Ethanol as a Household Fuel in Madagascar

Component C

FINAL REPORT

Review of Sub-Saharan Africa Experience in Scaling-up Household Energy Interventions

March 2011

Acknowledgements

This report was produced by a number of individuals and organisations, a full list of key informants can be found on page 99.

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Executive Summary

Ethanol is a fuel of increasing interest to the development community. However, if it is to be adopted on a large scale, comparisons need to be made against other fuels and technologies. At the same time, lessons learnt in disseminating biomass and charcoal technologies can provide useful lessons in its dissemination.

Review of programs, technologies and approaches

Since the early 1980s there have been wide-ranging international and national strategies to address energy issues in African households. A range of considerations have driven household cooking interventions in differing proportions and with varying degrees of overlap. These concerns comprise; the **health impacts** of smoke inhalation, particularly on women and children, issues around **deforestation** and desertification linked with consumption of fuelwood, the impact of burning of fuelwood and its impact on **greenhouse gas emissions** (GHGs) contributing to climate change, and the **drudgery, time lost and danger** of women collecting firewood and its cyclical contribution to maintaining poverty and vulnerability.

Efforts have included a **switch to alternative fuels** with associated new stoves (to reduce the need for fuelwood), improving the **efficiency of stoves** using existing fuels (to reduce fuelwood consumed, and/or reduce the quantity of smoke produced), technologies to **extract harmful smoke** from rooms without substantial interference with the cooking process itself, approaches to **change the behaviour** of cooks regarding the manner or location of cooking, and interventions aimed at **replenishing stocks of woodfuel** through afforestation.

Such interventions involve a variety of technologies and approaches, and within each intervention type, several products and practices of technology are used. The most relevant of these to the Madagascar situation are described in Chapter 1 of this report, reviewing projects and technologies focussing on ethanol stoves, biomass stoves, charcoal stoves, enhanced ventilation and low cost options.

In Madagascar, the main fuels in current use are fuelwood and charcoal, with a steadily increasing use of LPG in urban areas. With serious pressures on forested areas, and high levels of household air pollution from wood and charcoal being used on traditional stoves, options for reducing reliance on these fuels are being sought. Potential fuels include kerosene, LPG, ethanol, electricity, plant oil. Electricity is too expensive for people living in poverty, and requires widespread grid electrification, and this is unlikely in the foreseeable future in rural areas. Kerosene would need to be imported, and has not been shown to be popular in Madagascar.

The best potential option appears to be ethanol, particularly as sugar cane is grown in Madagascar, and although this industry has been in decline for some years, the potential for a strong and vibrant sugar industry that can also provide ethanol as a household fuel is a compelling argument for examining the options for ethanol in detail. This study looks back at the successful introduction of stoves and fuel within the African context. Table 1 shows a broad spectrum of options that are available, their potential for pollution reduction, cost effectiveness, fuel saving, life, and other factors specific to the intervention. Households may opt for combinations of changes; in West Kenya, hood and flues used with ceramic stoves (for better combustion and less time spent by the stove), hay boxes (insulated chambers which slow-cook hot food without fuel) and improved ventilation reduced kitchen levels of CO (used as a proxy for PM) by around **70%**. Most 'project' households in this study reported using pot lids regularly as a result of awareness-raising.

Table 1: Stove types, their fuel, distribution, product life and approximate cost

	Name of stove	Pollution reduction	Cost (US$)	Cost effectiveness	Fuel saving(%)	Approx life (yrs)	Notes
Ethanol & Gelfuel stoves	**CleanCook**	Very good – virtually zero particles	~$55	Fair – very clean, high up-front costs but long life	n/a	~10yrs	Needs good supply chain for ethanol and people to be able to afford fuel and stove
	NARI	Good	-	-	n/a	Research	No external test results available
	ProImpex	Good	-	-	n/a	Research	Tested at Aprovecho – some design changes advised for safety & performance
	SuperBlue	Not measured	$10		n/a	Not known	Seeking finance – not currently in manufacture
	Cooksafe	Good	Not known		n/a	Not known	Not currently in manufacture
	Greenheat	Not known	Not known		n/a	Not known	Not known – ethanol gel. Requires gelfuel which is costly per unit of energy
Woodfuel stoves	**Upesi**	Inconclusive; faster cooking reduces cook exposure	Between $2 and $6	Low cost and long-lasting. Used all the time.	50%	~4yrs	Very well accepted, widely available.

	Name of stove	Pollution reduction	Cost (US$)	Cost effectiveness	Fuel saving(%)	Approx life (yrs)	Notes
	Toko Mitsitsy	Not known	Low cost or home made	Very affordable but short product life	30% - 65%	-	Mainly designed for fuel-use reduction
	Vesto stove	Very good	$20-$30 (2004)	Fuel can be gathered – life not known	-	? Stainless steel	Uses a system known as updraft. Mainly in South Africa
	Onil stove	Very good	$100 often subsidised	Good where subsidy is available - Fuel can be gathered	60%-70%	5 – 10 years (estimate)	Used in Central America
	Philips	Excellent	Research		80%	Research	Use of fan to improve combustion is effective
	EcoStove	Very good	Not known	Fuel can be gathered	50%	5 – 10 years (estimate)	Promoted in Central America
	StoveTec	Very good	$12	Low cost stove with very good emission reductions.	40% (wood)	At least 2yrs - new	Stove body made in China - built into metal or ceramic casing. Charcoal version available
	Envirofit	Very good	$10-$40 subsidised	Very good at subsidised price as fuel can be gathered	60% wood	Not yet known	Charcoal version to be launched in Africa
Charcoal stoves	**KCJ**	Good	$2-$5	Cost effective in reducing levels of particles in the house, but leaving high levels of CO	30%-50%	5-10yrs	1.6million KCJ & various similar stoves. Traditional process produces substantial smoke.
	Gyapa	Reduced particulates	~$6	See KCJ	40%	At least 3 years	Very strong marketing campaign and carbon finance

	Name of stove	Pollution reduction	Cost (US$)	Cost effectiveness	Fuel saving(%)	Approx life (yrs)	Notes
	Ugastove	Reduced particulates	-	Carbon finance allows stove to be affordable	38% - 58%	At least three years	Carbon finance funded - voluntary market. Woodstove available
LPG stoves	**LPG sets**	Virtually 100%	~$50US	No smoke emission but often used only for rapid cooking, not main meals which use polluting fuels	n/a	5-10years	Used successfully in Kenya, in conjunction with fireless cooker as fuel costs are high. Need for savings for monthly purchase of fuel difficult for those on very low incomes.

Other technologies for smoke extraction & reduction

Type of intervention	Pollution reduction	Cost (US$)	Cost effectiveness	Fuel saving (%)	Approx life (yrs)	Notes
Smoke hoods	Very high as used all the time	Very high	Fairly expensive ~$50US. Long product life & no ongoing fuel costs	n/a	10	Adoption lower than hoped due to lack of 'modern' image.
Fireless cookers	Around 60% - 80% or more	Around 60% - 80% or more	Low cost - $0-5US. Effective as uses heat from food in insulated container. Requires additional stove as well	Variable	Very dependent on materials	Needs further research on safe use as warm food held in container for hours
Eaves spaces	50%-60%	Time cost or ~$5	Can be created by household member or local artisan.		Lifetime of house	Concerns re wild animals. Wire mesh blocks with soot

Type of intervention	Pollution reduction	Cost (US$)	Cost effectiveness	Fuel saving (%)	Approx life (yrs)	Notes
Keeping child away from stove	Not effective for mother during cooking periods	Time and convenience cost	Effective for child	<0>	n/a	Could take more time for mother as child not nearby
Cooking outside	High	n/a	Maybe not culturally acceptable and thus not adopted	Probably negative	n/a	Fuel use likely to increase as heat is blown away from pot.
Pot lids	Not known – but useful when feasible as speeds up cooking	Depends on whether pot has a lid	Yes	Good	n/a	Dependent on type of food and whether lid is appropriate to specific food.
Chopping wood thinner	Yes - wood burns more completely - – good as part of rocket stove technology.	Possibly time cost for woman with traditional stove	Not known	Depends on skill of cook	n/a	With traditional stove makes more labour intensive as fire tended more frequently
Room insulation	Can theoretically increase pollution in houses built with, for example, dry-stone walls, as smoke cannot escape	Very low – can be done by householder	Yes	Substantial, but not known	Ongoing task of re-plastering	Only makes good sense in cold regions where effective; needs added smoke venting
Awareness - raising	Yes – complementary activity	Project costs can be high – eg Gyapa approach	Yes – people need to 'own' the problem if they are to 'own' the solution	Dependent on technologies available, even if these are no-cost	Usually only done during project lifetime	Essential part of any study

PRACTICAL ACTION
Consulting

Health and quality of life benefits of household energy initiatives

The WHO estimates that there are nearly two million deaths and around 39million DALYS per annum due to household air pollution (HAP). Of these nearly 400,000 are in Sub-Saharan Africa. Exposure to HAP from unprocessed solid fuels nearly doubles the risk of pneumonia in children <5 years and with 20% of the world's population, Africa suffers around half of all deaths from pneumonia for children under five years. Evidence for this comes from studies on childhood pneumonia and chronic obstructive pulmonary disease from major research studies worldwide. HAP is also associated with low-birthweight and adverse pregnancy outcomes, increased risk in lung cancer (particularly for those who burn coal), increases in active tuberculosis, perinatal mortality, asthma, and middle ear infection in children, nasopharyngeal and laryngeal cancer, and cataract in adults. Details and references for these risks can be found in Table 2.1 in Chapter 2.

Evidence of HAP and exposure reductions through energy interventions in Africa and worldwide

$PM_{2.5}$ is a measure of the levels of tiny particles (less than 2.5microns) that get deep into the lungs causing ill-health. Carbon Monoxide (CO) has, until recently, been used solely as a proxy for particles, as the ratio between $PM_{2.5}$ and CO is fairly consistent. More recently, low-level CO has itself been implicated as damaging to health.

As very few studies have been done looking directly at the health impacts of various energy interventions, it is necessary to compare the various interventions in terms of their capacity to reduce smoke, but this makes a serious assumption that people will have enough money to purchase them, and having purchased them, will use them. Nevertheless, studies suggest that chimneyless improved woodstoves reduce the levels of particles by around 40%-50% and the CO by around 40%. A similar picture is found in other parts of the world that use large chimney stoves, where levels of CO are reported to be reduced by up to 90%, and $PM_{2.5}$ by around 60%[1].

Using LPG or ethanol stoves should, in theory, reduce the levels of $PM_{2.5}$ to virtually zero, but this seldom happens in practice as people use a mixture of stoves and fuels, when they are available. Reductions of around 64%-94% were reported for ethanol stoves in Ethiopia, whilst levels of CO in Ethiopia dropped by around 75%-80%, and by 72% in Kenya (where LPG was the fuel of choice for most study households).

[1] Results from stoves with chimneys must be treated with caution, as households tend to maintain chimneys well during project periods, but long-term evidence from earlier programmes indicate that these levels of maintenance are not always maintained. Chimneys that are not cleaned block up rapidly.

Some studies, where personal exposure was measured, have found that personal exposure reduces proportionately less than area pollution. For example, within the Maasai community in Kenya, a 75% reduction in 24-hour mean kitchen $PM_{3.5}$ and CO was associated with a 35% reduction in women's mean 24-hour CO exposure. Similar proportionate reductions were found for women and children using wood stoves in Guatemala. This is described in more detail in Section 2.5 of Chapter 2.

Thus, switching from wood, dung or charcoal to more efficient modern fuels, such as kerosene, LPG, biogas and ethanol, brings about the largest reductions in household air pollution. In many poor rural communities access to these alternatives is limited and biomass remains the most practical fuel. Biomass improved stoves that are adequately designed, installed and maintained can reduce household air pollution considerably. Stove location, housing construction and better ventilation are partial remedies. Changing behaviours can contribute; drying wood improves combustion and lowers emissions, using pot lids cuts cooking time, and exposure of young children can be reduced by keeping them away from polluted kitchens (if this is safe).

Nevertheless, care should be taken in attributing specific reductions to specific stoves, as the same stove can perform very differently at different times, locations and with different users. Changes in HAP and personal exposure measurements are influenced by factors such as how long the stove was installed before monitoring, the availability of appropriate fuel, stove maintenance and user support, the time spent by the woman in the kitchen, and the need for space heating. Percentage reduction of pollutants is dependent on the baseline level, and this can vary significantly even from household to household. This means that even with the same stove you get quite different estimates of performance when employing this frequently used measure.

Other impacts

It is unlikely that health alone will convince people that the use of clean technologies is an important part of their well-being. Examining the issues that are important to the cook is vital, as she is the person who will choose either to use the stove, or to revert to her previous cooking methods. Key factors other than health issues, which have emerged through interviews with cooks, include time and money saved, and smoke reduction leading to cleaner kitchens, homes, pots & utensils, clothes and stoves.

Time saving is the overwhelming factor observed in several studies around household infrastructure. An economic analysis of water and sanitation interventions indicates that time saved is again the most important benefit[2]. Financial factors are important in stove selection – affordability of both stove and fuel. Longer-term financial benefits, such as fuel saving and more time for productive work, are generally only observed after interventions have been installed and the cook becomes aware of these changes.

Social benefits identified by the cooks in a number of studies include: an improved sense of well-being, easier to work in clean environment, opportunities to do other things (time-saving), improved status within family, and better family life / relationships, a willingness to welcome visitors, less space heating in hot climates, attractive appearance of the technology, and the facility to produce timely meals.

Fuels are not intrinsically 'clean' or 'dirty' – it is the combination of fuel and technology that determines the level of emissions into the household. However, it is easier for liquid and gaseous fuels to be burnt cleanly.

Successful interventions

Chapter 3 provides examples of successful interventions whose manufacture have been shown to be sustainable. It is important to define what is meant by 'sustainable' within the context of household energy. A good definition might be '*an intervention whose numbers continue to grow beyond the end of the project period*'. Using this definition, virtually all the stoves that effectively reduce substantial amounts of smoke are still receiving support through ongoing NGO activities – albeit in the form of smart subsidies through training, promotion etc.

The most important factor in achieving fully commercial stoves is that people like the stoves and will want to use them. To be used, stoves must have the product attributes desired by the cooks, the stove quality must be good, and the fuel consistent. There must be a reliable fuel supply chain or people will revert to their previous practices. A good test of whether a stove is successful is whether people use it all (or most) of the time. An even better criterion is whether a stove is replaced at the end of its life. The same criteria apply to smoke-alleviation, where a stove will only reduce smoke if it is used all (or most) of the time. Overlooking this apparently trivial requirement has led to thousands of stoves being installed worldwide that only benefit those selling them.

