urban areas.[14] Models of the *Mirt* stoves were fairly homogenous although construction materials changed between regions (depending on the availability of construction material). The improved stoves cost around three dollars in Addis Ababa and between four and five dollars in other areas (depending on the transport costs). This is 5 percent of the per capita income of a rural household in Ethiopia. However, the program does not offer subsidies to stove users.

Like Eritrea, Ethiopia is in its second phase of program implementation. Since its establishment in 1997, approximately 5000 stoves have been disseminated in rural or semi-urban areas. This is a very small percentage of rural households, approximately 1 percent. However, the degree of dissemination and the growth in the annual dissemination rate to low-income rural households are more relevant evaluation criteria during the ‘Growth and Scale-Up’ Phase that the

[12] Louise Gifford, Mary. *A Global Review of Cookstove Programs*. Thesis. University of California, Berkeley, n.d. N.p.: n.p., n.d. Print.
[13] Ergeneman, Ayca. *Dissemination of Improved Cookstoves in Rural Areas of the Developing World: Recommendations for the Eritrea Dissemination of Improved Stoves Program*. Rep. N.p.: Eritrea Energy Research and Training Center, n.d. Print.
[14] *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem*. Rep. The Environment Department (Climate Change) The World Bank, May 2011. Web. 8 Jan. 2014.

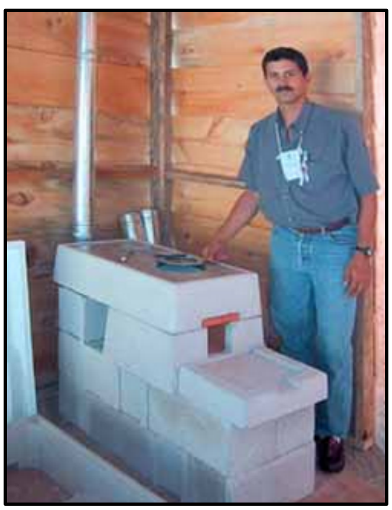


Mirt stove, Source: GTZ

Other Selected Improved Stove Programs

i) HELPS ONIL Wood Stove

HELPS International, an international nonprofit organization that has promoted various stove designs, has only within the last 5 years begun to expand and upgrade its manufacturing capacity. Costing more than US$100, The ONIL stove is relatively expensive. Thus, its main-market compromises users living in peri-urban areas and those relatively well off. Except for programs sponsored by HELPS International, consumers are expected to pay full price.



ONIL Stove
Source: Eliza Barclay, HELPS

Since its introduction, more than 80,000 stoves have been sold in Guatemala, Honduras, and Mexico, illustrative of its market demand. HELPS also offers products such as: an institutional stove, the ONIL cooker (retained heat cooker), the Nixtamal stove (a large pot boiler, a basic solar lighting system (to replace light from the open fire), and the ONIL water filter.[15]

ii) Recho Mirak (Haiti)

The World Bank-supported Miracle Stove project in Haiti was a direct response to findings of a 2005 report carried out by the Government of Haiti and funded by the Energy Sector Management Assistance Program (ESMAP) and the Ministry of the Environment.[16] The report's objective was to develop a household energy strategy that included the dissemination of improved charcoal stoves and the promotion of local production. Currently, some 20,000 improved charcoal stoves have been sold, and more than 10,000 quality labels have been distributed to qualified stove manufacturers.

[15] *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem*. Rep. The Environment Department (Climate Change) The World Bank, May 2011. Web. 8 Jan. 2014.
[16] *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem*. Rep. The Environment Department (Climate Change) The World Bank, May 2011. Web. 8 Jan. 2014.

