Two feet on the ground, Head in the clouds:

A critical review of improved household cookstoves in developing countries

By

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Abstract

In an ever increasing global world it is becoming more important for scientists and engineers to research the global, regional, and individual impacts of anthropogenic emissions. Day-to-day activities and the choices we make can have drastic regional and global implications; by critically assessing how these activities affect the environment and people we can make more informed and positive choices for sustainable solutions. However, in many situations technology interventions and policy changes, meant to improve conditions but implemented without proper foresight, have created unforeseen consequences. This research takes us beyond Michigan Technological University to households internationally where indoor air pollution from household combustion has created harmful emissions, strongly impacting the lives of countless individuals and the global environment. To combat fuel shortages and reduce harmful emissions, improved cookstove implementation projects have become the primary intervention measure. In order to ensure actual benefits of these development projects, our analysis critically examines the assumed social, health, environment, and economic benefits of switching from a traditional cooking method to an improved cookstove. Through a qualitative assessment we found that improved cookstove projects are not well accepted by people in developing countries. In line with the growing appreciation of participatory methods, we emphasize the need for post-implementation monitoring through three case studies for future design improvement. We found that the particles emitted from improved cook stoves have higher radiative forcing properties, are smaller, have a longer atmospheric lifetime but depending on the stove can have lower total emissions. We concluded that a more comprehensive quantitative study is needed to accurately assess the impact of introducing improved cook stoves.
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Introduction

More than three billion people, or almost half the world’s population, cook in their homes using traditional fires and stoves that use solid fuels such as wood, dung and crop waste (United Nations, 2010). The incomplete combustion of these fuels produces harmful gases and particles such as carbon monoxide (CO) and ultrafine particulate matter (PM$_{2.5}$), exacerbating acute lower respiratory infections, pneumonia, chronic bronchitis, chronic obstructive pulmonary disease and lung cancer (Bruce et al., 2000). Most affected are women and children who spend much of their time indoors tending to meals. According to the World Health Organization (2002), this basic human activity claims the lives of 1.5 million people every year. In addition, biomass cooking intensifies social and cultural inequalities. In Kenya, for example, poor families use more than 20% of disposable income to purchase fuel, or expel more than 25% of household labor to collect firewood (Kammen, 2001). Household biomass burning also has global implications, the effects of solid fuel burning (via black carbon emissions) on global warming potential (GWP) are believed to create the second highest net forcing agent behind carbon dioxide (CO$_2$) (Grieshop et al., 2009). Yet the switch from solid fuels to expensive alternatives, such as liquefied petroleum gas (LPG) and electricity will not happen in the near future for the majority of the planet’s underprivileged. While many improved stove designs have been introduced to combat these issues throughout Africa in the past 40 years, very few have had success in gaining widespread adoption with the exception of the Kenyan ceramic Jiko (improved stove). Additionally, some studies have actually found an increase in harmful emissions after stove intervention projects (Smith, 1999). Building off of these findings and from our invested interest as returned and future Peace Corps volunteers, we examined three health and environment variables altered by introducing improved cookstoves. Analysis was done through literature review, field interviews, emissions testing and laboratory analysis. The three areas analyzed in this study are social acceptance of improved cookstoves, particle morphology of emissions, and radiative characteristics of particles. A critique and further understanding of these three variables will provide important information for future design of appropriate intervention strategies.

Research

*The Improved Cook Stove*

The traditional cooking method in sub-Saharan Africa is the 3-stone method that uses wood and other biomass as fuel. In controlled laboratory testing, the 3-stone method wastes 74% of the energy produced by combustion of the fuel (Smith et al., 2007). One kilogram of fuel roughly produces 16 MJ of energy, however only 2.76 MJ of energy goes into the pot for cooking. Hypothetically, with the implementation of improved cook stoves that have the ability to both drastically increase the efficiency and better regulate the emissions released into the home there is potential for addressing issues related to human health and depletion of resources. A properly used improved cookstove can increase efficiency by 50%, thus reducing indoor air pollution by an exponential amount (Smith et al., 2007). Properly used improved cook stoves should have less of a negative impact on human health, the ecosystem, and resources – but very little research has proven this to be true (WHO, 2002).
Technology Adoption

Improved cook stove technology research began in the 1970’s in response to concerns over deforestation and associated loss of soil nutrients. In the following decades, the link between stoves, poor indoor air quality, and health became more pronounced, incorporating a social factor into stove development (Rwiza, 2009). Since then, PCIA member organizations have installed 1.4 million improved stoves worldwide, with the goal of 6 million stoves by 2010 (PCIA). Tanzania, one of the target countries, currently has a low improved stove usage rate (see Figure 1 for reference).