[2] Hutton, G., and L. Haller. 2004. Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level. Geneva: World Health Organization.

In the case studies described in this document, it can be seen that the most successful stoves programmes are collaborations between those introducing the stoves and the cooks themselves,

Fully commercial stoves

Of the stoves highlighted in this study, only the KCJ (Kenya Ceramic Jiko), the Upesi (Maendeleo) stoves, and, in some circumstances, LPG sets are fully commercial.

In the case of the Upesi and KCJ stoves, the products benefited from well-supported projects that allowed the creation of a market by providing support to training in manufacture and business services. Economies of scale allowed the product price to become affordable to increasingly large numbers. As in this case, using local skills and materials to manufacture stoves can make the price more affordable, but if stoves are only promoted if they are locally sourced, this slows down the rate of change to cleaner, healthier, technologies for people who might wish to buy them.

Semi-commercial stoves

Between a completely commercial operation, and a project with a limited time frame where the stoves are either given away, or sold cheaply, are commercial operations which nevertheless have the support of NGOs, or governments. This arrangement can be very successful, and appears to be a useful interim step to completely commercial distribution and long-term sustainability.

In the case study on LPG stoves in Sudan for example, a subsidy is still provided to support and train the women's organisations running the businesses that sell LPG sets, supply fuel and provide soft loans even though they are sold through other outlets completely commercially to those on higher incomes. The success in Sudan can also be attributed to low-cost fuel (produced in Sudan – no import duties), and heavy government promotion. Financial support to the women's organisations further increases the size of the market.

A similar structure is used for the Gyapa stoves, which are sold by independent businesses that are supported by the NGO EnterpriseWorks. The NGO does not sell these stoves directly, but rather creates the environment in which the stoves can be sold commercially by supporting new businesses with promotional support. The Vesto stove is manufactured by NewDawn engineering which also brings in external finance and supports training, development and promotion. Project Gaia is adopting a similar approach with the CleanCook stove, working with the Swedish-based firm Dometic, with plans to introduce assembly of the stove, and subsequently its manufacture, in other parts of the world. The Ugastove benefits from carbon finance to subsidise its cost and make it affordable.

Two stoves that work on similar principles – the StoveTec stove and the Envirofit stove - use 'rocket stove' principles. The first of these is a response from the Aprovecho Research Center to fulfill the need for a less-polluting wood stove, and it supports design, development and promotion. The Envirofit stove is of similar design, and benefits from substantial backing of the Shell Foundation. It is planned that this stove will, in time, become totally commercial.

In Central America, two chimney stoves, the Onil and Ecostove stoves use a 'rocket principle' to increase energy output and reduce emissions. They require consistent and ongoing support to consumers in the early days if they are to work efficiently. Regular visits by NGO staff ensure that they are being properly maintained.

Although not a stove, smoke hoods were piloted in Kenya and found to reduce more than 60% of smoke. Further research in Nepal has provided even greater gains. No dissemination is taking place in Kenya, but around 2,000 have been sold semi-commercially in Nepal, and this is ongoing.

Non-commercial technologies

Among the most sustainable of all technologies are those that can be produced at no-cost, or minimal cost, and yet alleviate smoke. Finance is needed for promotion, but a good technology of this sort will disseminate with minimal input through word of mouth. Examples of this are eaves spaces, fireless cookers (hayboxes) and low cost stoves. The Toko Mitsitsy of Madagascar, is a mudstove introduced by the Andrew Lees Trust. It was designed mainly to reduce fuel use, and dissemination is through 'training of trainers'. Although a successful and low-cost technology, the stove life is short. These approaches are highly cost effective and a useful adjunct to more expensive technologies.

Very recent stoves without a proven track record

Among ethanol stoves, the ProImpex stove and the ISPM stove (Institut Supérieur Polytechnique de Madagascar stove) are currently under development in Madagascar and are showing potential. The Aprovecho Research Center, as part of this project, tested both stoves and highlighted areas where further development would be useful. The NARI ethanol stove in India shows promise, but to date no independent testing has been permitted by the designers. Results show that these three stoves can use lower (60%) concentrations of ethanol, but none of them produces a sufficient heat output at low fuel concentrations - heat is needed to drive off the water in the fuel. All these stoves work better at higher ethanol concentrations.

Gasification for woodstoves is an approach where the volatile gases are driven out of wood and burnt as a gas. The Philips stove uses this principle, with an external fan to provide a measured mix of air and gas. This achieves a very clean fuel, and produces charcoal as a by-product. These stoves are perhaps too expensive for low-income communities until their durability is better proven.

Interventions that failed to achieve sustainability beyond the project life

Failure of some ethanol stoves can be attributed to several factors. The use of gelfuel, initially heralded as the fuel of the future, led to stoves, such as the SuperBlu, being promoted that were not appropriate to the target market. Putting additives into ethanol to make it gel produced a fuel that did not vaporise readily, slowing down the combustion process and not allowing sufficient mixing of combustible vapour and air. This provided a slower cooler flame that is not useful for cooking, albeit the fuel is still in use for occasional space heating. This stove also suffered some quality/safety issues. The CookSafe stove of South Africa performed well in tests in this study – but no longer appears to be in production as a household stove.

Social factors

Promoting acceptability
Actions that support getting the right technology accepted by a community include; **getting the product right** by introducing the product, seeking feedback, and addressing changes required by those testing the product to make it desirable.

Unless the product is right for the customer, no amount of promotion will sell it. **Promoting the product heavily at start-up using attributes that are considered most important by the cook** (e.g. cost/savings, attractive design, speed of cooking) whilst retaining the efficacy and affordability of the product; **ongoing development of technologies** in response to customer feedback, as successful technologies will be copied, and ongoing improvements are needed where there is healthy competition. **Ensuring that products are both safe, and safely used** – with cooking demonstrations, involvement of local government and other NGOs to change the culture where needed.

A serious accident could set back a programme for years as well as causing distress.**Training in manufacture, marketing and sales** is needed to ensure quality products. Product life is important if people are going to spend a substantial part of their savings. This is particularly important where carbon finance is used and **support with start-up**, with product design, technology promotion, purchase of raw materials, wholesale goods, premises, transport (in the early stages) and feedback from customers. NGOs can play a key role at this time in support to entrepreneurs through community-based approaches.

Promotional activities

Awareness-raising can lead to a greater prioritisation of the dangers of smoke and is a key role for NGOs, supported by local government and collaborating with other NGOs and private businesses, in engaging local communities and influencing policy-makers. Each key group should be targeted; customers, local authorities, private enterprise (finance and entrepreneurs), other NGOs, health and education people etc., with messages tailored for each group.

For local communities, messages must be locally appropriate and engage with the issues that matter to the cook – not necessarily health (eg time saving, cleaner houses). Health messages, in particular, need to be accurate. For policymakers, engagement in projects from their instigation is likely to create far greater buy-in than a report at the end. Activities at country and regional level will increase the geographic scope and effective impact of a project. Creating the infrastructure for dialogue between policymakers at all levels and practitioners can lead to well-informed policies when major policy documents (such as PRSPs) are being revised.

Finance

Finance arrangements may be needed by both customer and manufacturer. For the customer, revolving finance and soft loans can work well, although for those on a very low income, the rate of repayment may be very slow. Revolving finance can work well within community groups where livelihoods do not depend on the rate of repayment. Some form of credit may be needed by entrepreneurs for all the set-up costs; premises, raw-materials and equipment, promotional costs, and staff costs. Within Madagascar, low-income communities form the major part of the total population. If the upfront price of a stove is too great for the target market, insufficient will be bought to create that market. To reach this large potential market, a way must be found to reach the 'bottom of the pyramid' by making the ethanol stoves affordable to this market segment. Carbon finance could provide this additional finance stream.

The role of carbon finance

If carbon finance is properly directed towards stoves which have been proven to have a long product life, produce real and ongoing reductions in greenhouse gases, and are shown to be well-accepted by the users, it can make stoves affordable which would otherwise be too costly for those living in poverty. The addition of the 'Gold Standard' ensures that there are substantial developmental benefits[3].

Carbon finance provides a basis for maintaining a professional commercial relationship between the user and the stove provider. Stoves are continuously monitored, and it is in the best interests of those obtaining the carbon finance to

[3] http://www.cdmgoldstandard.org/

ensure that the stoves work well, and that they are well liked. This in turn benefits the stove user. This is described in detail in Section4.4.

At present, a major bottleneck is the absence of an agreed methodology for ethanol stoves. This methodology needs to be drafted, and accepted by the CDM Executive Board before any carbon finance is available for ethanol stoves.

Roles of key actors

For the introduction of new fuels and technologies, governments and businesses need to work together to joint objectives. It is not easy to present the roles of each separately, because they are reliant on one another. This study suggests that the optimum combination of public and private-sector roles is as follows.

Role of Government

Influential individuals within key institutions (e.g. Minister of Energy) can have a profound impact on the success of such initiatives. An essential role of Government is in the development of a biofuel strategy and policy conducive to the use of such fuels in household energy provision, built around market research on the size and demographic of the market.

Safety issues should be paramount, with rigorous testing of stoves – particularly for new designs – to ensure that they are fit and safe to use. Setting government quality standards could reduce the levels of accidents, and promote both consumer confidence in purchasing a stove, and carbon finance by requiring a minimum product life and minimum quality standards for different specific genres of stove.

The Government has a crucial role in regulating pricing, leaving as much as possible to market forces, but intervening with pro-poverty policy where needed. This is particularly critical for new fuels such as ethanol, which are competing with both established household energy markets, and with the transport sector.

Another role is in facilitating partnerships between government bodies (environment, forestry, energy and trade and industry) and other organisations both North and South such as the private sector and NGOs. Governments can create an enabling environment for private sector investment through addressing major barriers such as a lack of clarity of regulations and legislation, lack of security of investments, prohibitive investment costs and duties.

In terms of finance, governments should seek to provide information, even out subsidies for all fuels to create a level playing field, and facilitate carbon finance acquisition.

Generating demand for unfamiliar clean fuels, can be a major barrier to private-sector involvement and to successful uptake. The Government has an important role to play in education and raising public awareness.

Role of the private sector

The private sector has an essential role to play in applying commercial and marketing approaches to the various social, environmental and public health issues implicit in household energy and clean fuels. The private sector needs to provide choices of technology for households with different levels of income, promote specific technologies and services at affordable costs – making technology prices fairly competitive in the market. For this, it needs to invest in developing technologies for easier production, improved supply chains to ever-increasing markets, apply a commercial approach to scaling up, and leverage finance, including carbon finance, for stove purchase. Commercial approaches are proving to be successful as they are generally demand-driven. However, most of these organisations have the support of NGOs in the early stages, particularly training in business skills and financial management.

The private sector is well placed to develop the carbon potential of projects and leverage carbon finance, more particularly in collaboration with government through the CDM, or through the voluntary market (see Case study Toyola – Chapter 3).

Role of NGOs

All cases described in this document involve NGOs at their inception. NGOs can play a key role in undertaking pilot programs and demonstration projects. They can work with other actors in facilitation, supporting services, sector co-ordination, advocacy, piloting, linkage with community groups, and demonstrating safe practices. Where projects are instigated by international organisations, local NGOs are vital in learning about problems or issues that beneficiaries might not wish to divulge to those outside the community. NGOs can act as 'honest brokers' who can act on behalf of a community –negotiating with banks, or local authorities on behalf of the community they serve. Language issues are more easily resolved when applying questionnaires or group discussions. People are more likely to respond when discussing issues in their local language.

Role of the consumer

Products must perform well within the context of the household into which they are installed. The very best technology, if it is not acceptable to the cook, has an effectiveness of 0%. There are countless examples of good technologies lying unused as they do not fulfil the needs of those for whom they were designed without consultation. Those living in poverty do not have the luxury of adopting goods or services which do not address their needs.

From this it follows that a key factor in sustainability is to get this fundamental requirement correct if a technology is to succeed. Products need to be thoroughly tested and reviewed by a representative sample of consumers, feedback obtained in a structured way, and the issues identified addressed and re-piloted, until a desirable product is developed.

PRACTICAL ACTION Consulting

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Introduction

The 'Ethanol as a Household Fuel in Madagascar Project' has three components namely; Health Benefits, Economic Assessment and Review of African Lessons for Scaling-Up. This document is the draft report of Component C of the project 'Review of African Lessons for Scaling-Up'.

Since the early 1980s there has been a wide range of initiatives which have sought to address energy issues in African households. These initiatives fall into the two main categories of; interventions relating to electricity provision, and interventions relating to improved household cooking with the latter group being most relevant to this project. A range of considerations have driven household cooking interventions in varying proportions and with varying degrees of overlap[4]:

- Concern regarding the **health impacts** of smoke inhalation, particularly on women and children.
- Concern regarding **deforestation** and desertification linked with consumption of fuelwood.
- Concern regarding **greenhouse gas emissions** (GHGs) from burning of fuelwood contributing to climate change.
- Concern regarding the **drudgery, time lost and danger** to women collecting firewood and it's cyclical contribution to maintaining poverty and vulnerability

To address these concerns a wide variety of types of intervention have been attempted, again with varying degrees of overlap and addressing the issues described to varying degrees, which may be categorised as follows:

- Interventions to **switch to alternative fuels** with associated new stoves (reduce the need for fuelwood).
- Interventions to improve the **efficiency of stoves** using existing fuels (reduce fuelwood consumed, and/or reduce the quantity of smoke produced).
- Interventions to **extract harmful smoke** from rooms without substantial interference with the cooking process itself.
- Interventions **changing the behaviour** of cooks regarding the manner or location of cooking.
- Interventions aimed at **replenishing stocks of woodfuel** through afforestation.

[4] Smith, K R Viewpoints – an interview with Professor K R Smith *Boiling Point 56* HEDON Household Energy Network, 2009

Such interventions involve a range of technologies and approaches, within each intervention type, various products and practices of technology are used. The most relevant of these to the Madagascar situation are described in Chapter 1 of this report, reviewing projects and technologies focussing on ethanol stoves, biomass stoves, charcoal stoves, enhanced ventilation and low cost options.

The report goes on to review all interventions, with a particular focus on health benefits, cost-effectiveness and scaling-up and sustainability considerations. Each key consideration is addressed in subsequent chapters of this report, based on a review of secondary literature, interviews and analysis of experience gathered by project consortium team members over many years in the sector. The examples draw focus on Sub-Saharan Africa but also incorporate interventions and lessons from other regions where applicable.

The final section of this report draws out key lessons relevant for the Madagascar scenario including the roles of the public and private sectors, different intervention types, and evaluation criteria. Finally, a framework is proposed for successful scale-up of household energy interventions.