Haitian Recho Mirak
Source: Nathaniel Mulcahy

Traditionally, the small, three-legged charcoal stoves were made out of scrap metal. To capitalize on the raw materials and skill-sets of traditional stove makers, similar basic resources and techniques were employed to manufacture the improved Recho Mirak stove. This "miracle stove" has a closed combustion chamber, and offers a 40 percent reduction in charcoal consumption, which has the advantage of reducing the cost of input materials. However, the stove requires 30 percent more metal than its traditional counterpart. Given the export market for used sheet metal, it became more difficult for producers to find the required used metal as the project scaled to increase the demand for stove

proposing that they produce and sell stove-making kits from which the producers would manufacture the improved stoves. Had this worked, it could have alleviated the raw-materials shortage, easing the constraints on production, increasing the volume of stoves produced, and reducing the stoves average unit price. However, local suppliers were not interested in getting involved.

iv) GERES Charcoal Stove

In 1999, GERES introduced the New Laos Stove (NLS), supported by trainers from Thailand where the stove was earlier marketed under the name "Thai Bucket." This initiative is known for its successful institutional model for selling the improved cook stoves.[17] GERES' innovative method of introductory training enabled a group of cook-stove producers to conduct initial comparative tests against the competing traditional model (known as the "Traditional Laos Stove").

Charcoal Stove
Source: GERES, Cambodia

The NLS technical design is an updraft combustion stove with a grate. From 2003 to 2010, overall NLS sales exceeded its initial projected target -- selling approximately one million units. According to the manufacturer, the NLS saves a considerable quantity of charcoal compared to traditional stoves. Due to the proven ability of the NLS to reduce carbon emissions, GERES-Cambodia was the first project developer in the world to put forward an improved cook stove project to trade on the

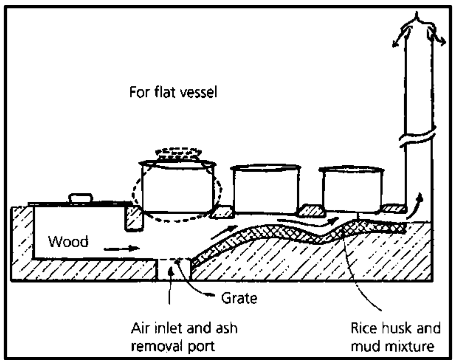
The process of achieving these results is important to understanding ways to promote improved biomass stoves. However, it should be understood that the main stove promoted under the GERES program is a charcoal stove, and there has been

[17] *One Goal, Two Paths*. Rep. N.p.: International Bank for Reconstruction and Development / The World Bank, 2011. Print.

more success selling charcoal stoves around the world because the fuel is purchased in the market.[18] One problematic aspect that evolved in the course of implementation was the choice of decentralized production at small units. Having multiple, widely scattered producers made it difficult to control product quality. Over the years, some 31 production centers have been consolidated into 5 centers, producing only NLS units.

v) Astra Ole Stoves

Indian Institute of Science (IISc) has been involved in the field of biomass combustion and gasification research for over 15 years; developing several cook stoves. Its most famous development, the Astra Ole, is made up of mud. Gas emitted during combustion is taken out



Source: UNhabitat

through the chimney. The Astro Ole stove is a 3 pot stove with a grate and an enclosed combustion chamber. Primary air enters the fuel box through the ducts present between the pans and chimneys. These duct sizes can be varied during production, depending upon the vessel used by the costumer. The stove can make use of twigs, bark, husk, bagasse, and stems as fuel. The main advantage of this stove is that its design is similar to that of the traditional cook stove, thereby making the switch towards the astra ole, simple and convenient. The average efficiency of the stove is 35 percent - doubling the efficiency of

vi) Philips Stoves


Source: PHILIPS

In 2006 Philips developed a micro gasifier cook stove that is fuelled with small pieces of wood. The inner wall of the combustion chamber is made up of ceramic composition material to sustain a large amount of heat produced during combustion, which reduces the lifespan within the combustion chamber. A 12V fan present below the grate supplies primary and secondary air. Primary air enters the firebox via vents present in the fixed grate made of cast iron, and secondary air is preheated before reaching the combustion chamber through holes present at the top of the combustion chamber. The speed of the fan can be varied uniformly from maximum to minimum; thereby the user can adjust the power produced by the stove by

once fuel combustion begins, the fan is driven by the thermo-electric generator that