![Distribution of fuel usage in Northern Tanzania from household surveys conducted in 2009.](image)

These numbers may seem impressive at first glance, but give way under closer scrutiny. As mentioned in the introduction of this report, 3 billion people, half of the world’s population, rely on biomass combustion for heating, cooking, and light energy. If 1.4 million stoves have been implemented since 2002, which have affected the lives of 7.6 million people (PCIA), only 0.25% of the total need has been met over the past nine years. With over 400 member organizations in the PCIA, one would expect a higher dissemination rate. These statistics only pertain to the implemented stoves; low donor interest and lack of personnel have diminished the demand for post-implementation studies to almost negligible. If improved stoves have been an on-going research topic for forty years and the technology is available, even if cost prohibitive, why has the acceptance rate remained so low?

The answer lies in the lack of consumer feedback, even though “stakeholder participation is central to sustainability and sustainable development” (Rwiza, 2009). In a recent stove and fuel emissions comparison report, researchers at the Aprochevo Research Center (ARC) recommend “the use of well-
designed pot skirts” (10), constant attention with regard to feeding the fire, and low wood moisture content (Jetter and Kariher, 2009). While these considerations are appropriate for a laboratory setting when attempting to optimize thermal and combustion efficiency, there is no mention in the report of whether these were desirable attributes for the end-users. Improved stoves are often installed in tropical climates that experience seasonal periods of intense rainfall. For example, dry wood may be available during the dry season but impossible to locate during the rainy season, leaving the stove users with few options. “Constant attention with regard to feeding the fire” is time intensive, both before use and while cooking. Women, traditionally the primary cooks, are also responsible for childcare, household chores such as cleaning and laundry, and tending the family garden. The additional time necessary to prepare the fuel and tend to the fire may simply not be available. Finally, the pot skirts may impede normal cooking practices (such as being the wrong size for a pot), causing the user to discard the part.

In field studies conducted by Mwemezi Rwiza in “peri-urban” and rural Tanzania, and a case study review reported by Travis Ostrom, several design considerations were reoccurring factors for user acceptance. Construction of the wide variety of improved stove designs depended on the cost (Rwiza 23, Ostrom 18), the availability of materials (Rwiza 23, 30), and space conditions (Rwiza 31). Later acceptance or abandonment (return to former stove design) was dictated by the number and sizes of pots the stove could accommodate (Rwiza 31), culture (in one home there were two stoves in two separate kitchens because a daughter and mother-in-law cannot cook in the same room) (Rwiza 33), and whether the design allows for other non-cooking attributes (heat, light, insect repellent, etc.) (Rwiza 29-32).

In both cases, the users found informational sessions before construction helpful (Rwiza 25-26, Ostrom 17). Ostrom also highlighted the need for post-implementation monitoring as a means to reinforce the educational component of the informational sessions and to provide technical support (17). Both authors recommend some participatory planning component in all stages of the project (Rwiza 2009, Ostrom 18). As none of the case study acceptance factors correlate with the ARC researchers design recommendations, it is evident how little user participation is incorporated in improved stove design and why improved stove dissemination has been unsuccessful thus far.

*Case Study: Fronterizo and Cantón Libertad, Guatemala*

The student chapter of Engineers Without Borders-USA has been affiliated with the villages of Fronterizo and Cantón Libertad, Guatemala, since 2005. The villages are home to return civil war refugees, approximately 400-500 people total. Until now, the focus of the group and communities has been increasing the availability of potable water. Originally, the communities accessed water at shallow, unprotected hillside springs. These sources were and are susceptible to runoff contamination, and have high E. Coli and coliform counts (tested by EWB-USA Michigan Tech during assessment trips in 2005, 2009, 2010, and 2011). They are also subject to seasonal variability because the water table drops significantly during the dry season. The successful construction and maintenance of four deep wells
(implemented in 2006 and 2010) currently provide the villages with a year-round supply of clean groundwater.