1. Review of projects, technologies and approaches

Until fairly recently, the only fuels available for low-income communities were based on wood and/or residues. More recently, fuels that can be easily made to burn cleanly have become more widely available – particularly to those living in urban areas. Any fuel can be made to burn 'cleanly' (ie without discharging a lot of emissions into the kitchen), but it must be burnt in a well-designed stove. Liquid and gaseous fuels have the potential to burn the most cleanly, although the technology still has to be well-designed.

The most important factor, and one that is often overlooked, is that women *have to use* the stove or the efficiency gain is nil. Perhaps the largest example is the Indian Stove Program. Only in a few parts of India did this succeed where there was local consultation and the stoves were sold commercially. Fuels and technologies must be desirable and effective, easy to use and save time – or they will be ineffective and will fail. The majority of examples given in this section provide an overview of fuel/technology combinations that have been shown to be successful through the levels of adoption that have been achieved.

Getting the technology right - India

The Government of India's National Program of Improved Cookstoves introduced some 33 million biomass-based improved stoves in rural areas during 1984-2000.

Available studies indicate that problems, such as design failures, lack of public acceptance, quality control, plague the program[5] .

With all types of stove, the price paid is always a major factor, but can be misleading unless the useful life of the stove is also considered. Stoves which have a long life tend to be more expensive as the build quality and materials used are usually of better quality. However, as the up-front cost may prevent those living in poverty from purchasing a better-quality stove, ways must be found to address this issue.

1.1. Introduction to fuel types and characteristics

1.1.1. Ethanol

Ethanol (Ethyl Alcohol - C_2H_5OH) is a clear liquid with a distinctive 'ethanol' smell. It can be distilled from sugar or starch crops, in particular sugarcane, maize, sweet sorghum, sugar beet and cassava. Ethanol has been distilled for millennia as drinking alcohol, and there are records of an engine using a mixture of ethanol and

[5] ESMAP, ' India's National Program of Improved Cookstoves – A Growing Challenge' *Household air pollution, Energy and health for the poor* , Issue 5, September 2001

turpentine in 1826, and subsequent forays as a transport fuel in the early part of the 20th century. Its mainstream use as a fuel dates back to the late 1970s, (when lead was banned in petrol), and ethanol could be used as an oxygenator in transport applications)[6].

The use of ethanol as a household fuel is even more recent, with early ethanol stoves used originally for marine craft from around the early 1980s and more recently for developing countries from around the start of this century.

1.1.1.1. Ethanol manufacture

Ethanol can be made from three types of crops and raw materials:

- sugar-bearing crops, such as sugar cane and its by-product molasses, sugar beet, and sweet sorghum
- starches, including cassava, potatoes, and maize
- cellulose from wood, grasses, and agricultural residues.

Sugar cane and molasses are the most common and economical sources of ethanol at the present time. Although starches and cellulose are less common sources, they are currently receiving more attention.

1.1.1.2. Ethanol and the environment

Debate is ongoing as to whether ethanol is environmentally friendly or whether it poses substantial risks to the ecosystem via localised impacts on deforestation or global impacts on climate. Ethanol processed by industrial distillation on a small or moderate scale, from crop residues, or from crops grown on marginal lands, is generally thought to provide environmental benefits, reducing levels of deforestation and, when burnt in a well-designed stove, reducing the emissions of GHGs into the atmosphere.

However, small-scale artisanal manufacture of ethanol requires around 100kg of woodfuel to produce 40–50 litres of *toaka gazy*[7], and it is highly questionable whether there are any environmental gains to be achieved, albeit smoke may be taken out of the kitchen, and the wood is not of the type commonly used for woodfuel. Toaka Gasy stills need wood because a specific technology is needed to burn crushed and dried cane waste.

By contrast, a small micro-distillery (such as the micro-distillery described in Component B of this study) uses solely sugar-cane products. It runs only on ethanol and the power produced by ethanol. It uses an ethanol-powered generator to

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[6] (http://www.fuel-testers.com/ethanol_fuel_history.html

[7] Locally made Malagasy rum - [personal correspondence]

produce electricity to run the pumps and to heat the "beer" or produce steam. The alternative is a steam boiler designed to burn the sugar cane straw or the bagasse.

In large-scale refineries, such as those used in Brazil, the crushed stalk (bagasse) can be used to provide heat and power for the process and for other energy applications [8].

Thus savings in wood of around two kilograms per litre can be made through more technically-advanced processes.

Where carbon finance (accessed through the recently agreed Gold Standard for stove fuel), is to be used, the rules state that 'the project proponent is obliged to provide an equivalent level of justification for quantities of greenhouse gas emitted from production as from use'[9]. Some moves are being made to distil ethanol artisanally through solar-powered stills. This approach is still at the research stage[10].

1.1.1.3. Safety

Ethanol burns with a slow, slightly visible flame. The combustible ethanol vapour/air mixes are explosive at some concentrations, so ethanol should be stored in closed containers and bottles, particularly where it is close to ignition sources. It is transported in bulk in barrels or tankers, where it is treated as a combustible fuel. Tanker spillages require that the fuel is contained and that it is diluted and kept cool to prevent explosive mixtures. Bulk ethanol should be stored in a cool place, in closed containers, which are grounded to eliminate static electric sparks.

Within the household, care must be taken to quench the flame when filling ethanol stoves as the flame is very difficult to see. Some ethanol has an additive to make it more visible. Two of the stoves described in the next section use an adsorbent fibrous filler in the fuel chamber onto which the ethanol is poured, so the fuel cannot spill. One stove is designed so that it cannot be filled with the flame ignited.

In health terms, ethanol causes dryness to the skin, so should not be left on the skin for exposed periods. If ingested, it causes intoxication and large quantities can cause damage to the nervous system (as with drinking alcohol). The anhydrous form has a severe drying effect on mucous membranes of the mouth and throat. Because of these issues, ethanol should *always* be denatured and dyed before distribution. (Denaturing involves the addition of a very bitter ingredient that makes it extremely unpalatable).

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[8] IEA (2007) Biofuel Production, IEA Energy Technology Essentials, January 2007 https://www.iea.org/techno/essentials2.pdf

[9] JP Morgan Climate Care *Indicative Programme, Baseline, and Monitoring Methodology for Improved Cook-Stoves and Kitchen Regimes* – The Gold Standard May 2008

[10] Jorapur, R M & Rajvanshi, A K, 'Alcohol distillation by solar energy' in ISES Solar World Congress Proceedings, Vol. I, Part II. Pp. 772-777 (1991). Pergamon Press, Email: nariphaltan@gmail.com 1991

Because ethanol is purchased, the risks associated with gathering fuel, particularly for women and children in conflict situations, are eliminated (there is a growing body of evidence that women gathering fuel from distant locations are highly vulnerable to assault from aggrieved landowners and, in conflict zones, from warring[11]).

1.1.1.4. Ethanol and carbon finance

Ethanol sourced from residues and distilled in small distilleries is ideally placed to benefit from carbon finance, in terms of both reductions in the use of forest resources, and in reduced emissions.

1.1.1.5. Ethanol gel

Ethanol gel is commonly known as gelfuel and is made from ethanol, with a thickening agent to make it viscous. This property can be useful in stopping spillages, but gelfuel will also stick to the skin, making it more problematic if the gel ignites unintentionally. A major advantage of gelfuel is that it can be distributed in a simple pot, without the risk of spilling it. However, this characteristic makes it difficult to control the temperature of the stove accurately, and burners have to be designed with different size openings which are lit to provide different levels of heat output.

Gel fuel is a compound of ethyl alcohol (ethanol) and organic pulp (cellulose). The two are gelatinised with addition of water forming a clear and transparent compound with a gel like consistency. The composition of the fuel by weight is ethanol (76 %), cellulose (5 %) and water (19 %). The quoted gross calorific value of gel fuel by manufacturers is 22.8 MJ/kg. Small amounts of colouring and denaturing agents are added to enhance the visibility of the flame and to avoid consumption of the gel fuel respectively[12] .

The fuel is generally sold in canisters onto which the burner is set, making it easy to use. However, it is impossible to mix gel and air, so gel stoves tend to burn slower and to produce more soot because there is not sufficient oxygen for the reaction to go to completion – this problem is exacerbated at higher power. As gel fuel can carry much less energy than alternative fuels, about three times more gel per meal by mass is required than for alternative liquid fuels[13] .

The evaporation of ethanol is an important issue, particularly if diluted ethanol is used in the stove, as any ethanol left in the burner after cooking ends will evaporate over time, leaving behind water which will not ignite. Studies by GTZ (Mhazo, 2001) on gelfuel stoves indicate that the losses through evaporation are very high if the lid of the fuel pot is not firmly closed. Three stoves were used to heat water on full power for the durations shown. The losses between each event were as shown:

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[11] Karlsson, G V [ed.], *Generating opportunities – Case studies on energy and women UNDP, 2001*
[12] Mhazo, N. Comparative Performance of Gel Fuel Stoves, GTZ December 2001
[13] Lloyd, P. Visage, E. The testing of gel fuels, and their comparison to alternative cooking fuels (~2006)

Table 1.1: Evaporation losses from ethanol gelfuel stored in (semi-) / open container				
Cooking periods	**Between cooking**	**Loss by evaporation (grams)**		
(minutes)	(minutes)	Tight lid	Loose lid	No lid
15 minutes in the morning (10:00hrs)	135	1.4	3.2	6.8
30 minutes in the afternoon (12:30 hrs)	120	2.3	1.5	10.2
10 minutes in the late afternoon (15:00 hrs)	110	1.6	3.2	16.7
45 minutes in the evening (17:00 hrs).	975	1.9	10.9	15.7
	Total losses	7.2	18.8	49.4

1.1.2. Solid fuels

Worldwide, more than three billion people depend on solid fuels, including biomass (wood, dung and agricultural residues) and coal, to meet their most basic energy needs: cooking, boiling water and heating[14] . The inefficient burning of woodfuel on an open fire or traditional stove indoors creates a dangerous cocktail of hundreds of pollutants, primarily carbon monoxide and small particles, but also nitrogen oxides, benzene, butadiene, formaldehyde, polyaromatic hydrocarbons and many other health-damaging chemicals. For many households, there is no option but to burn wood and many are too poor to afford technologies that can make it burn more efficiently and cleanly. Low cost measures can improve the way wood is burnt; more expensive technologies can make it burn very cleanly.

1.1.3. Charcoal

(Adapted from: Charcoal in Africa, Importance, Problems and Possible Solution Strategies by Dr. André Seidel, Eschborn, April 2008)

In Africa over 90 % of the wood taken from forests is woodfuel, and the majority is consumed directly as wood. However, a varying but substantial amount is transformed into charcoal. More than 80% of the charcoal is used in urban areas making it the most important source of household energy in many African cities. It is estimated that about two million people are economically dependent on charcoal production, transport and trade. There are several reasons for its popularity:

- it has double the energy density of fuelwood
- it is therefore relatively lightweight and easier to transport

[14] Rehfuess, E. Fuel for Life: Household energy and health, WHO Press, 2006 www.who.int/indoorair/publications/fuelforlife.pdf

- it is easy to store over long period of time
- when burned, it usually produces less fumes and noxious compounds than wood
- in most cities it is cheaper than kerosene, LPG or electricity
- it has the image of 'modern' energy and sells well.

Charcoal is produced in rural areas and mainly used in the cities; transport is an essential component of the 'charcoal chain'. A survey in Kenya has shown that more than twice as many people are involved in charcoal transportation as in production.

Charcoal is sold through a variety of channels sometimes involving a complex system of wholesalers and retailers. Little charcoal is sold at the production site. The bulk is sold either at the roadside, at markets or in small shops.

The majority of charcoal is used by urban households, and there is a significant institutional (schools, hospitals etc.) and industrial demand (curing tobacco, smoking fish etc.) in some countries.

The major problem related to charcoal production is deforestation and land use. Whether or not this can be avoided by adequate legal frameworks and forest management is still debated. The use of traditional kilns with very low efficiency requires as much as 10 kg of wood for 1 kg of charcoal, releasing large amounts of greenhouse gases during carbonisation.

On the consumption side, burning of charcoal in traditional stoves is very inefficient and results in an increased demand. As a response to the negative effects of charcoal production some African states banned charcoal as a fuel, but this proved to be counterproductive as no viable alternatives were available to consumers and so the producers manufactured charcoal covertly, which prevented the use of improved technologies. The use of charcoal was not significantly affected; and the price went up and remained at a higher level after the ban was lifted.

Sustainable charcoal in Madagascar

The GREEN-MAD project in Madagascar seeks to achieve sustainable charcoal production through an integrated approach intervening at forestry level as well as improved kiln and fuel-efficient stoves. In the Antsiranana district in Madagascar the project has been implemented since 1995 with support from GTZ. Charcoal is the main fuel for households; each family averages 590 kg per year. The objective is to promote sustainable use of forest resources and to ensure the supply of fuel of the region. All measures were accompanied by ecological and socio-economic studies.

Woodfuel plantations are being established using fast growing species. The plantations are managed by local communities which are entitled to use certain forest areas sustainably. After training, communities develop plans for natural resources management. By 2008, about 3500 hectares of wood fuel plantations had been established[15] .

[15] http://www.gtz.de/de/dokumente/gtz-en-forest-governance-2008.pdf

1.1.4. Kerosene

Kerosene (paraffin) is widely used in many urban centres in Sub-Saharan Africa. Subsidies have been applied in many countries, for the fuel, making it relatively cheap, and low-cost appliances are widely available. Kerosene can be used for both cooking and lighting, and can be bought in small quantities, making it a less-polluting option to woodfuel.

> **Kerosene and Safety**
>
> In 2004, the South African Paraffin Association (PASASA) completed South African Bureau of Standard (SABS) tests on the nine most commonly used paraffin stoves in South Africa. All nine stoves failed on six or more of the codes. The most common stove - the non-pressure or wick stoves failed all key safety tests including fuel container, fuel temperature, combustion, marking and instructions. PASASA added an additional test, knocking it over after one hour of use. The non-pressure or wick stoves all immediately erupted in flames when knocked over (HEDON)[1] .

There are documented cases of kerosene being contaminated with water to increase profits, making it a very polluting fuel, and there are serious safety issues. With increasing fossil fuel prices, subsidies are being reduced in many countries.

As with all household energy technologies, it is the stove/ fuel combination that is important;*Boiling Point* 56 provides an excellent overview[16 17] .

1.1.5. Liquified Petroleum Gas (LPG)

LPG is the first of the really 'clean' fuels to have been widely disseminated in Africa. Particularly in oil-rich countries such as Sudan, it has become the fuel of choice. With the price comparable to charcoal in some areas (near to the Nile terminals) and the government promoting it, people will adopt stoves provided that the up-front cost of the stove and gas bottle can be spread over several months by soft loan, revolving finance, or other financial mechanism. Provided instruction on its use is given, LPG is a safe, clean, fuel. The main problems associated with it are access to the fuel away from central depots – which can make it expensive, and the need to buy large quantities; which can be a problem for those on low income who are used to buying on a daily basis, and/or do not have the means to transport the heavy bottle.