[18] *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem.* Rep. The Environment Department (Climate Change) The World Bank, May 2011. Web. 8 Jan. 2014.

charges the battery. These stoves can generate power ranging between 1.5 to 3 kW. More importantly, the Philips stove reduces fuel consumption by 55 percent, and reduces carbon emissions by approximately 90 percent.

vii) Rocket Stoves (StoveTec)

The Aprovecho Research Center designed the StoveTec stove, a model that encompasses all the proven features learned through Aprovecho's several years of stove program experience (120 projects in over 50 countries).[19] Since 2007, the StoveTec design has been manufactured in China by Shangou Stove Manufacturers, which has the capacity to mass-produce durable stoves at affordable prices. Only recently has StoveTec started to market the stove, and dissemination is in its infancy. The company is searching for potential retailers who would be interested in purchasing the improved cook stove in large quantities. The approach is to establish regional distribution hubs with partners around the world to ensure product availability and to build awareness among stove users within those countries. According to the manufacturer, about 150,000 stoves have been sold at its retail price of approximately $10 per stove.

Source: StoveTec

The StoveTec stove is made of sheet metal with a line of ceramic clay. The clay ensures efficient heat capture and transfer. The top part of the stove is a cast-iron disc on which pots can be placed. The stove also comes with a pot skirt that encircles the pot to ensure efficient heat transfer. The rocket-stove design originally used for the stove ensures that combustion occurs in the space directly above the fire; this ensures lower carbon emission.

Compared to cooking with an open fire, the StoveTec stove has the advantage of using 40 to 50 percent less wood or charcoal, and it cuts down cooking time by about half, thus reducing carbon emission by 50 to 75 percent

viii) GTZ Household Stove Deployment Program in Kenya

The Promotion of Private Sector Development in Agriculture, implemented by the GTZ in partnership with the Government of Kenya's Department of Agriculture, targeted Kenya's rural and urban households in Transmara's Western and Central cluster; stove producers, installers, and dealers; and social institutions and productive users.

[19] *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem.* Rep. The Environment Department (Climate Change) The World Bank, May 2011. Web. 8 Jan. 2014.

Jiko Kisasa Stove
Source: GVEP International

Various models were brought into the market. The Jiko Kisasa stove is made of ceramic and metal. It has the potential of reducing firewood use by 40 percent, while another model - the Rocket Mud Stove (RMS) - has a savings potential of 60 percent. The price of each Jiko Kisasa varies from US$1.5 to $3, while the RMS ranges from $2.5 to $3. Over the life of the project, about 1 million of these improved cook stoves have been purchased.
A major project goal was to promote the adoption of energy- saving devices among social institutions, including schools, hospitals, and colleges. This was

technicians and potential financing institutions. In addition, cooperation was sought with school feeding programs in order include the advocation improved stoves in their work. In addition, mainstreaming of HIV/AIDS groups into stove activities for HIV-positive people has also been conducted. Such groups were provided with equipment (stoves and production materials) and skill training for capacity building.[20]

ix) Uganda Stove Manufactures, Ltd. Charcoal Ugastove

Uganda Stove Manufacturers, Ltd. is a charcoal stove–producing company that developed an improved cook stove known as the *Ugastove*. Initiated as a family business, Uganda Stove Manufactures was able to utilize carbon funds to finance its startup stoves business.[21] The *Ugastove* project grew out of a U.S. Environmental Protection Agency (EPA) grant to commercialize the *Ugastove*. This financing was used to build a local manufacturing facility in order to develop the design of the stove, the air & carbon monitoring system, and to conduct market research.