EWB-USA Michigan Tech wishes to continue a working relationship with the villages by starting an improved stove project. The majority of families in both communities cook over an open flame using some variation of the traditional, three-stone system. From personal observation, indoor air quality is extremely poor and large quantities of fuel (locally collected wood) are used daily. While the effectiveness of improved stoves remains debatable, stoves are an improvement in thermal efficiency and fuel economy over the three stone system. Combined with a ventilation system (few kitchens have windows, although the building structure is not entirely enclosed. See Figure 1 for reference) and community participation during the design process, the implementation of improved cook stoves may reduce fuel usage and cook time.

![Figure 1: Typical stove and kitchen in Canton Libertad, Guatemala (Andrea Walvatne).](image)

Individual surveys were conducted by EWB-USA Michigan Tech members in community members’ homes during assessment trips in May 2010 and March 2011. For both trips, permission to seek further information (through the interviews) was obtained during community meetings prior to surveying. The surveys were “focused interview” (Rwiza 20) in structure but intended to create as much of a conversation atmosphere as possible. This was done to put the interviewee at ease and to prevent
leading questions. Unfortunately, IRB approval is not a requirement for EWB-USA assessments and was not obtained for either visit (thus the results from the assessments could not be published in this report).

For future trips, EWB-USA Michigan Tech will obtain IRB approval for all survey work. The group is beginning to organize the gathered information spatially using ArcGIS, and will continue to update the “ethnographic map” after each return visit to the villages. For future work with an improved cook stove project, the group will investigate using the life cycle assessment approach developed by Travis Ostrom in 2010 to improve the acceptance rate of the design.

**Particle Morphology**

In combustion processes ultrafine primary particles (monomers) are produced through incomplete combustion. These individual particles, attracted by ionic energy, will cluster forming aggregate chains and eventually spine like structures. Aggregation of the particles influences their overall impact on climate change and human health. Fractal geometry and structural coefficients provide quantitative morphological characterization of this random system in order to determine their overall impact. Fractal structures are described using a scale between 1 and 3 where 1 is a straight line, 2 is a flat surface, and 3 is a spherical volume. Quantifying the fractal dimensions provides important information on the formation process, absorption, reflection, and atmospheric life of particles. Biomass burning produces dark soot particles that can have very different physical and chemical characteristics depending on fuel type, thermal efficiency, mixing rate, and fuel to air ratios. This section of the report assesses the impact of altering these parameters, through implementing improved cook stoves, and how it affects particle morphology.

Unaggregated particles will have a higher surface area to mass ratio and will have a smaller radius, thus increasing its likelihood of alveolar deposition. Agglomerate particles with smaller monomer radiuses have a constant absorption cross section with fractal dimensions less than 2 but increase rapidly greater than 2 (Lui et al, 2008). Reduction of systematic light absorption also decreases with particle clusters with large monomer particles, large number of particles, and particles with a large refractive index. There is also little change to the single scattering albedo between chain like structures and agglomerates (Liu et al, 2008). This emphasizes the importance of increasing scattering interaction among singular spherical particles. In some circumstances the increased combustion temperature causes the particles to burn (oxidize) faster than they pyrolyze and agglomerate – higher temperature reduces soot. During pyrolisis in higher combustion temperature conditions the hydrogen radicals are stripped away, causing a higher carbon-hydrogen ratio – leaving more soot monomers unable to agglomerate (Slowik et al, 2004). Most primary soot particles are hydrophobic and are only deposited through dry deposition. Condensation and chemical reactions with mostly hydrogen radicals, results in agglomeration make them hydrophilic, allowing for wet deposition, which is more efficient. Two details should be drawn from the above discussion; 1) increased temperature (improved thermal efficiency) reduces the number of particles, 2) however, increased thermal efficiency also produces smaller particles that will be unable
to agglomerate and become hydrophilic because of fewer hydrogen radicals. Although these particles are fewer they will have a higher overall absorption cross section, have longer atmospheric lifetime, and have a higher risk for entering respiratory systems. The experiment below was developed to assess if this is true in the field by comparing aerosol emissions from a three stone fire (thermally inefficient) with an improved mud stove (thermally more efficient).

The methods and techniques used to quantify the differences in particle morphology were done through image processing using a Field Emissions Scanning Electron Microscope (FESEM). In the laboratory we collected aerosol emissions on polycarbonate filters using an open faced pop-top holder and a diaphragm pump drawing at .5 LPM. Fuels type and conditions were kept constant through a Water Boiling Test (WBT) and filters were collected during the simmering phase of the test for 5 minutes creating an even loading on the filter. The filters were prepared on metal mounts coated with carbon tape. Operating accelerating voltage of the FESEM was .1 KeV to keep a shallow interaction volume because of the small size and composition of the sample. Images were taken at 20,000 and 100,000x magnification in order to analyze sub-micrometer fractal dimensions of particles and to get a representative distribution of particle type and size (see Figure 3).