1.1.6. Other fuels

Several other fuel options are available, or are becoming available, which are outside the range of this study.

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[16] Lloyd, P. ' Developing safe Paraffin appliances in South Africa' *Boiling Point 56,* 2009
[17] Truran, G. 'Household energy poverty and paraffin consumption in South Africa', *Boiling Point 59*, 2009

Electricity – once considered the fuel for the rich, is becoming more widely accessible to low income communities. However, although households may be 'electrified', the majority of households living in poverty cannot afford to use it. Another key factor in its adoption is the connection fee, and the tariff. A low tariff to a basic threshold of kilowatts will only be successful if people can afford the connection fee. Where the connection fee is high, more than one household may tap into a single connection, and end up paying a high tariff for most of their energy [18] .

Plant oil – is causing a lot of interest at present, with Bosch-Siemens announcing their Protos stove[19] . This mainly uses jatropha oil. Jatropha tends to grow on the margins of other crops benefiting from their cultivation. Studies based on this growth on 'marginal lands' indicate that yields are often lower when it is grown as a crop.

Briquettes and residues – Small-scale briquetting of fine residues can be highly successful – particularly where the residues are from crops such as coconut residues. If they are produced as a business on a larger scale to use up residue 'mountains', once the backlog of residues is used up, feedstock has to be found elsewhere, it becomes a monetised commodity, and the price of the briquettes tends to rise. Crop-residue briquettes made by the households may be seasonal.

Stoves which take fine residues, such as rice husk, have to be designed to cope with fine, low calorific value particles which leave behind a lot of ash for the same amount of heat. These specially designed rice-husk and fine particle stoves are available and successful[20] . Unless both the raw materials used in their making, and the type of stove, are closely controlled, briquettes and residues can aggravate the household air pollution problem as the residues generally have lower calorific values than wood, and their burning characteristics are very different[21].

1.2. Selected organisations and interventions

The stoves in this section are typical examples selected for their overall efficiency and wide commercial distribution, or because they are of specific interest to the study location. A brief description of each stove is provided in Table 1.1. In the following sections, ethanol suppliers and stoves are listed separately, whilst biomass and charcoal stoves together by supplier (because several suppliers and organisations provide both charcoal and biomass stoves).

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[18] Foley, G. 'Tariffs for rural grid electrification' *Boiling Point 45*, 2000
http://www.hedon.info/TariffsForRuralGridElectrification

[19] http://w1.siemens.com/responsibility/en/sustainable/protos.htm

[20] http://rolexawards.com/en/the-laureates/alexisbelonio-the-project.jsp

[21] http://practicalaction.org/practicalanswers/product_info.php?products_id=224

Table 1.2 Stove types and their fuel, distribution, product life and approximate cost					
Type of stove	**Type of fuel**	**Info date**	**Numbers disseminated**	**Approx life (yrs)**	**Cost (US$)**
CleanCook	Ethanol		6000 in Ethiopia	10yrs	$30 - $50
NARI	Ethanol	2009	-	Research	-
ProImpex	Ethanol	2009	-	Research	-
SuperBlue	Ethanol	2008	Seeking finance	-	$10
Cooksafe	Ethanol		-	-	-
Greenheat	Ethanol gel		-	-	
Upesi	Biomass & residues	2004	4000-5000 p.a. West Kenya	4yrs to 10yrs	Between $2 and $6
KCJ	Charcoal		1.6million KCJ & several similar stoves	5-10yrs	$2-$5
Toko Mitsitsy	Biomass	2004	>36,000 by project end - still being made	-	-
Gyapa	Both biomass & charcoal	2009	>150,000 and ongoing in Ghana	At least 3 years	~$6
StoveTec	Both biomass & charcoal	2009	36,000 in first year of operation	New	
Vesto stove	Biomass & residues		1000 between 2002 & 2005	? Stainless steel	$20-$30 (2004)
Envirofit	Biomass & residues	2008	25000 by end '08	New	$10-$40 subsidised
Philips	Biomass	2006	-	Research	Research
Onil stove	Biomass	2009	Over 50,000	-	$100 often subsidised

1.3. Ethanol stove organisations

When burnt in a well-designed ethanol stove, emissions are extremely low – comparable to those of bottled gas (LPG), with carbon dioxide and water vapour as the products of combustion. This virtually eliminates the dangerous pollutants associated with traditional stoves and three-stone fires. Two of the designs discussed use fuel that can burn using ethanol containing substantial amounts of water. However, neither of these stoves will work on 'raw' artisanal ethanol which contains a high percentage of water (40% - 50%), and in both cases, heat produced is wasted in vaporising the water to drive it off. Ideally, ethanol destined for household use should have most of the water removed at the point of manufacture.

1.3.1. Project Gaia & Gaia Association

Project Gaia is part of a global initiative developing and promoting clean-cooking alcohol stoves and fuels for developing and emerging markets and for disadvantaged and marginalized people who suffer poor health and high levels of mortality from cooking over polluting fires. Project Gaia is currently working in Brazil, Ethiopia and Nigeria and will lend its support to other markets where alcohol fuels or the resources to produce them are available. The Project Gaia Research Studies began in 1998[22] .

The Gaia Association was founded in 2005 as an Ethiopian NGO to carry forward successful pilot studies of an ethanol-fuelled cooking stove of Swedish origin, owned by the Electrolux Corporation and thereafter by Dometic AB, a business that came out of Electrolux.

1.3.1.1. The CleanCook Stove

The CleanCook stove comprises a pressed or folded body, built of either stainless steel or protected mild steel. The fuel tanks hold ethanol in a special adsorptive fibre so that it cannot spill out. The stove is designed such that the fuel tank cannot be accessed to add fuel while the flame is burning. The tanks are not pressurized so they will not flare and cannot be made to explode. The burner flame is easily adjusted or extinguished by means of a simple regulator. The CleanCook is of stable and durable design, and its burner regulator is its only moving part. Two versions are available – a single burner stove and a double burner (as shown).

CleanCook stove with insert showing absorbent fibrous core

Laboratory tests on the stove indicate a mean CO to CO_2 ratio of less than 2% (within WHO guidelines for CO[23] .Particulate emissions are negligible, and are very comparable to emissions from LPG stoves. To date, Project Gaia and the Gaia Association have distributed around 6000 stoves worldwide. The stove was highly rated on safety using criteria set up by Iowa State University. Manufacture of the stove is about to move to Ethiopia, which should reduce the price.

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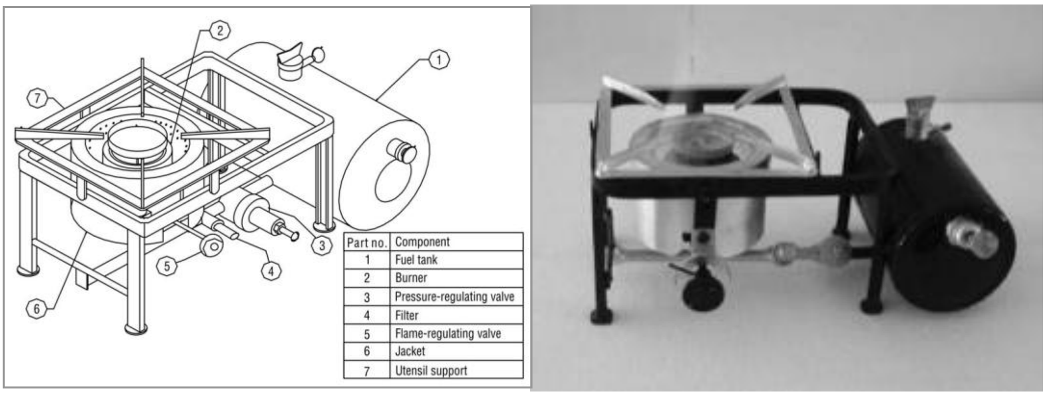
[22] www.projectgaia.com and www.projetogaia.org
[23] WHO (with ILO & USEPA) Environmental Health Criteria 213 CARBON MONOXIDE (WHO copyright) http://www.inchem.org/documents/ehc/ehc/ehc213.htm#1.10 [Accessed April'09) 1999

1.3.2. The Nimbkar Agricultural Research Institute

The Nimbkar Agricultural Research Institute (NARI) is an NGO and non-profit research and development institute based in India[24] . The Institute undertakes research and development in agriculture, renewable energy, animal husbandry and sustainable development. A complete technology for producing ethanol from sweet sorghum has been developed, and a number of high ethanol yielding varieties have been produced. A pilot plant capable of producing 50 litres per day of 95% ethanol using only solar energy for distillation has been set up at NARI.

1.3.2.1. The NARI Ethanol Stove



The NARI stove has been designed to run on 50% ethanol, intended for use in rural areas where it is distilled by local people. A preheating step is required to cold-start the stove (as is required by the presently-used kerosene stoves). The burner (2) vaporizes the ethanol-water mixture just before combustion. The resultant clean flame burns with a yellowish-orange colour and has a temperature of around 850º to 900º C. This low temperature and colour is due to the presence of water vapour in the combustion zone. The jacket (6) provides the turbulence required for complete combustion of the ethanol vapour. The flame can be regulated easily by turning the knob on the the flame-regulating valve (5). The extent of the flame regulation it provides is roughly comparable to that of the conventionally-used LPG stoves.

A pressure regulating valve (PRV) (3) regulates the flow rate of fuel. If the fuel tank (1) is filled with 1.8-2 litres of fuel and is pressurized up to 150 kPa by the hand-pump attached to the fuel tank, the stove can be operated for a continuous period of two hours without further pumping (enough time to cook a meal for 4 to 5 people).

To date, no independent tests have been performed on the stove, but field tests showed CO levels around 10ppm close to the stove where the cook would be working. As ethanol is a controlled substance in India, the stove is not yet at the dissemination phase. An integral stove/light combination has also been designed.

[24] http://www.nariphaltan.org/nari/

1.3.3. Societe Proimpex Agro-Industrie

This company started up in December 1993 in the field of agro-industry to market vegetable oils, collaborating with farmer organisations to supply raw materials. By 2001, the company had started a business developing and making small agricultural tools and appliances, such as mechanical rice-weeders and vegetables choppers to speed up composting, dealing nationally with farmers associations to develop agricultural techniques based on these tools. In 2003, the company started developing cooking stoves, for which patents are pending.

1.3.3.1. The ProImpex Stove

ProImpex stove images

The ProImpex stove, developed in Madagascar, is intended to burn high-water-content ethanol distilled by local farmers from locally-grown sugar cane residues. The device is seeking a patent[25] , and was independently tested during the project. Like the NARI stove, although designed to use artisanal alcohol, it will not burn untreated artisanal ethanol (a type of locally-made rum), which contains too much water.

There are two types of stove available; a larger burner to take one large pot (1), comprising a set of small sub-burners fed through a mixing valve from a single supply line splitting to two supply lines then through a series of tubes underneath the stove (2), and a single burner stove (4). The flow regulator, a simple squeeze valve (RHS, 2) constricts the plastic supply tube to restrict flow and to shut it off. To ignite the stove, ethanol is allowed to pool on the burners before ignition. Upturned plastic bottles with their bases removed are used as open fuel tanks for both stoves (6).

In the larger stove, the operator has to ignite each of the burners in turn (1). On ignition, the flame slowly develops (5) as the burner heats up. If an unlit stove sits

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[25] http://www.wipo.int/pctdb/en/ia.jsp?ia=EP2008/051152

with ethanol in it, the strength of the ethanol will be reduced from previous burning (ethanol burned and water remained behind) or will decline by absorbing water from the atmosphere, and ethanol evaporating into the atmosphere, making it difficult to light. In this case, the stove has to be primed with 60% ethanol from the top, so that the stronger ethanol can be lit.

A discharge tube from a reservoir around the flame area discharges a mixture of residual water containing some (unknown fraction) of ethanol to a bottle by gravity feed (3). The consultants on this study tested the liquid discharged when the stove was demonstrated to them, and showed that it could be ignited, indicating a high percentage of residual ethanol being lost, and that a high concentration of ethanol was used for the demonstration. If the stove is not well regulated this liquid can overflow the reservoir designed to collect this water/fuel mix, so care must be taken in its operation.

The stove burns steadily, as shown above, at more than 60% alcohol (recommended by the developer), who has indicated that it is not possible to obtain a stable combustion from the beverage grade artisanal alcohol, and that it must always be further distilled to achieve a higher alcohol content, and that the acidity must always be reduced to a pH close to 7 to prevent rapid corrosion of the stove.

Tests at the Aprovecho Research Center

The stove was tested at various concentrations of ethanol, and for safety. It was found that at 60%, the stove could not provide enough energy to boil 2.5 litres of water, although it could do so using 95% alcohol. The large ProImpex reached 98C using 60% alcohol, but could only establish a simmer at 94C rather than 96C. It could reach boiling point using 95% ethanol. In terms of dry ethanol weight, it used around one quarter more fuel than the CleanCook stove used by the project. Full details and comparisons of all the stoves tested are in Chapter 5 of Component B report.

The main recommendations from Aprovecho around the stove characteristics, safety and ease of use include:

- The flow is very difficult to control with the provided hardware. There seems to be too much or too little flow, no matter where the controller is placed.
- The construction of fuel flow lines was poor, as fuel was leaking out of several connections in the tubing.
- The small Proimpex seems too underpowered to be useful, especially when there is water in the fuel.
- Perhaps the pot supports could be lower, placing the pot closer to the flames. This might decrease fuel use, but should be tested.
- The separate fuel holder poses the danger that the long fuel supply tubing may be tripped on, or pulled, which could knock over the stove and pot or possible spill the fuel. It would be preferable to have the fuel source very close to the stove itself.

- Fuel likely to spill out drain tube.

In 2007, 200 of these stoves were manufactured in Madagascar, but none has been distributed to date, so nothing was known of the usability or desirability of the stoves before tests were conducted during the project. As with the NARI stove (the other ethanol stove that can burn diluted ethanol), there has been no independent testing; neither the emissions of the stove, nor the percentage of the heat produced by the alcohol that will be used in boiling off its water content has been tested. Evaluations through this project under Component B are still in negotiation with SPAI.

1.3.4. BluWave Limited

BluWave Limited is a Malawi incorporated and controlled company based in Blantyre. The company has adopted liquid ethanol combustion technology to develop domestic heating and lighting devices and industrial burners since 2001 for marketing in Malawi and neighbouring countries[26].

The company could manufacture up to 100,000 stoves per year and includes an ethanol fuel plant which could produce up to 12 million tonnes of ethanol per year, plus a bottle manufacturing and recycling plant which could manufacture 24 million half-litre bottles per annum.