Ugastove
Source: David I. Levine

Today the *Ugastove* project works in partnership with Impact Carbon (formerly the Centre for Entrepreneurship in International Health and Development), based in San Francisco. Logistical support was provided by the PCIA and GTZ-supported Promotion of Renewable Energy and Energy Efficiency Program (formerly the Energy Advisory Project). Marketing and dissemination efforts for the *Ugastove* have been concentrated in Kampala, where charcoal is used by a majority of the population, with limited extension in other urban areas. It is reported that nearly 60,000 *Ugastoves* have been sold since 2005. Over the years, Uganda Stove Manufacturers have developed several stove types: charcoal

These stoves are not subsidized, but the company has access to carbon finance for marketing, training, and other soft costs. Technically the stoves are similar to the

[20] *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem*. Rep. The Environment Department (Climate Change) The World Bank, May 2011. Web. 8 Jan. 2014.
[21] Ibid.

less expensive improved Jiko stoves, common in many urban areas of Africa. However, the stoves have more substantial fuel efficiency. According to the manufacturer, they can achieve a US$130 reduction in household fuel costs over three years.

4 PREVIOUS RESEARCH ON WONDERBAG

This section provides a brief overview of prior Wonderbag related studies, based entirely on materials provided by Wonderbag. This information is provided for background only and does not constitute a review of the methods or findings of any of the activities discussed.

1.1 360° Research – South Africa

The Durban-based market research and consultancy firm, 360 Research, conducted the majority of Wonderbag studies to date. Although their survey projects go by several different names in the literature provided, I believe their work can be classified into two main studies: Kitchen Test 2011 (KT2011) and Kitchen Test 2012 (KT2012). Before summarizing these studies, I will provide a description of the distribution of Wonderbags in South Africa. These statistics have been gleaned from several of the 360 Research documents.

By the end of December 2011, approximately 100,000 Wonderbags had been registered in the Wonderbag database. The vast majority (80,000 bags) were distributed in Kwa Zulu Natal, a south-eastern province on the coast of South Africa (SA). The other 20,000 bags had been distributed throughout the rest of SA. At this time, another 400,000 Wonderbags were scheduled to be distributed in the Mpumalanga, Limpopo, Gauteng, and North West Provinces by June 2012[22]. 360 Research states that “ethnicity, socio-demographic and residence geotype profiles across these regions in South Africa are similar.” It appears that the retail chain, Shoprite, distributed the vast majority of Wonderbags. The target consumer of the Wonderbag, based on uptake rates, is LSM 4-7 black consumers[23] in both formal and informal housing.

The main objectives of the 2011 Kitchen Test study (also known as Project Wonderful) were to 1) study typical usage patterns, 2) estimate the percentage of

[22] See file <Summary of_LSM, ETHNIC AND GEOTYPE PROFILES ACROSS REGIONS _2012 kitchen test.docx>

[23] The file <LSMDescriptions2012.pptx> provides a great summary. 360 Research explains, “LSM – SAARF Living Standard Measure is a unique means of segmenting the South African market. It cuts across race and other outmoded techniques of categorizing people, and instead groups people according to their living standards using criteria such as degree of urbanization and ownership of cars and major appliances. It divides the population into 10 LSM groups, 10 (highest) to 1 (lowest). For further information, refer to www.saarf.co.za.”

users who abandon the Wonderbag over time, 3) motivate more frequent usage, and 4) identify the number of carbon credits generated by Wonderbag usage. Their sampling strategy consisted of 400 phone interviews with Wonderbag owners, 21 in-depth interviews with frequent Wonderbag users, and 4 focus groups with infrequent Wonderbag uses. The 400 phone respondents were randomly selected from a group of 7219 registered Wonderbag owners who had valid contact information. I have deduced that their main findings are drawn from the phone interview data. 360 Research states that registered Wonderbag owners reflect consumers living across South Africa in all demographic segments, although they are skewed toward the LSM 4-8 demographic (70% of the sample). Electricity is the main source of fuel used (82% of the sample), then paraffin (9%) and gas (7%). They assert there is no reason to assume that registered and unregistered Wonderbag owners have different usage profiles but they do not explain why this assumption holds. Of the 400 people interviewed, they find that 46% of respondents still have their Wonderbag. There is 9% of the sample that claims they never owned a Wonderbag and 46% of the sample no longer have it. Of those who currently possess a bag, 79% have used it in the past week and 98% have used it in the past 3 months. On average, the Wonderbag is used 2.7 times per week. The Wonderbag is used to keep food warm in 57% of households, while 39% use it in order to cook more than one meal at a time, and 4% use it to give food to someone else.