![Figure 2: FESEM images of particles from diesel combustion taken in Arusha Tanzania on July 17th 2011. A) 20,000x magnification illustrates the ability for visual representation of particles. B) 100,000x magnification of a fractal aggregated particle.](image)

This report only summarizes the results of the qualitative assessment of particle type, comparing improved cook stove and three stone fire emissions. The quantitative analysis of fractal dimensions of individual particles will be published at a later point. For this report we wanted to qualitatively assess if particles from thermally more efficient combustion have different morphologies compared to a three stone fire. Figure 4 represents a sample of what the different filters from three stone and improved stove look like. We used 23 images at 20,000x magnification to characterize the types of particles present. We then placed each particle in the entire filter into one of four categories which represents whether they are primary particles or secondary agglomerates and if their estimated fractal dimension.
Figure 3: FESEM images of particle distribution. A) Particles from 3 stone fire, notice that they are mostly all agglomerated into tight packed aggregates. B) particles from emissions of an improved cook stove, notice that there are far more primary particles and the aggregated particles are more fractal.

The four categories are spherical and fractal for primary particles and for agglomerates whether they are fractal chain structures or aggregated into a compact sphere. The results from this analysis are displayed in Figure 5. The traditional three stone fire shows a near Gaussian distribution where the aggregated particles are slightly more than the primary particles. On the other hand the improved cook stove shows a linear distribution with the far greater majority of particles placed in the primary spherical particles. What this means is the higher thermal efficiency does not allow particles to aggregate quickly, producing smaller primary particles with a longer atmospheric lifetime. Further analysis is needed to quantify the significance of these findings.
Figure 4: Graphs showing the distribution of particle types and morphology. The Y axis is the number of counts (N=23) A) 3 Stone Fire. B) Improved cook stove.

In the natural environment it is critical to have the capabilities of quantifying complex systems like ultrafine particles. In development projects as well as research it is all too common to only assess one aspect of an intervention or product and not take into account the full life cycle and impact of an intervention. Sustainability comes from an objective analysis weighing the entirety of an impact on changing a system. This study provided an initial framework for that final holistic assessment.

**Black Carbon versus Organic Carbon**

Black carbon is a light absorbing aerosol with a graphite-like structure and is a by-product of incomplete combustion. Black carbon produced by open fires form large, compounded molecules and has been credited as a major contributor to global warming. A higher black carbon to total carbon ratio is an indicator that there have been higher levels of incomplete combustion. Incomplete combustion creates more particulate matter as well as higher levels of carbon monoxide which are both harmful to humans.
More efficient burning would create more complete combustion. Therefore the efficiency of a stove can be tested by measuring its black carbon to total carbon ratio. Unlike previous testing results, Figure 7 suggests the three stone stove is more efficient than any of the tested improved stoves. Because three stone fires are open to the atmosphere, it is possible that the increased oxygen flow to the flame is increasing combustion efficiency. The amount of Black Carbon and organic carbon produced by combustion can be measured by the amount of light that is absorbed by each because black carbon absorbs more light than organic carbon. The amounts of each can also be measured by the temperature at which they combust (Bahner, 1).

![Figure 5: Average of Black Carbon/Total Carbon ratios determined using IMPROVE TOR, NIOSH TOR and NIST TOR methods. Fuel and burning phase were kept constant throughout 3 iterations for each testing of the four stoves. (Data courtesy of Dr. Bernine Kahn-EPA)](image)

It is because of black carbon’s light and heat absorbing properties that it is a contributor to global warming. Heat from sunlight hitting black carbon in the atmosphere will be absorbed and stay in the atmosphere. Black carbon also contributes to global warming by reducing the reflective properties of snow, ice and clouds, absorbing that light and holding it within the atmosphere. Organic carbon on the other hand, is credited as assisting with the cooling of the planet because these compounds reflect light back into space instead of locking it within the earth’s atmosphere.