1.3.4.1. The SuperBlue stove

SuperBlue stove

The original SuperBlu stove, although low in price, did not perform well in tests: it suffered from manufacturing problems and fuel safety, stove flaring and emissions, and poor performance at start and simmer.

Assessed against the Improved Ceramic Charcoal Stove (ICS), comparisons were made on a simple scale of 3=better than ICS, 2= similar to ICS, and 1= worse than ICS. At the time of testing[27] the stove was found to be worse on safety, better on usability and the performance was similar.

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26 http://www.undp.org/partners/business/gsb/projects/GSB%20Malawi%20project%20SuperBlu%20II%20Stove%20one%20pager%20(2).doc

27 Robinson, J. Bio-Ethanol as a Household Cooking Fuel: A Mini Pilot Study of the SuperBlu Stove in Peri-Urban Malawi . Report accessed from http://www.hedon.info/TheSuperBluStove#LatestInformation [April'09]

1.3.4.2. The SuperBlu 11 stove

The UNDP has included this ethanol-based stove in its Growing Sustainable Business Programme (GSB) which encourages the private sector to expand employment and livelihood opportunities through the development of new products and services that address the needs of the poor.

The stove has no consumable parts, and it converts into a heater in cold conditions by using a ceramic cylinder which fits on top of the stove, which heats up and retains and radiates the heat to the surroundings. On top of the cylinder a space is provided for a kettle.

Currently, BluWave does is seeking capital to produce and sell stoves on an economically viable scale and is seeking a partner to invest in producing and bringing the stove to the market through the UNDP Growing Sustainable Business Initiative.

1.3.5. Cooksafe

Cooksafe, part of GIK StoveCo, is a South African company that designs, manufacture and distributes ethanol stoves and fuel products made in South Africa. Currently, it does not appear to be trading, although test results at Aprovecho show it to be viable stove.

1.3.5.1. The Cooksafe stove

The target market is mainly the low income market, which uses paraffin as the primary fuel source for both cooking and heating. The stove is made of steel, is easy to store, reliable and lightweight. It has a low centre of gravity and non-slip feet, making it stable. Each burner is fitted with a patented material which absorbs the ethanol into the burner. The burner is then lit. The heat of the flame can be adjusted by regulating the air flow into the unit using the regulator handle. As with the CleanCook stove, once ethanol is introduced to the stove, it cannot spill even when the unit is tilted, moved or turned upside down. The sales literature is commendably honest[28]. It mentions:

Cooksafe stove

- Slight discolouration of pots and pans, suggesting that combustion is not complete.
- The need to use a specially designed CookSafe bottle with angle spout so that all the fuel reaches the fuel tank.
- Because the ethanol is so clean burning, it is often difficult to see the flame, and it is very important to ensure that the burner is off and that there is no

[28] http://www.cooksafe.co.za/

flame before transferring any ethanol into the burner unit.

- Ensuring that all ethanol in the burner is burnt off after use, as the ethanol left will slowly evaporate causing a slight odour, which can be unpleasant.

1.3.6. Greenheat Manufacturing

Millennium Gelfuel was first developed in Zimbabwe in 1996. In 2000 the World Bank provided research & development grants to Greenheat manufacturing, and tests were carried out throughout Africa. Greenheat South Africa was opened as a subsidiary, and now has factories and warehouses in Durban & Johannesburg. There is a strong research & development ethos to improve and create new products.

1.3.6.1. Greenheat stoves

Gelfuel burner

The stove benefits from a gelfuel burner with two sets of holes that allow three levels of heating – low, moderate and high. The shallow geometry of the fuel tank ensures a short distance between fuel and burner– otherwise power is reduced. When the stove is off, the stove must be closed off to prevent evaporation. These stoves fill a niche market for when there are power outages, but gelfuel is declining in popularity as a fuel for those on low incomes as it is low-powered and expensive compared with other forms of cooking fuel.

1.4. Biomass stoves and charcoal stoves

Biomass stoves have undergone a transformation in the last decade. Previously considered as the next step up from a three-stone fire if 'no other was available', their design has been developed to a stage where well-made stoves can be a good option in many situations, albeit they still have emissions higher than WHO air quality standards. The most obvious reasons for using them include:

- availability of fuel supply – in some instances at no monetary cost
- the need for warmth as well as heat
- they are useful for long slow cooking
- well-designed stoves will burn a variety of biomass materials which would otherwise be agri-wastes.

Despite these advantages, many so-called 'improved' biomass stoves produce unacceptable levels of smoke, chimneys can block, time-consuming and arduous fuel gathering is not always reduced, and over-exploitation of wood resources can exacerbate deforestation.

All improved stoves work by transferring more of the heat produced to the pot than an open fire. An open fire

Traditional charcoal stove - Kassala Sudan

is often 90% efficient at the work of turning wood into energy - *combustion efficiency*, but only a small proportion, from 10% to 40%, of the released energy makes it into the pot – *heat transfer efficiency*[29] . Many successful technologies, which increase the heat transfer efficiency, do little to deal with the remaining 10% of non-combusted fuel which causes household air pollution.

Many stoves, particularly those with chimneys, tend to be massive, and whilst the body of the stove is heating up, the combustion gases are cool, combustion is incomplete and emissions are at their greatest[30] . The newer stoves based on the 'rocket' principle, address the combustion efficiency at the same time as the heat transfer efficiency (Still, ~2003).

Traditional **charcoal stoves** are usually made of metal without insulation, which leads to most of the heat escaping. With efficiencies of 10% – 25 %, and more wood used in making the charcoal, using traditional stoves wastes a lot of energy and many emit large quantities of carbon monoxide.

The efficiency of charcoal use can be enhanced by improved stoves. They burn charcoal with an efficiency of 30 to 50 % above the traditional stoves and emit much less pollution. Charcoal consumption per capita is reduced (27% - 42 %).

1.4.1. Selected biomass and charcoal stoves

1.4.1.1. Upesi woodstove – East Africa

Upesi ceramic liner

The Upesi stove (also called Maendelao) has been promoted since 1995, mainly by the international NGOs, Practical Action and GTZ. The stove is targeted at rural households in order to reduce woodfuel use. A ceramic liner (illustrated) can be built into a mud fireplace to make a fixed stove, or can be clad in mild steel, to make a portable stove. The stove liner is very low cost (<$2) making it accessible even to low-income households.

Fuel consumption can easily be halved, and some projects have reported measurable emission reductions. Although this is not the most efficient, or the most clean-burning stove, it will burn all shapes and sizes of woodfuel and residues, provided they are dry, making it both well-accepted and encouraging good practice. *Upesi* stoves are now commercially bought and sold – households buy them on a regular basis and they completely replace the three-stone fires in districts where they

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[29] Bryden, M., Still, D, Scott, P, Hoffa, G, Ogle, D, Rob Bailis, Ken GoyerDesign Principles for Wood Burning Cook Stoves, Aprovecho Research Center, Shell Foundation, Partnership for Clean Indoor Air (~2003)

[30] Smith, K. Short primer on stove efficiencies, 2002

are popular, such as in many parts of Kenya and surrounding countries. Dissemination of this stove will be discussed in more detail in Chapter 3.

1.4.1.2. Upesi portable stove – East Africa

The portable *Upesi* is a well-established low cost stove burning wood and residues, and used in Kenya and surrounding countries. Cladding has two advantages:

- The stove can be used out of doors (weather and social custom permitting), reducing levels of household air pollution
- The stove is often bought in towns by relatives working there and carried to relatives living in rural areas. Steel-clad *Upesi* stoves are very portable.

Upesi portable stove

1.4.1.3. Kenya Ceramic Jiko – Sub-Saharan Africa

This stove, usually called the KCJ, is perhaps the best-known of all the charcoal stoves used in Africa. Originally launched in 1982, it is widely used in virtually all the countries of Sub-Saharan Africa. Industries have been built up around it, recycling steel drums, collecting and preparing clay, manufacturing, promoting, and selling it.

The firebox is insulated and the ceramic liner reflects the heat inwards. With less heat loss, the higher temperature allows more complete combustion. The holes in the bottom retain the charcoal, whilst allowing ash to fall through. The air flow is limited by the hole size. The stove burns with low levels of particulates, but fairly high levels of carbon monoxide. The KCJ is reported to save 30-50% charcoal[31] .

1.4.1.4. Toko Mitsitsy - Madagascar

The Toko Mitsitsy stove is built from local materials; red earth, termite mounds, or clay, and ashes or sand – with mixes varying according to region.

The stove is popular with local communities, and safer than an open fire. Independent evaluations, in 2001, and again in 2004, indicated that (compared with a traditional three stone fire) it provides:

- 30-65% savings in firewood use.

[31] (Adapted from: http://www.appropedia.org/Kenya_Ceramic_Jinko).

- 30-70% savings in cooking time.
- 20-60% costs savings in purchase of firewood.
- It accepts a variety of fuels, e.g. maize husks, and can boil water in a quarter the time of traditional open stoves, creating time savings that increase economic opportunities for women such as weaving.
- Wood saved per 2500 stoves in use is accruing at a rate of more than 5000 tonnes per annum.

Training in the construction of the TM fuel efficient woodstove in Southern Madagascar has been carried out by the Andrew Lees Trust from 1999 to date[32] .

1.4.1.5. Gyapa stove - Ghana

Gyapa stoves comprise a range of stoves made by EnterpriseWorks in Ghana, mainly fuelled by charcoal, but with one model available for woodfuel. The stove comprises a metal body with ceramic liner. The dissemination of the various sizes of charcoal stove has been highly successful and will be discussed in Chapter 3.

Gyapa stove

EnterpriseWorks/Vita calculated that, in Ghana, as a result of the stove there was;

- a 40% saving on charcoal
- over 5,000 hectares of forest area saved per year
- nearly 100,000 tonnes of CO_2 reduced in a year.

A woodfuel version, tested by Berkeley Air, showed marked reductions in levels of particulates in the kitchen (from 650 to 320 µg/m^3), and CO kitchen concentration dropped below the WHO guideline to 8.5 µg/m^3. However, this stove is a good example of an excellent technology that has not been widely adopted. Currently there is sufficient woodfuel in the locations where it is sold, and those who gather fuel are those in the greatest poverty. They do not see the need to purchase a woodstove.

1.4.1.6. Ugastove - Uganda

Photo: JPMorganClimateCare

Ugastove biomass stove

Ugastove is a new business venture manufacturing stoves in Uganda. The stove project (then a project known as UCODEA) benefited from a US EPA

Ugastove charcoal stove

[32] (http://www.andrewleestrust.org/fuel.htm and personal correspondence).

grant in 2004-2006, which funded both design and business development. Preliminary data shows that UGASTOVE's wood burning stove reduces CO by 54% and PM2.5by 49%.

Field Kitchen Performance Tests show that the stoves reduce the consumption of fuel by 38-58% compared to traditional stoves. This is one of the first stove projects being funded through carbon finance on the voluntary market via J.P. Morgan ClimateCare. It is designed to the 'gold standard' which requires socio-economic benefits as well as greenhouse gas reduction. The stoves have been shown to reduce fuel costs, saving a household around $130 over three years, improving energy access and creating employment for both women and men. Ugastove now manufactures around 200 stoves per day.

Ugastove also sell a popular range of improved charcoal stoves which come in a range of five sizes. The distinctive colour scheme coats a durable sheet-steel metal casing. A ceramic inner lining provides major improvements in heat-retention compared to standard charcoal stoves.

1.4.1.7. StoveTec Wood/Charcoal Burning Cook Stoves - international

The StoveTec portable cook stoves were developed by Dr. Larry Winiarski at the Aprovecho Research Center. The stoves are designed for household cooking, and are designed to last for several years, although conservatively rated at two years for carbon finance as they are still very new.

StoveTec wood / charcoal stove

The stove illustrated can burn both wood and charcoal. Every version for household use feature handles, a refractory ceramic combustion chamber, a painted steel body, cast iron stove top and a steel stick support. They are the result of many years of in field experience and are currently used in many stove projects and carbon credit programmes worldwide.

Independent testing has shown that the StoveTec stoves reduce biomass fuel use by about 40% compared to the open fire. They burn more cleanly than an open fire, reducing household air pollution and health hazards from breathing smoke. They have been shown to produce significantly less emissions that contribute to global warming[33] .

1.4.1.8. Vesto stove – Southern Africa

The Vesto stove is manufactured by New Dawn Engineering, in Southern Africa. It is a variable energy, fuel-efficient wood

Vesto stove

33 (http://www.stovetec.net).

burning stove, based on a modified 25 litre paint can. It consists of five main components;

- the main stove body with a wire handle
- the fire grate with holes punched through it, including a replaceable insert at the bottom
- the folded stainless steel strip to support the pots
- the secondary air controller
- the primary air controller.

The way in which air is circulated through the stove allows the heat output to be variable. The Vesto can accommodate fuel with cross-sections varying from twigs to 110mm diameter wood, preferably 200mm long or less (over-filling a wood stove makes it produce a lot of smoke). The stove was designed for mass production, so that large numbers of stoves could be made commercially. The stove was designed both to appeal, and to be affordable, to a mass market and to make mass production feasible. Factors such as the material costs, production processes and marketing strategies were planned such that the stove cost no more than a large pot. It had to be attractive in appearance, reduce fuel costs and reduce emissions.

1.4.1.9. Envirofit stove – India

Photo: Envirofit

Envirofit Gen111stove

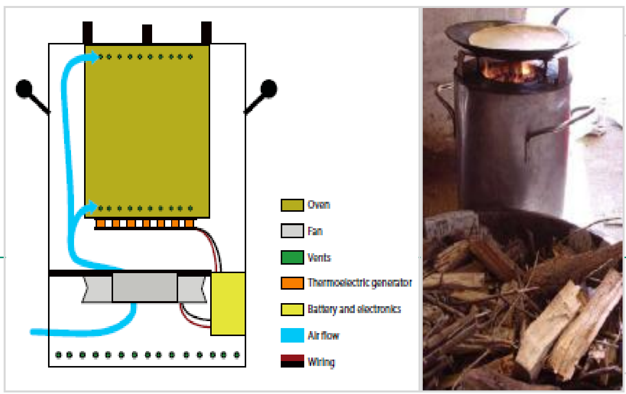
The Envirofit range of stoves were developed through an initiative by the Shell Foundation Breathing Space programme, aimed at finding ways to alleviate household air pollution for the masses worldwide who live in poverty, and who cook on rudimentary biomass stoves. Key criteria for pursuing this initiative included;

- Feasible solutions to alleviating household air pollution
- Financially viable business models to ensure scale up and commercial sustainability

The strategy behind their dissemination will be discussed in Chapter 3.