The 2012 Kitchen Test study (also known as Project Shweshwe) improved upon the 2011 study. It sought to determine 1) the fraction of owners recorded in the Wonderbag database that were still using a Wonderbag, 2) the fraction of users who cook with electrical or fossil fuel-buring stoves, not firewood, 3) the amount of cooking fuel Wonderbag users and non-users consume in one week, 4) other quantitative data on habits and usage, and 5) qualitative insights and attitudes toward the Wonderbag. Although 773 Wonderbag owners agreed to be interviewed by phone, only 300 respondents satisfied the following criteria: 1) they were current Wonderbag users, 2) their primary cooking fuel was electricity, and 3) they had used the Wonderbag in the last 7 days. 360 Research then monitored this subset of the sample more closely. They identified a comparison group of non-Wonderbag users and measured total household electricity usage in both groups with metering devices. They justify their choice of measuring total electricity usage, instead of just stove electricity usage, by their desire to obtain a conservative measure of fuel usage. They are concerned that Wonderbag households may consume slightly more fuel than non-Wonderbag households precisely because they are aware of the Wonderbag's efficiency gains (Jevons Paradox). After matching Wonderbag and non-Wonderbag homes on all parameters, namely socioeconomic factors (LSM), household size, household type, geographic area, and ethnicity, the variation in family habits produced vastly different electricity usage between homes, rendering their results statistically imprecise. The coefficient of variation was too high (CV of

5.53 – trimmed mean). A CV of this size would require a sample of 11,750 respondents[24]. Reasons for high variation include migrant lifestyles; varying numbers of family members who work at home or are unemployed, different cooking styles, and differences in other activities that use fuel.

Future research could improve upon their methodology by selecting a larger sample and measuring cooking fuel usage instead of total household fuel usage. Additionally, a study should report its refusal and attrition rates. Finally, these studies attempt to motivate more frequent Wonderbag usage while estimating current usage. This could potentially introduce bias by giving respondents the message that they should be using the Wonderbag more than they currently do.[25]

1.2 TNS Research Surveys – South Africa

TNS Research Surveys conducted Project Powerball in SA in May, 2012. They sought to measure electricity, paraffin, and gas usage of Wonderbag and non-Wonderbag households. An enumerator handbook and a map of the sampling sites are the only documents about Project Powerball that are provided in the background materials. The handbook mentions that the sampling quota is 130 Wonderbag users and 130 non-users. The map demonstrates the survey was implemented in Durban and surrounding areas.

1.3 Energy Management Solutions (EMS) – South Africa

EMS performed a cooking test in order to determine fuel savings attributable to the Wonderbag in SA. They cooked 13 recipes twice, once with the Wonderbag and once without. They used an electric stove as their fuel source and find that using a Wonderbag saves between 0.14 – 1.12 kWh of electricity and anywhere from 15 – 150 minutes of cooking time, depending on the dish.