However, since black carbon and organic carbon do not remain in the atmosphere for as long as other aerosols, climate specialists feel that reducing black carbon emissions into the atmosphere will cause a more significant change than targeting other aerosols (Bahner,2). These specialists believe that reducing black carbon is a more achievable goal and may reduce the rate of rising global temperatures. However, since organic carbon is a cooling agent and since aiming to reduce black carbon will reduce organic carbon, the cost and benefits of their total temperature changing capacity must be considered.
The tropospheric aerosol burden has a direct effect on GWP through the backscattering and absorption of incoming solar radiation. Carbonaceous aerosols represent a significant portion of the tropospheric burden and are strongly light absorbing. According to conservative estimates, one ton of black carbon causes about 600 times the warming of one ton of CO₂ over a period of 100 years. Therefore, black carbon is estimated to be the second largest contributor to radiative forcing, second only to CO₂. Globally, household combustion accounts for as much as half the world’s black carbon production as well as a significant amount of total carbon monoxide and volatile organic chemical emissions (Smith, 2009). It is believed that continually reducing present day emissions of black carbon over the next fifty years to remove 25Gt C from the atmosphere would be equivalent to doubling the efficiency of two billion cars (Grieshop et al, 2009). Moreover, the estimated life time of carbonaceous particles is of the order of days to several weeks, so reducing black carbon should result in immediate global response. Further studying the particulate and aerosol emissions form biomass burning will provide detailed scientific information about the extent of local health hazards and global implications. The results will potentially motivate government and development organizations to implement sustainable solutions that reduce emissions and improve cooking methods. However does implementing improved combustion technologies actually increase efficiency and reduce particle emissions?

Radiative forcing is the difference between the amount of heat absorbed by the earth’s atmosphere as compared to the heat released by the atmosphere. Black and organic carbon have radiative forcing properties because black carbon absorbs and organic carbon reflects heat while they are active in the atmosphere. Knowing how these properties function and their impact on the changes in temperature in the earth’s atmosphere will help researchers to better understand the causes of global warming in the atmosphere. See Figure 6 for reference.
Figure 6: Radiative forcing (W m⁻²) and its effects on Global Warming Potential. Note that the third most important factor contributing to radiative forcing is black carbon emissions (extracted from Smith, 2009).

To achieve more efficient burning, fuel in a combustion chamber must have access to more air than is stoichiometrically required for more complete combustion. More complete combustion will lower the amount of black carbon and organic carbon particles released during burning.

If improved stoves that can produce more efficient and complete combustion become widely accepted, the overall amount of black carbon being released into the atmosphere will be reduced. Less black carbon in the atmosphere would cause less heat to be trapped in the atmosphere and more light could be reflected back into space from snow and ice.
Global Impact

Fuel emissions affect climate change by contributing particulates, soot, and green house gases into the atmosphere. Reducing fuel emissions would have an impact similar to improving the efficiency of automobiles and could be an additional mitigation wedge. By expanding our regional knowledge about health risks and negative impacts to the environment, the scientific community’s and policy maker’s abilities to make accurate climate impact predictions and choices regarding cooking stove implementation and intervention will be enhanced.

The knowledge about cooking stove efficiency and acceptance obtained by this research will serve to more accurately define the hazards from cooking fuel combustion, thus better informing policy makers and health workers on the effects and extent of indoor air pollution in rural Tanzanian villages. The critical analysis of the impact of implementing improved cook stoves will provide important information for development project designers in assessing the most viable option for indoor air pollution interventions. This information will be used by academics and governments in the re-designing and implementation of appropriate stoves, houses, ventilation systems or a more holistic educational program. Additionally, the project will provide a better understanding of the overall impact of improved stoves.

Future Research

The work presented in this paper can be used as a framework for future analysis. More research is needed in quantifying health, social and ecological impacts, more accurately measured fuel consumption, and finally the extent and impact of black carbon and particulate morphology on GWP.

The examination of the effects of solid cooking fuels at the household level on emissions and public health are often overlooked according to the World Health Organization. Indoor air pollution is a major environmental and public health hazard for many of the world’s poorest, most vulnerable people. However, current evidence is based on a limited number of studies, few of which have measured smoke exposure directly (WHO, 2002). Further research is needed to quantify the health impacts of intervention projects on improving indoor air pollution from cooking.

In-situ indoor air pollution measurements are vital for the understanding of global impacts from burning solid fuels. Globally household combustion accounts for as much as half the world’s black carbon production as well as a significant amount of total carbon monoxide and volatile organic chemical emissions (Smith et al., 2009). Research will be done using an optical ionization measurement technique for characterization of micrometer and sub-micrometer aerosols in household environments (Litton et al., 2004). To gain a better understanding of the real world productions of aerosols and black carbon from household solid fuel burning, particulate measurements will be performed at numerous households using improved and local stove designs with various fuel types at different periods of the
year. Additionally, in a laboratory setting a small smoke box equipped with ventilation hood, and a constant output atomizer will be used to compare aerosol output from local fuels. The data obtained will provide insight into quantifying indoor and outdoor air pollutants, and their effects on global climate change and respiratory diseases.