1.4.1.10. Philips stove - international

This gasifier stove uses the heat from the stove itself to charge up a battery within the stove. The battery powers a fan that enables a very accurate amount of air to



PhotoPhilips Research

be passed through the fuel mix, creating near-perfect combustion conditions and reducing the levels of pollutants to near zero. This stove is still at the development stage.

1.4.1.11. Onil stove – Nicaragua, Guatemala

Chimney stoves have not been particularly successful in Africa, but for completeness, a successful chimney stove used in Latin America is discussed. The Onil stove promoted by HELPS international, is a 'rocket-type' woodfuel chimney stove used in Nicaragua and Guatemala[34] .

The inside of the stove is made of highly insulative material, reflecting heat back into the stove rather than absorbing it. The opening for fuel is small, so the wood has to be cut into smaller pieces, encouraging combustion.

There is a 'step' just before the fuel entrance to let sufficient air pass through to cause complete combustion.

The height from firebed to heating surface is long enough to allow near-complete combustion before the smoke is vented through the chimney to the outdoors

In the illustration, food is placed on a hotplate (plancha). In other versions of this type of stove, pot recesses would allow the hot gases to brush against the pot, transferring heat before being vented.

Good education is vital with these stoves as the flue must be cleaned on a weekly basis or it will block up with soot. The components are produced commercially, and the stove is subsidised at the point of sale[35] .

1.4.1.12. Ecostove

The Ecostove is a portable, commercial stove which is produced by the organisation Prolena at around 100 stoves per month. They are sold on the open market; some subsidy is used to part-subsidise the stove cost for women who use them to make food for sale, such as tortilla makers and vendors of nacatamales.

[34] http://www.onilstove.com/
[35] http://www.youtube.com/watch?v=U_e0vOfjvH0

1.5. Enhanced ventilation – all countries

In this section, smoke hoods, windows and doors¸ and eaves spaces will be discussed. Flues which are integral to stoves have already been mentioned in the stoves section.

1.5.1. Smoke hoods

Smoke hoods are very effective at alleviating smoke from open fires. A project led by Practical Action indicated that in Nepal (where the stoves were used for both cooking and space heating), around 85%-90% of the carbon monoxide (used as an indicator) was removed for both cooking and background levels. The number of minutes when room concentrations were >9ppm was reduced from 367 to 56. Smoke is vented through a wide chimney through the roof (Bates, 2007).

Smoke hoods in Tanzania & Nepal

Recent laboratory tests at Aprovecho have showed very positive results (personal correspondence – data not yet available).

A useful aspect of smoke hoods is that it allows households to use the stove/fire combination to which they are accustomed, so is socially acceptable as very little change is required of the cook – perhaps not leaning over the stove (which is again, a positive aspect). The Nepali hood is both larger and taller to accommodate alcohol brewing than its counterparts in Kenya and Tanzania.

Although the smoke hood option was available in Kenya during the scaling up phase of the project, and proved technically very successful in both Kenya and Tanzania, women in Kenya opted for the more 'modern' LPG stove, albeit they only used it for fast cooking and reverted to the more polluting three-stone fire for long slow cooking.

Practical Action has recently begun to collaborate with Bosch-Siemens (BSH) to look more closely at the technology interface of smoke hoods with social and household needs.

1.5.2. Windows

There are mixed views on how successful ventilation is as a means of alleviating smoke. A recent study in South Africa indicated that households with more than one ventilation source open had lower levels of household air pollution than those with only one opening[36], and similar findings were cited in [37]. However, the use of openings appears to be very site and climate specific. The authors cite smoke disseminating quickly after the lunchtime meal because the households tend to ventilate their rooms at this time. This approach does not address the central issue of the woman cook standing close to very high levels of pollutants as she prepares food, nor the problems associated with very high levels of pollutants where the fire is left lit to keep warm, and where opening doors and windows would be counterproductive.

Fireless cooker - Kenya

Results based on the size of windows compared to levels of pollutants were not found to be significant in the Practical Action studies in Kenya, Nepal and Sudan. These windows did not contain glass, and the effects of opening/not opening the shutters at night were not examined.

1.5.3. Eaves spaces

Practical Action showed that the use of longitudinal openings along the walls, just beneath the thatch, proved effective in reducing levels of pollutants in Kenya.

Eaves space above installed *upesi* stove, Kenya

Using the staining caused by a traditional fire or stove set against an internal wall to determine the length of the space to be cut out, the Kenya team showed that around 40% of the smoke pollution could be removed.

This is a low-cost and useful way to alleviate smoke, although problems associated with wild animals getting into the kitchen required that a wide mesh was stretched along the length of the space – this can block with smoke if not cleaned regularly.

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[36] Barnes B R, Mathee, A, Krieger, L., Shafritz, L., Favin, M., Sherburne, L. 'Testing selected behaviors to reduce household air pollution exposure in young children' Health Education Research 2004 19(5): Oxford Journals, 2004 http://her.oxfordjournals.org/cgi/content/full/19/5/543

[37] Dasgupta, S., Huq, M., Khaliquzzaman, M.,Pandey, K., Wheeler, D. 'Indoor air quality for poor families: new evidence from Bangladesh' *Indoor Air, Volume 16, Number 6*, Blackwell Publishing, December 2006

1.6. Behaviour change & low-cost interventions

There are several low-cost and no-cost options that can be used to alleviate levels of inhaled smoke – particularly for the women who cook, and their children.

Cooking out of doors can be effective, particularly in rural areas with low levels of dust and other pollutant sources (eg traffic, industry, waste burning). A study in South Africa has shown that it is particularly successful at reducing child exposure[38]. Outdoor cooking is not usually as energy-efficient as the flame tends to be blown around and not reach the pot effectively. Also, it can be too hot, or too cold, or raining, and there are many social customs preventing people from cooking out of doors.

Putting children in another room, and/or away from the fire may prevent cases of ALRI, but this is only an option where it is safe, and where mothers are comfortable with others caring for their children.

Solar cookers can be bought at very low cost. If women are in a position to put out food in the full sun without having to tend it all the time, this can be an excellent technology. However, it may mean that they are unable to attend to other activities, and may prevent them from earning. Where the custom is to cook the main meal at night, solar cooking may not be appropriate unless used in conjunction with a 'fireless cooker' (insulated box – haybox). In this case, food can be cooked at no cost and be ready in time for a meal.

Fireless cookers have proved very successful in the Practical Action study in Kisumu, Kenya. With most of the population living in poverty, this low-cost option has been highly effective. Made by local women, or by the cook herself, attractive 'cookers' can be made from woven straw baskets, insulated with cushions lagged with cut up old clothes. They can also be an integral part of the stove assembly, sunk into the mud base into which the cooker is installed[39] .

Using pot lids can reduce the amount of firewood used by a factor of three[40]. This is more feasible where water is being heated or food is being boiled in water. It is less useful where food needs constant stirring, for example, when making *ugali* (a staple thick maize meal 'porridge' in Kenya).

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[38] Barnes, B.R., Mathee, A., Bruce, N. , Thomas, L. 'Protecting children from household air pollution exposure through outdoor cooking' in *Boiling Point 52,* 2006

[39] Okello, V. The role of awareness creation in igniting interest in smoke alleviating technologies; a study in mobilization and community involvement, HEDON CleanAirSIG conference, July 2007 www.hedon.info/docs/VincentOkello.pdf

[40] Ballard-Tremeer, G. 'How many of these improvements are in your stoves programme?' Boiling Point 40, Household energy and health, 1998 http://www.hedon.info/HowManyOfTheseImprovementsAreInYourStovesProgramme

Chopping up firewood into thin pieces can greatly enhance combustion, reduce smoke and increase efficiency. However, it is time-consuming and arduous for the cook, and requires some sort of chopping tool.

Insulating households in cold regions. Where stoves are used for space-heating as well as cooking, the use of insulation can substantially reduce the need for heating. However, insulation will also prevent smoke going out of the house in the same way that it prevents heated air from escaping. Other means of venting smoke (such as smoke hoods) should be included[41].

Awareness-raising is perhaps the most important intervention of all is the need for. Unless households take 'ownership' of the problem as 'their' issue and not that of the organisation promoting whatever technology is on offer, then nothing will change in the longer term. Community discussions, promotions through demonstrations, media, exchange visits, can all help to make people aware both of the problems of smoke and that there are ways in which it can be alleviated.

Awareness-raising through community meetings

1.7. Evaluating scaling up and sustainability

1.7.1. Monitoring household energy technologies

The techniques used to monitor household energy technologies are complex due to a number of factors:

- Stoves are within people's homes, so any project will impact on the normal household activities.
- Variables differ from house to house (types of food, fuel, stove, occupants etc.).
- Laboratory tests have been shown not to reflect what happens in reality.
- Cooks used to a particular stove will cook on it much more effectively than the researcher.
- Smoke levels change with location of monitor relative to the stove, and new technologies may be differently located within the house.
- People's responses may differ dependent on whether they have bought or have been given the appliance.

[41] Bates, E. et al, *Smoke, health and household energy Volume 2: Researching pathways to scaling up sustainable and effective kitchen smoke alleviation, Practical Action 2007 http://practicalaction.org/?id=smoke_book_2*

- Seasonal changes may affect both the dryness of the fuel, and the fuel itself – for example, where agricultural residues are used when available.
- Stoves are only effective if people use them, and even good technologies will not be used unless they address the issues that are important to the user.
- To achieve meaningful measurements, laboratory tests to determine how stoves behave must be backed up with household measures to show fuel consumption and levels of pollutants.
- For pollutants, because of the wide range of available equipment, test duration, and position of monitors, the best option is often to look at the 'before-and-after' case in order to determine whether a technology is effective at alleviating smoke.

1.7.2. Measuring adoption and usage rates

Before stoves can begin to be effective, people must want to adopt them. Counting the number of stoves installed during a project (particularly if they are subsidised) does not give a good idea of adoption rates once the project is over. A measure of sustainability is to look at the rates of adoption to see if the numbers being purchased would give sufficient incentive for entrepreneurs to continue selling and maintaining stoves beyond the project end. A growing market is another good indicator. Efforts should be made to match supply and demand closely.

Having purchased a stove, it is necessary to monitor whether people use it on a regular basis, and for a substantial fraction of their total daily cooking. This requirement has become very important if carbon finance is sought, as stoves can only generate carbon savings if they are being used. Questionnaires and spot checks can identify whether the stove is in regular use, and the other technologies that are being used in a household.

1.7.3. Inter-dependence of scaling-up and household air pollution reductions

Care must be taken when implementation moves from the project phase. During a project, households will be visited, encouraged to save for fuel, to keep the stove clean and functional, to ensure that revolving finance is working well, that fuel supplies are available, and any small problems can be fixed etc.

Once the project ends, unless there is a sufficient infrastructure to continue to provide this support, to replace stoves that have reached the end of their useful lives, to retain the links with lending institutions, and to ensure a good supply chain, there is a serious risk that if things go wrong, people will revert to their former cooking patterns. If this happens, not only is all the work that has been done for nothing, but all the health benefits, and other quality of life benefits, also disappear.

Getting the technology right - India

The Government of India's National Program of Improved Cookstoves

Setting up infrastructure to move from project to commercial phase is an important factor, and monitoring usage and maintenance patterns for technologies beyond the end of the project is very useful in learning for the future view of projects, technologies and approaches. Until fairly recently, the only fuels available for low-income communities were based on wood and/or residues. More recently, fuels that can be easily made to burn cleanly have become more widely available – particularly to those living in urban areas. Any fuel can be made to burn 'cleanly' (ie without discharging a lot of emissions into the kitchen) but it must be burnt in a well-designed stove. Liquid and gaseous fuels have the potential to burn the most cleanly, although the technology still has to be well-designed.

introduced some 33 million biomass-based improved stoves in rural areas during 1984-2000.

Available studies indicate that problems, such as design failures, lack of public acceptance, quality control, plague the program. (ESMAP,2001)

The most important factor, and one that is often overlooked, is that women *have to use* the stove or the efficiency gain is nil. Perhaps the largest example is the Indian Stove Program. Only in a few parts of India did this succeed, where there was local consultation and the stoves were sold commercially. Fuels and technologies must be desirable and effective, easy to use and save time – or they will be ineffective and will fail. The majority of examples given in this section provide an overview of fuel/technology combinations that have been shown to be successful through the levels of adoption that have been achieved.

With all types of stove, the price paid is always a major factor, but can be misleading unless the useful life of the stove is also considered. Stoves which have a long life tend to be more expensive as the build quality and materials used are usually of better quality. However, as the up-front cost may prevent those living in poverty from purchasing a better-quality stove, ways must be found to address this issue.

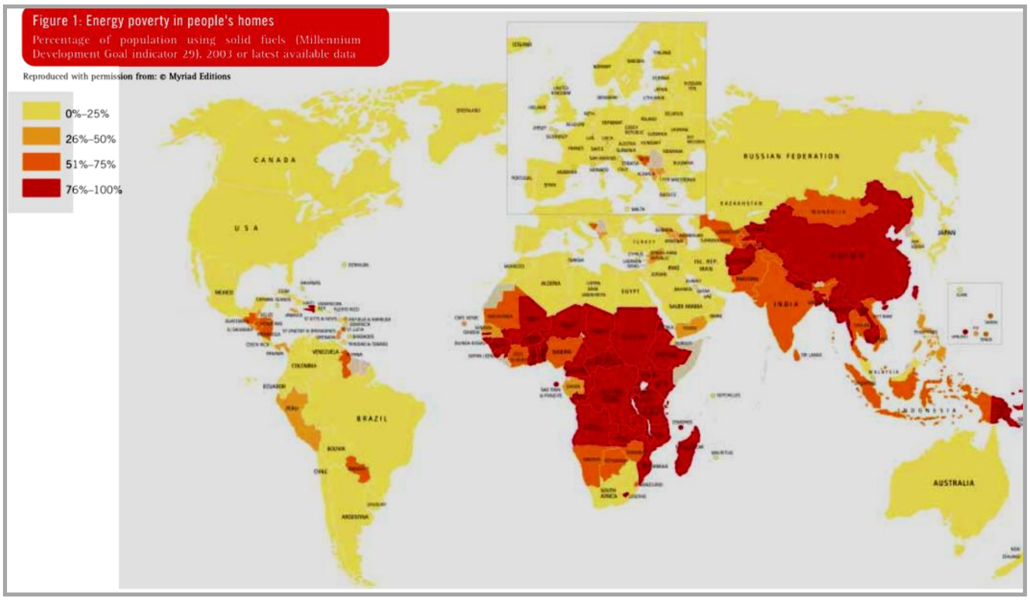
2. Health and quality of life impacts of reductions in household air pollution

This chapter investigates the different ways in which one can reduce household air pollution, and how those reductions can improve health and quality of life.