1.4 Universities of Oxford and Kigali – Rwanda

Ethan Worth (Univ. of Oxford) and Claude Mugunga (Univ. of Kigali) led a combined Baseline Survey and Kitchen Performance Test (KPT) of the Wonderbag in Rwanda in May 2012. The Baseline Survey measured the quantities of wood-fuel (both firewood and charcoal) used in households cooking in a conventional manner without Wonderbag intervention. The KPT was run under direct-paired sampling conditions, as opposed to matched-pairing, meaning that each household carried out both

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[24] See file <KT2012 Methodolgy selection.docx>

[25] This is stated in the following documents: <NOTES FOR THE READER OF THE FOLDER_2012 RESEARCH.docx> and <NOTES FOR THE READER OF THE FOLDER_2011 RESEARCH.docx>

phases of the test, rather than two matched households carrying out one phase each. They randomly selected 177 households in 5 clusters that span urban, peri-urban, and rural areas. All tests lasted 7 days (one day of instruction, 3 days of cooking without the Wonderbag, then 3 days of cooking with it). Enumerators weighed wood 3 times per day and kept a meal log for each household.

The data from 15 households was discarded due to measurement error. Participants were required to collect or purchase their own fuel in order to avoid the potential bias arising from overuse or lack of care. A free Wonderbag was offered at the end of the study to help incentivize participation. The authors find that the Wonderbag saves, on average, 5.11 kg/kitchen/day of wood-fuel or, equivalently, 1.86 tonnes/kitchen/year of wood-fuel.

5 THE DURBAN WONDERBAG HOUSEHOLD SURVEY

For our empirical analysis of Wonderbag performance in day-to-day household life, we conducted an extensive household survey in Durban, a large South African city where Wonderbag has been deployed for over two years. In this section we summarize the basic logistics of the survey.

5.1 Pre-Departure

After assembling the core research team in Berkeley (comprising six students and a faculty research supervisor), we began to develop the sampling instrument. Using information from previous Wonderbag studies and sales, potential enumeration areas were determined. A rough draft of the Wonderbag survey was also created using questionnaires from former cook stove impact evaluations as a guideline.[26] Questions fell under the broad categories of demographic information, cooking practices, cooking fuel types, or Wonderbag usage. This provisional draft was uploaded to Nexus 7 tablets using Open Data Kit (ODK) software, and several trials were conducted to find the optimal electronic version of the survey.

Additionally, we contacted faculty teaching in various social science departments at the University of KwaZulu-Natal (UKZN) to assist in our recruitment of enumerators. We described the project and our intentions, and requested the contact information of graduate students with research experience, strong language and communication skills, and local knowledge of specific communities in the greater Durban area. We sent out an online application to the recommended candidates, and scheduled interviews for our first week in South Africa.

5.2 Arrival and Field-Testing

Upon arriving to Durban, we conducted enumerator interviews. We selected twenty-one graduate students to join our team full time: five lead enumerators who would assist in field-testing the survey, management of smaller teams, and conducting daily progress reports, and sixteen full-time enumerators recruited from the local population. Six additional enumerators were hired on a stand-by basis.

Our first full week in Durban consisted of getting acquainted with the area and determining the logistics of deployment. After the enumerator team was formed, we field-tested the survey with the five lead enumerators. This phase lasted one week, and was conducted in the townships of Inanda and Ethembeni. Lastly, we made contact with and visited the Director of the South African Statistics Office in Durban, Ravi Naidoo. He provided us with the computer programs and data from the 2001 and the 2011 census, as well as enumeration maps of KwaZulu-Natal.

[26] The complete questionnaire is reproduced in an annex below.

During the initial field-testing stage, a UC Berkeley team member was paired with an enumerator. Team members were rotated amongst enumerators throughout the day to provide perspective and feedback. At the end of each day, we reviewed the data from the ODK website, and took into account enumerator recommendations. The lead enumerators not only assisted in rephrasing certain questions, but provided insight into Zulu family structure, township protocol, local government hierarchy, and information on cooking practices. As such, we continually restructured the survey during the first week to clarify any ambiguities, and to add or delete questions. We were able to adapt the survey to linguistic and cultural differences, ensuring that the information needed for proper analysis was captured. Because of this constant feedback and small group size, the lead enumerators were comfortable with the format of the questionnaire and had solidified their delivery early on.