This field campaign will provide an improved characterization of global aerosols, clouds, and particulates from combustion and biomass burning, hence quantification of radiative forcing and regional health risks. Additionally, the data will serve as a regional baseline to measure the effects of sustainable changes such as increased fuel efficiency, social practices, and improved stove technologies.

Conclusions

Indoor air pollution is a major environmental and public health hazard for many of the world’s poorest, most vulnerable people. Burning biomass fuels indoors accounts for a significant portion of the global burden of disease in developing countries. For the past 40 years improved stoves disseminated by NGO’s and international agencies have been the conventional “solution” to this problem with varying success. We have shown qualitatively that the conventional method of intervention may have unintended consequences that could cause the switch from traditional three stone cook to improved stoves to have a negative impact. Further quantitative analysis is necessary to confirm these preliminary results.
References


Smith, K., Balakrishnan, K. Mitigating climate, meeting MDG’s, and moderating chronic disease: the health co-benefits landscape. Commonwealth Health Minister’s Update 2009, p59-65.


Appendices

Tables

Table 1: United Nations-Millennium Development Goals (MDG) related to household energy practices (modified from WHO, 2006). 21
### Appendix A: Tables

Table 1: United Nations-Millennium Development Goals (MDG) related to household energy practices (modified from WHO, 2006).

<table>
<thead>
<tr>
<th>Millennium Development Goals</th>
<th>Contribution of improved household energy practices</th>
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<tr>
<td>Goal 1: Eradicate extreme poverty and hunger</td>
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|  | • Saving time spent being ill or having to care for sick children will cut health care expenses and increase earning capacities.  
|  | • Where fuels are purchased, increasing fuel efficiency and thus cutting down on the quantity of fuel needed will ease constraints on already tight household budgets.  
|  | • Improved household energy technologies and practices will open up opportunities for income generation.  
|  | • Access to electricity will provide a source of light for economic activities in the evening and a source of energy for operating, for example, a sewing-machine or refrigerator.  |
| Goal 2: Achieve universal primary education |  |
|  | • With less time lost in collecting fuel and due to ill health, children will have more time available for school attendance and homework.  
|  | • Better lighting will allow children to study outside of daylight hours and without putting their eyesight at risk.  |
| Goal 3: Promote gender equality and empower women |  |
|  | • Alleviating the drudgery of fuel collection and reducing cooking time will free women's time for productive endeavors, education and child care.  
|  | • Reducing the time and distance that women and girls need to travel to collect fuel will reduce the risk of assault and injury, particularly in conflict situations.  
|  | • Involving women in household energy decisions will promote gender equality and raise women's prestige.  |
| Goal 4: Reduce child mortality |  |
|  | • Reducing indoor air pollution will prevent child morbidity and mortality from pneumonia.  
|  | • Protecting the developing embryo from indoor air pollution can help avert stillbirth, perinatal mortality and low birth weight.  
|  | • Getting rid of open fires and kerosene wick lamps in the home can prevent infants and toddlers being burned and scalded.  |
| Goal 5: Improve maternal health |  |
|  | • Curbing indoor air pollution will alleviate chronic respiratory problems among women.  
|  | • A less polluted home can improve the health of new mothers who spend time close to the fire after having given birth.  
|  | • A more accessible source of fuel can reduce women's labor burdens and associated health risks, such as prolapse due to carrying heavy loads.  |
| Goal 6: Combat HIV/AIDS, malaria and other diseases |  |
|  | • Lowering levels of indoor air pollution levels can help prevent 1.6 million deaths from tuberculosis annually.  |
| Goal 7: Ensure environmental sustainability |  |
|  | • Where biomass is scarce, easing the reliance on wood for fuel through more efficient cooking practices will lessen pressures on forests.  
|  | • Moving up the energy ladder and using improved stoves can increase energy efficiency and decrease greenhouse gas emissions.  |
| Goal 8: Develop a global partnership for development |  |
|  | • Recognition in development agendas and by partnerships of the fundamental role that household energy plays in economic and social development will help achieve the Millennium Development Goals by 2015.  |