2.1. Introduction

Over half of the world's population uses solid fuels including biomass (wood, charcoal, dung, crop residues) and coal to meet their daily household energy needs such as cooking and heating (Figure2.1). This rises dramatically in the poorest areas, 77% in Sub-Saharan Africa, 74% in Southeast Asia, and 74% in Western Pacific regions.

Figure 2.1: Population (%) using solid fuels (2003 or latest available data)



Taken from WHO Fuel for Life: Household Energy and Health
http://www.who.int/indoorair/publications/fuelforlife/en/

The relationships between a reliance on biomass fuels and health and quality of life are complex and inter-related. Most disease-related health impacts are associated with exposure to high levels of household air pollution generated by the incomplete combustion of biomass fuels. The procurement and use of the fuel, and of the household energy devices (stove / lamp), also have diverse significant impacts.

Although there is a growing body of evidence that links reductions in household air pollution with improved health, it is not possible to compare costs of interventions with changes in health directly. This is due to many factors which include;

- the way in which household monitoring has been undertaken in past studies
- the different ways in which people use interventions
- the differing pollutant levels into which interventions are introduced, as the relationship between health and pollutant reductions is not linear
- the very large and expensive projects needed to describe the pollutant/ health relationships
- the very limited sources of information as a result of the last point. 'To date, only one study has investigated the impact of an improved stove on childhood pneumonia and women's respiratory health. Therefore, we cannot yet draw clear-cut conclusions about which interventions are most effective in saving children's and women's lives'[42] .

What can be said is that investing in household energy pays off. A global analysis, recently conducted by WHO, shows a payback of US$ 91 billion a year from the US$ 13 billion a year invested to halve the number of people cooking with solid fuels by providing them with access to LPG by 2015 (for ethanol, the investment at the time of the analysis was higher for the same economic benefit). Making improved stoves available, by 2015, to half of those still burning biomass fuels and coal on traditional stoves, generates an economic return of US$ 105 billion a year over a ten-year period. Time gains from reduced illness, fewer deaths, less fuel collection and shorter cooking times, valued at Gross National Income (GNI) per capita, account for more than 95% of the benefits. There is debate on the appropriate valuation of time[43] .

The best evidence to date is described in the paragraphs below.

2.1.1. Household air pollution

The burning of solid fuel produces large amounts of potentially hazardous pollutants, including particulate matter, carbon monoxide, sulfur oxides (coal), formaldehyde, nitrogen dioxide, and carcinogens such as benzo(a)pyrene [44]. The fine particles (<2.5 μm in diameter ($PM_{2.5}$)) and small particles (<10 μm in diameter (PM_{10})) can be breathed easily deep into the lungs, and have the greatest potential for detrimental health effects. Levels of PM_{10} can peak as high as 10,000$\mu g/m^3$ [45] during cooking

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[42] Rehfuess, E. Fuel for Life: Household energy and health, WHO Press, 2006 www.who.int/indoorair/publications/fuelforlife.pdf

[43] Rehfuess, E. Fuel for Life: Household energy and health, WHO Press, 2006 www.who.int/indoorair/publications/fuelforlife.pdf

[44] Ezzati, M. & Kammen, D M.,2002, The health impacts of exposure to household air pollution from solid fuels in developing countries: knowledge, gaps, and data needs.Environ Health Perspect. 2002 Nov;110(11):1057-68.

[45] $\mu g/m^3$ = microgrammes per cubic meter

indoors on an open fire or poorly ventilated stove. A 24-hour average concentration of PM_{10} in homes using biomass fuels may range from 200 to 5000$\mu g/m^3$ depending on type of fuel, stove and housing[46] (Ezzati 2002). This can be compared to the standard set by the US Environmental Protection Agency for an annual average of < 50$\mu g/m^3$ or a daily average of 150$\mu g/m^3$ [47].

2.2. Health impacts of exposure to household air pollution

Daily exposure to these high levels of pollutants over a long period means that the cook, and often the children who remain near the stove, are at significant risk of a range of common and serious preventable diseases (Bruce et al. 2000). Table 2.1 provides an overview of current evidence in brief, described in further detail in this section.

Table 2.1: Evidence of the burden of ill-health caused by household air pollution

Name of organisation	Country	Deaths per annum	Ill-health per annum	Overall burden of disease	Research base	
Global estimates - WHO	Global	1.6million	39million DALYs	3.7% developing countries. 4th major risk factor	Smith et al. WHO	2004[48] 2002
WHO	Sub-S Africa	396,000			WHO	
	Global			Exposure to HAP from unprocessed solid fuels nearly doubles risk of pneumonia in children <5 years	Dherani et al 2008	2008[49]
WHO	Africa	50% worldwide pneumonia deaths children <5		20% of the world's population	WHO	2002
	Rural Turkey		23% all COPD cases, Turkey		Ekici et al	2005[50]

[46] Ezzati, M. & Kammen, D M.,2002, The health impacts of exposure to household air pollution from solid fuels in developing countries: knowledge, gaps, and data needs.Environ Health Perspect. 2002 Nov;110(11):1057-68.
[47] http://www.epa.gov/air/criteria.html#3.

[48] Smith et al, 2004. Smith, K.R.; Mehta, S.; Maeusezahl-Feuz, M. Indoor air-pollution from solid fuel use. In: Ezzatti, M.; Lopez, A.D.; Rodgers, A.; Murray, C.J.L., editors. Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. World Health Organization; Geneva: 2004. p. 1435-1493.
[49] Dherani M, Pope D, Mascarenhas M, Smith KR, Weber M, Bruce N.Household air pollution from unprocessed solid fuel use and pneumonia risk inchildren aged under five years: a systematic review and meta-analysis.Bull World Health Organ. 2008 May;86(5):390-398C.
[50] Ekici et al, 2005. Ekici A. Ekici M. Kurtipek E. Akin A. Arslan M. Kara T. Apaydin Z. Demir S. Obstructive airway diseases in women exposed to biomass smoke. Environ. Res. 2005;99:93–98.

Other evidence			
Cause of ill-health	**Finding**	**Author**	**Year**
Study on childhood pneumonia	HAP is definite risk factor	Rudan et al	2008[51]
Chronic bronchitis in rural non-smoking women and chronic obstructive lung disease	HAP is associated risk factor	Torres Duque Smith et al	2008[52] 2004[53]
In Mexico, non-smoking women – various lung diseases	Comparable to smokers	Moran-Mendozo et al	2008[54]
Marked increase in risk of lung cancer, particularly in women	Exposure to coal smoke in China	Smith et al	2004[55]
Low birth weight in infants	Zimbabwe and Guatemala - maternal exposure	Mishra	2004[56]
		Boy	2002[57]
Increased TB (OR 2.4)	Mexico – cooking with biomass	Perez-Padilla et al	2001[58]
Increases risk of TB	Meta-analysis and systematic review	Lin et al	2007[59]
Perinatal mortality, asthma, and middle ear infection in children, nasopharyngeal and laryngeal cancer, and cataract in adults	Associations with exposure to household air pollution	Bruce et al	2000[60]

[51] Rudan, I., Boschi-Pinto, C., Biloglav, Z., Mulholland, K., Harry Campbell, H., Epidemiology and etiology of childhood pneumonia WHO, BULL, 2008 http://www.who.int/bulletin/volumes/86/5/07-048769/en/print.html [accessed May 2010]
[52] Torres-Duque C, Maldonado D, Pérez-Padilla R, Ezzati M, Viegi G; Forum of International Respiratory Studies (FIRS) Task Force on Health Effects of Biomass Exposure. Biomass fuels and respiratory diseases: a review of the evidence. Proc Am Thorac Soc. 2008 Jul 15;5(5):577-90
[53] Smith et al, 2004. Smith, K.R.; Mehta, S.; Maeusezahl-Feuz, M. Indoor air-pollution from solid fuel use. In: Ezzatti, M.; Lopez, A.D.; Rodgers, A.; Murray, C.J.L., editors. Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. World Health Organization; Geneva: 2004. p. 1435-1493.
[54] Moran-Mendoza O, Pérez-Padilla JR, Salazar-Flores M, Vazquez-Alfaro F. Wood smoke-associated lung disease: a clinical, functional, radiological and pathological description. Int J Tuberc Lung Dis. 2008 Sep;12(9):1092-8
[55] Smith et al, 2004. Smith, K.R.; Mehta, S.; Maeusezahl-Feuz, M. Indoor air-pollution from solid fuel use. In: Ezzatti, M.; Lopez, A.D.; Rodgers, A.; Murray, C.J.L., editors. Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. World Health Organization; Geneva: 2004. p. 1435-1493.
[56] Mishra V, Dai X, Smith KR, Mika L. Maternal exposure to biomass smoke and reduced birth weight in Zimbabwe. Ann Epidemiol 2004; 14:740–747.
[57] Boy et al, 2002. Boy E. Bruce N. Delgado H. Birth weight and exposure to kitchen wood smoke during pregnancy in rural Guatemala. Environ. Health Perspect. 2002;110:109–114.
[58] Perez-Padilla et al, 2001. Perez-Padilla R. Perez-Guzman C. Baez-Saldana R. Torres-Cruz A. Cooking with biomass stoves and tuberculosis: a case control study. Int. J. Tuberc. Lung Dis. 2001;5:441– 447
[59] Lin HH, Ezzati M, Murray M. Tobacco smoke, household air pollution and tuberculosis: a systematic review and meta-analysis. PLoS Med 2007; 4: e 20.
[60] Bruce et al, 2000. Bruce N. Perez-Padilla R. Albalak R. Household air pollution in developing countries: a major environmental and public health challenge. Bull. World Health Organ. 2000;78:1078–1092.

Estimates indicate that, globally, household air pollution is responsible for around 1.6 million extra deaths and the loss of just over 39 million DALYs[61] [62]. These figures are equivalent to 3.7% of the overall disease burden in developing countries, making exposure to household air pollution the fourth most important risk factor after malnutrition, unsafe sex and lack of safe water and inadequate sanitation[63] . The 2002 estimates for Sub-Saharan Africa suggest that some 396,000 deaths per annum are attributable to household air pollution.

There is now a strong association between ALRI, particularly pneumonia and household air pollution[64]. A recent systematic review and meta-analysis concluded that exposure to household air pollution from unprocessed solid fuels almost doubles (OR=1.78) the risk of pneumonia in children <5 years old (Dherani et al 2008).

A 2002 review by the WHO showed that African and South East Asian children suffered from ALRI disproportionately compared to the rest of the world. In fact, the African region has 20% of the world's population of children <5 years old, yet it has 50% of worldwide deaths from pneumonia in this age group. After an extensive review of the available research on childhood pneumonia[65], categorised household air pollution as a definite risk factor, consistently supported as such by the large majority of the evidence.

The association of exposure to household air pollution with chronic bronchitis (long-term cough and phlegm) and chronic obstructive lung disease (narrowing of airways in the lung, which is progressive and can be only partially reversed) is also well established in non-smoking women living in rural areas, (Ezzati et al, 2005; Smith et al., 2004).

In women from rural Turkey, it is estimated that after allowing for possible confounding factors, 23% of chronic obstructive pulmonary disease (COPD) could be attributed to exposure to biomass smoke (Ekici et al., 2005).

It was observed in Mexico, that non-smoking women chronically exposed to wood smoke 'have obstructive lung disease, chronic bronchitis, emphysema and pulmonary hypertension comparable to smokers' (Moran-Mendozo et al., 2008).

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[61] DALY- disability adjusted life year is a robust measure of disease burden and reflects both mortality and morbidity of a disease.

[62] Smith et al, 2004. Smith, K.R.; Mehta, S.; Maeusezahl-Feuz, M. Indoor air-pollution from solid fuel use. In: Ezzatti, M.; Lopez, A.D.; Rodgers, A.; Murray, C.J.L., editors. Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. World Health Organization; Geneva: 2004. p. 1435-1493.

[63] WHO (2005) Fact sheet number 292 - http://www.who.int/mediacentre/factsheets/fs292/en/index.html [accessed May 2010]

[64] Smith et al, 2000. Smith K.R. Samet J.M. Romieu I. Bruce N. Household air pollution in developing countries & acute lower respiratory infections in children. Thorax 2000;55:518–532

[65] Rudan, I., Boschi-Pinto, C., Biloglav, Z., Mulholland, K., Harry Campbell, H., Epidemiology and etiology of childhood pneumonia WHO, BULL, 2008 http://www.who.int/bulletin/volumes/86/5/07-048769/en/print.html [accessed May 2010]

There is evidence, mainly from China, that exposure to coal smoke in the home markedly increases the risk of lung cancer, particularly in women (Smith et al., 2004).

Studies from Zimbabwe and Guatemala showed that maternal exposure to household air pollution was associated with low birth weight in infants[66] (Boy 2002).

The evidence for the association between household air pollution and tuberculosis (TB) remains moderately strong with a case control study from Mexico showing an increased risk (OR 2.4) of TB associated with cooking with biomass stoves (Perez-Padilla et al., 2001).

A recent meta-analysis and systematic review argued that the evidence supports the hypothesis that exposure to respirable pollutants from household air pollution increases the risk of TB (Lin et al., 2007).

Perinatal mortality, asthma, and middle ear infection in children, nasopharyngeal and laryngeal cancer, and cataract in adults are all diseases with associations with exposure to household air pollution (Bruce et al. 2000).

Headaches (probably due to CO inhalation), eye irritation from the smoke of the fire and backaches from cooking on low stoves or carrying heavy loads of fire wood may not be life-threatening illnesses, but nevertheless are chronic, uncomfortable debilitating conditions associated with the daily use of solid fuels and coal for cooking and heating.

2.2.1. Increased risk of burns

Around 200,000 people are injured or lose property in kerosene-related fires each year. When spilt, kerosene (paraffin) burns with a hot flame that is spread by water and will flare up or flash. In a typical wick stove, an explosive situation can also be caused if the flame spreads to the fuel tank, or if vapour pressure builds when the fuel tank becomes over-heated. Ethanol does not have these properties. It burns with a lazy, cool flame and can be put out by water. Denaturing agents can provide an additional safety measure by colouring alcohol's clear blue flame to make it more visible in the daylight.

The use of stoves used at ground level can present a safety problem. There is an increased risk of burns and scalds due to the open nature of fires, and location on the floor. Cooks are at risk of clothes igniting, especially in countries such as India where long skirts are worn. When cooking with non-dried wood, small pieces of hot fuel can break off and set other things on fire. Also a mobile small child is at risk of falling, crawling into an open hearth, knocking over open fuel containers, or being scalded from knocking over pots which are sitting on stoves at floor level. This can

[66] Mishra V, Dai X, Smith KR, Mika L. Maternal exposure to biomass smoke and reduced birth weight in Zimbabwe. Ann Epidemiol 2004; 14:740–747.

potentially cause significant burns which in turn can result in long-term disability and social and economic burden.