In the first week, it became apparent that townships were also extremely large—neighborhood after neighborhood of houses and settlements were nestled throughout rolling hills. The roads and paths between them were often free form, with minimal structure and signage. It became clear that our enumerators would have trouble accessing neighborhoods if they were unfamiliar with them. This was partially due to the difficulty of finding street names and houses in settlements, but also because the public transportation system was very inefficient, requiring certain vans (called taxis) to go back to a main station or hub in order to get to another location. Most potential enumeration areas would require our team to use anywhere between two to four separate taxis, and they would need to know the routes beforehand.

The second week of field-testing included the entire team of twenty-one enumerators, and began with training at the UKZN campus. Introductions were made, intentions and goals discussed, questions answered, and the entire questionnaire was clarified and performed several times by each enumerator. Later in the week, full scale field-testing began in Chesterville and in different parts of Inanda. We split enumerators into four separate groups, each led by one UC Berkeley team member and one lead enumerator. New enumerators were paired with either a lead enumerator or a UC Berkeley team member to increase learning of the survey and tablet.

At the end of each training day, we held a group meeting, and UC Berkeley team members clarified anything that came up. Enumerators also asked questions and/or described scenarios they encountered in which the survey could not adequately record the response. In the evenings, changes were made to the survey, and the new version was tested on a tablet in its entirety.

The survey was finalized by the end of the second week of field testing, available on the tablets in both Zulu and English, and all enumerators were conducting surveys on their own. By this time, the UC Berkeley team would randomly visit enumerators during interviews throughout the day, offering feedback and ensuring consistency among delivery. Additionally, GPS coordinates were taken at every township for mapping and survey tagging.

The tablets and the ODK software increased efficiency and allowed the UC Berkeley team members to follow along with each interview. Coincidentally, however, both our field-testing sites were very successful and in Wonderbag-dense areas. We were able to find Wonderbag users by going door-to-door, and while this was great for field-testing, it provided a false sense of accessibility to frequent Wonderbag users.

5.3 Survey Deployment in Neighborhoods

We began full deployment the following week in the township of Kwadengezi, continuing into Umlazi, Chesterville, Newlands East, Newlands West, Mount Edgecombe and Kulala North over the next two weeks. While in the outskirts of Mount Edgecombe, two female enumerators experienced a violation of security: men were watching and harassing them to such a level that they were unable to continue working after an hour. Their entire group had to be collected and moved to a different location.

For the following day, a new location was selected by using a different method; Kwamakhuta was chosen by conducting extensive research on registration cards from Shoprite promotions. Not only was Kwamakhuta a location with high Wonderbag sales in a concentrated area, we had two enumerators with local township knowledge and we were able to get in contact with the ward councilor and police chief.

Upon arrival to Kwamakhuta, we checked in at the police station and asked if there were any areas that should be avoided. We took their advice and phone numbers in case of emergency, and began surveying. As had been done in previous townships, the team was split up into groups so that males were evenly distributed, and a buddy system was in full operation. In spite of all these precautions, each group received multiple warnings from residents that they were not safe. Residents often cited young men who use whoonga, a relatively new street drug gaining popularity in South African townships, as the problem. We were informed that addicts targeted items that they could resell easily, and newcomers in their areas were easily spotted, and as such, prime targets for theft and violence.

Even though the survey itself was successful in capturing the necessary information, we faced several logistical constraints while conducting surveys in neighborhoods. We aimed to conduct fifty percent of total surveys with Wonderbag users, which was not possible, as almost all neighborhoods surveyed were not densely populated enough with Wonderbag users.

We also discovered varying levels of Wonderbag usage once users were actually found. Some people who owned Wonderbags did not even use them, mainly citing that they either did not know how to cook with them, or did not like the taste or texture of the resulting food. Snowball sampling also did not work as we had anticipated. We found that frequent Wonderbag users often did not know many other Wonderbag users—they could direct us to at most three other households in the neighborhood. Moreover, it was often difficult to find these households, and if they were found, enumerators had to return the next day, at a specific time, to conduct an interview; several times, these households turned out to be infrequent Wonderbag users. It became clear that there was not a large enough network of Wonderbag users in these neighborhoods. Almost everyone had heard of the Wonderbag, but successful and frequent users seemed to be isolated.

A snowball sampling method might have worked if the project had a longer timeframe. The number of surveys an enumerator could conduct in one day was significantly reduced when they were required to follow an appointment schedule, travel to houses that were far away from each other, or find houses without clearly marked addresses. Furthermore, setting up appointments in advance required at least three phone calls: an initial call, a follow up call the day of the interview and a third call to clarify the house's location once in the field. As such, phoning turned out to be very resource-intensive. Moreover, while the Wonderbag database is vast, it does not have good geographic indicators (i.e. it does not provide accurate information on the place of residence). Even when two households with the same townships were listed, these two Wonderbag owners may live twenty minutes apart by car, making it difficult to move between specific houses. Additionally, several phone numbers in the database turned out to be either disconnected or were owned by a family member who did not actually live in the household (the number had been used just for registration during the Shoprite promotion).

Another constraint with neighborhood survey deployment was security—new faces and electronics stuck out. Theft is on the rise in many of these townships due to whoonga, as addicts steal to fuel their addiction. Our tablets were a clear target. The enumerator teams were frequently warned by concerned residents about "whoonga boys," and several of our enumerators reported being stalked or watched by groups of young men. Although we used the buddy system and took every possible precaution, we could not afford to keep our enumerators in pairs during deployment interviews. During field-testing stage, we were always in pairs, which shielded us from this problem. Female enumerators were particularly vulnerable since they were entering houses alone—sexual assault was a major concern. One week into survey deployment, we had a particularly bad day with multiple warnings from residents. As such, the idea of surveying in Shoprite stores came up in discussion, and was tried the following day.

5.4 Survey Deployment in Shoprite Stores

Surveying directly at the point of Wonderbag distribution paid off immediately. Our enumerators were able to do ten to fifteen surveys per day, over half of which were with Wonderbag users of varying degrees. During neighborhood deployment, our enumerators conducted approximately five surveys per day. Enumerators no longer had to spend time walking, skipping locked houses, or getting lost. They were able to ensure that at least fifty percent of their surveys were with Wonderbag users by screening and skipping people who did not use the Wonderbag. Security staff was also present at each Shoprite location, and the sheer volume of customers added safety. Additionally, UC Berkeley team members were able to keep track of the enumerators at all times.

The Shoprite survey environment had two limitations: lack of privacy and impatient participants. Since the surveys were being conducted in public, some participants were reluctant to provide their full name, address, age, and income. However, with a strong introduction, official nametags, Shoprite permission, and UC Berkeley presence, legitimacy was established early on. If someone happened to be uncomfortable with disclosing such information, participants could provide their initials, neighborhood, age range, and income bracket. The enumerators also had to learn to conduct the survey more efficiently to appease impatient shoppers. Despite these challenges, safety and finding Wonderbag users was the priority. Moreover, this strategy ensured that Shoprite customers were being interviewed directly, particularly the women who shop and cook.

Due to the initial success of the Shoprite survey deployment, we continued to conduct surveys in various locations throughout the greater Durban area until the end of our time in South Africa. The Shoptite locations that were sampled included Mount Edgecombe, Bridge City, Pinetown (Old Main Road and Hill Street), Berea, Umgeni Road, Bridge City, West Street, Britannia, Newtown, Kwamashu, Newlands, Brickhill, Isipingo, Chatsworth Shoprite, Brickhill and Montclair. At the end of our time surveying in Durban, 4004 surveys had been conducted.

6 CONCLUSIONS

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