Clothes, bedding and house fires from knocking over candles are very common in the absence of electricity.

2.2.2. Poisoning

Paraffin (kerosene) is an inexpensive fuel that can be sold in convenient quantities to low-income communities making it a popular choice for the main household fuel. Each year, 80,000 children ingest paraffin[67] , and although paraffin ingestion results in few deaths (0.74% cases Krug E et al), acute respiratory distress, central nervous system impairment and pneumonia are common symptoms. Summer months see a dramatic rise in paraffin ingested poisoning when the heat makes children thirsty and seeking fluid they drink paraffin from soft drink bottles mistaking it for water [68] [69].

The key to prevention is education on the dangers of paraffin, along with child resistant containers stored at a high level. Research has proved that packaging dangerous substances in child-resistant containers reduces ingestion by at least

47%.

There are very few reported cases of children ingesting ethanol, probably because it is not yet such a popular household energy source, and ethanol ingestion does not cause such severe health effects as kerosene, even in children. Ethanol used for household fuel must always be 'denatured' with an unpalatable bitter agent to remove it from the food chain. This approach is likely to be successful in those countries where there is easy access to locally-produced drinking alcohol.

2.2.3. Injury gathering fuel

Most collection of fuel is carried out by women, and school-age children are often involved. Although not well studied and quantified, there is sufficient evidence that injuries (from falling with heavy loads), animal bites (snakes, etc) are quite common. Women have an increased risk of backache and uterine prolapse. In some areas, particularly of political instability, women are at risk of physical threats, assault and rape (PAC, 2009).

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[67] Shell: Case study: Improving paraffin safety in South Africa http://www.shell.com/home/content/responsible_energy/environment/responsible_products/case_study_south_africa/case_study_sa_000407.html

[68] Oguche S, Bukbuk DN, Watila IM. Pattern of hospital admissions of children with poisoning in the Sudano-Sahelian North eastern Nigeria. Niger J Clin Pract. 2007 Jun;10(2):111-5.

[69] Siddiqui EU, Razzak JA, Naz F, Khan SJ. Factors associated with hydrocarbon ingestion in children. J Pak Med Assoc. 2008 Nov;58(11):608-12.

2.3. How is exposure to household household air pollution reduced?

Interventions for reducing exposure to household air pollution can be grouped under three headings (Table 2.2).

Table 2.2: Interventions for reducing exposure to household air pollution

1: Source of pollution	2: Living Environment	3: User behaviours
Improved cooking devices • Improved biomass stoves without flues • Improved stoves with flues attached **Alternative fuel-cooker combinations** • Briquettes and pellets • Charcoal • Kerosene • Ethanol • Liquefied petroleum gas • Biogas, Producer gas • Solar cookers (thermal) • Other low smoke fuels • Electricity **Reduced need for the fire** • Insulated fireless cooker (haybox) • Efficient housing design and construction • Solar water heating	**Improved ventilation** • Hoods, fireplaces, chimneys, built into the structure of the house • Windows, ventilation holes, e.g., in roof, which may have cowls to assist extraction **Kitchen design and placement of the stove** • Kitchen separate from house reduces exposure of family (less so for cook) • Stove at waist height to reduce direct exposure of cook leaning over fire	**Reduced exposure through operation of source** • Fuel drying • Use of pot lids to conserve heat • Good maintenance of stoves and chimneys and other appliances **Reductions by avoiding smoke** • Keeping children away from smoke, e.g., in another room (if available and safe to do so)

Source: Modified from Ballard-Tremeer and Mathee[70].

[70] Ballard-Tremeer G. and Mathee A., 'Review of interventions to reduce the exposure of women and young children to household air pollution in developing countries.' *Background paper for USAID/WHO*

All of the methods listed will provide some degree of smoke alleviation. People will be more likely to adopt if they are given options as it is their lifestyle which needs to change. In a study in Kenya, a stepwise approach enabled people to start making changes whilst the knowledge on the dangers of smoke were new. They might start with low-cost options, enabling them to save money through reducing fuel use, and with the aspiration to easier and more effective measures at a later date (Bates, 2007).

2.4. What impacts do interventions have on exposure to household household air pollution?

2.4.1. Evidence from Africa

There are a few development programmes within Africa that have carried out an evaluation of the impact of their intervention on household air pollution within households. Table 2.3 outlines some of those programmes and the impact recorded on household air pollution.

Table 2.3: The impact of household energy interventions on household air pollution in Africa

Name of organisation	Country	Intervention name/ description	Kitchen particles PM2.5[71]		Kitchen CO		Personal exposure (CO or PM)	
			% Reduction	Residual level	% Reduction	Residual level	% Reduction	Residual level
Enterprise Works / VITA	Ghana	Gyapa Wood Burning Rocket Stove	52%	320µg/m^3	40%	8.5µg/m^3		
UGASTOVE	Uganda	Rocket Stove	49%	1175µg/m^3	54%	15.7ppm		
Practical Action Kenya (Phase 1)	Kenya, (range offered; little difference between costly and low-cost options) Data shows mean reductions.	Fireless cookers – basket & built in type Upesi stoves Rocket stoves Solar cookers Smoke hoods and eaves spaces LPG sets	Wet Season 50% Dry season 38%	Wet season 300ug/m^3 Dry season 290ug/m^3	Wet season 41% Dry season 39%	Wet season 3.8ppm Dry season 3.7ppm	Wet season 52% Dry season 54%	Wet season 2.1ppm Dry season 1.6ppm

International Consultation on Household Energy, Household air pollution and Health, Washington, DC, 4-6 May 2000.

[71] If more than one monitoring post intervention- final one reported here

Practical Action Kenya (Phase 2)	Kenya,	As above			72%	2.52ppm		
Project Gaia[72]	Kebribeyah Camp, Ethiopia	CleanCook Ethanol stove	94%	130µg/m^3	79%	14.6ppm		
Project Gaia	Bonga Camp, Ethiopia,	CleanCook Ethanol stove	84%	150µg/m^3	75%	5.6ppm		
Project Gaia	Addis Ababa, Ethiopia,	CleanCook Ethanol stove	64%	220µg/m^3	76%	5.9ppm		

Note: For $PM_{2.5}$ the WHO 24-hr mean interim air quality guideline is 75µg/m^3

In East Africa, low-cost Upesi-type stoves without flues, burning either wood or residues, can reduce kitchen pollution by up to **50%** by improving combustion. And focusing the heat on the pot. Charcoal emits considerably less PM (tiny particles), and stoves such as the Kenyan Ceramic Jiko (KCJ) yield particulate levels in the region of **10%** of those from open wood fires. Newer flue-less wood stoves with improved combustion such as the *Rocket* stove are being introduced and evaluated in a number of African countries;

- Work developing hoods with flues for highly polluted Kenyan Maasai homes reported reductions in 24-hour mean $PM_{3.5}$ of 75% from more than 4300 µg/m^3 to about 1000 µg/m^3 [73].
- Households may opt for combinations of changes: in West Kenya, hood and flues used with ceramic stoves (for better combustion and less time spent by the stove), hay boxes (insulated chambers which slow-cook hot food without fuel) and improved ventilation reduced kitchen levels of CO (used as a proxy for PM) by around **70%**.

Some studies, where personal exposure was measured, have found that personal exposure reduces proportionately less than area pollution;

- In the Kenyan Maasai study, a **75%** reduction in 24-hour mean kitchen $PM_{3.5}$ and CO was associated with a **35%** reduction in women's mean 24-hour CO exposure.

Similar proportionate reductions were found for women and children using wood stoves in Guatemala.

[72] O'Brien, C. UNHCR *Kebrebeyah Camp Report, Project Gaia Research Studies*, October 2005

[73] Practical Action, Reducing household air pollution in rural households in Kenya: working with communities to find solutions The ITDG Smoke and Health project, 1998-2001 http://practicalaction.org/docs/advocacy/smoke-project-report-kenya.pdf

2.4.2. Impacts of improved stoves: Evidence from rest of the world

Improved stoves with flues have been promoted extensively in several Asian countries, although many were found to be in poor condition after a few years. Some studies from India have shown variable and sometimes modest or minimal reductions in pollution.

Similar experiences with flued stoves have been reported from Latin America.

- *Plancha* stoves in Guatemala (made of cement blocks, with a metal plate and flue) can reduce PM by **60%** to **70%**, and by as much as **90%** when well-maintained

  Typical 24-hour PM levels with open fires of **1000–2000 μg/m^3** have been reported to have been reduced to **300–500 μg/m^3** and, in some cases, to less than **100 μg/m^3**.

- A Mexican intervention study assessing the *Patsari* flued stove in Michoacán state found a **74%** reduction in median 48-hr kitchen concentrations of $PM_{2.5}$ and **77%** reduction in CO[74].

Personal exposure has been found to reduce proportionately less than area pollution.

- A study of personal particulate exposure in Guatemalan children <15 months reported mean 10- to 12-hour $PM_{2.5}$ levels of 279 μg/m^3 for open fires and 170 μg/m^3 for *plancha* stoves, a **40%** difference.
- However in Mexico a study of the impact of the Patsari stove showed a proportionate reduction in personal CO (**78%**) to kitchen levels (**77%**) but not in personal exposure to median 24-hr PM2.5 (**35%**) compared to median 48-hr kitchen concentrations of $PM_{2.5}$ (**74%**) (Cynthia AA et al 2008).

Table 2.4 shows some examples of the impacts of stoves on HAP and personal exposure throughout the world.

[74] Cynthia AA, Edwards RD, Johnson M, Zuk M, Rojas L, Jiménez RD, Riojas-Rodriguez H, Masera O. Reduction in personal exposures to particulate matter and carbon monoxide as a result of the installation of a Patsari improved cook stove in Michoacan Mexico. Indoor Air. 2008 Apr;18(2):93-105.

Table 2.4: Examples of the impact of household energy interventions on household air pollution across the world.								
Name of organisation	Country	Intervention name/ description	Kitchen particles PM2.5[75]		Kitchen CO		Personal exposure (CO or PM)	
			% Reduction	Residual level	% Reduction	Residual level	% Reduction	Residual level
South East Asian Region								
ARTI[76]	Maharashtra India	Laxmi chimney stove with a grate.	45% p=<0.06	**48-hr average** 0.99 mg/m³ SD 1.23	45% p=<0.008	**48-hr average** 8.37 ppm SD 10.22		
		Bhagyalaxmi chimneyless stove with a grate	49% p=<0.079	**48-hr average** 0.48 mg/m³ SD 0.55	38% p=<0.024	**48-hr average** 6.91 ppm SD 7.02		
Development Alternatives[77]	Bundelkhand Region, India	Sukhad: two pot mud stove with chimney	44% p=<0.01	**48-hr average** 0.36 mg/m³ SD 0.47	69% p= <0.001	**48-hr average** 2.68 ppm SD 2.8		
ENPHO-APEC/ESAP	3 districts Dolakha: Central high Dang: Western Ilam: Eastern Nepal	Mud/ brick National ICS program	66% p= <0.001	**24- hr average** 0.73 mg/m³ SD 0.65	62% p= <0.001	**24- hr average** 8.4 ppm SD 7.25		
Region of the Americas								
RESPIRE study	San Marcos Guatemala	Plancha chimney stove			90% 95% CI	**48-hr average**	**Mother** 61%	**Mother** 2.2ppm

[76] Dutta,K, Shields, K N, Edwards, R. Smith, K R, 'Impact of improved biomass cookstoves on indoor air quality near Pune, India' *Energy for Sustainable Development • Volume XI No. 2 • June 2007*

[77] Chengappa, C., Rufus Edwards, R., Bajpaic, R., . Shields, K. N., Smith, K. R., 'Impact of improved cookstoves on indoor air quality in the Bundelkhand region in India' *Energy for Sustainable Development* Volume 11, Issue 2, June 2007

					(92-87)	1.1 ppm SD 1.4	95% CI (65-57) **Child** 52% 95% CI (56-47)	SD 2.6 **Child** 1.5ppm SD 1.9
CRECER study	San Marcos Guatemala	Plancha chimney stove	62%	**48-hr average** 0.34 mg/m^3 SD 0.49	66%	**48-hr average** 2.50 mg/m^3 SD 4.41	**Mother** 35% **Child** 22%	**Mother** 1.35 mg/m^3 SD 1.45 **Child** 0.73 mg/m^3 SD 0.58
GIRA	Michoacán Mexico	Chimney wood stove 'Patsari'	67% p=<0.001	**48-hr average** 0.34 mg/m^3 SD 0.27	66% p=<0.001	**48-hr average** 3.02 ppm SD 2.66		
Winrock/ Eco Centro/ USAID	District of Inkawasi Peru	Inkawasina 'Rocket' Stove	70%	**24-hr average of PM_4** 201 ug/m3 SD 189	71%	**8-hr mean max value** 23ppm SD 16		

However, comparing the impacts of different household energy interventions should be done with caution. The same stove could perform very differently at different times, locations and with different users. Changes in HAP and personal exposure measurements are influenced by many variable factors such as how long the stove was installed before monitoring, the availability of appropriate fuel, stove maintenance and user support and the need for space heating.

The method of measuring the change in HAP can also affect the results. Percentage reduction is dependent on the baseline level, and this can vary significantly even from household to household. This means that even with the same stove you get quite different estimates of performance when employing this frequently used measure.

2.4.3. Impact of cleaner fuels: Evidence from Africa

South Africa is one of the few countries with large biomass and coal-using populations that has invested in rural electrification sufficiently to support cooking. A study comparing non-electrified and electrified villages in the North West province found 3.6 years after grid connection, that 44% of electrified homes had never used an electric cooker[78]. Only 27% of electrified homes cooked primarily with electricity, the remainder using a mix of electricity, kerosene, and solid fuels. Despite mixed fuel use, households cooking with electricity had significantly lower 24-hour mean respirable PM and CO levels, and significantly lower mean 24-hour CO exposure for children <18 months.

Ethanol, Kerosene and LPG can deliver energy with much lower pollution levels, although for practical and cost reasons, households may not fully substitute for solid fuel. For example, Project Gaia showed substantial reductions in refugee camp situations but the reduction was less dramatic in an urban setting where there were more cooking fuel choices available and where fuel had to be purchased (see Table 2.3).

2.4.4. Evidence from the rest of the world

A study in rural Guatemala comparing LPG with open fires and *plancha* chimney stoves found that *LPG-using households typically also used an open fire for space heating and cooking with large pots*. Consequently, the *plancha* homes had the lowest pollution. Other studies from India have shown that kerosene and LPG users had much lower kitchen pollution, reflecting different cooking and space heating requirements;

- In rural Tamil Nadu, 2-hour (meal time) kitchen PM_{resp} levels of **76 µg/m^3** (kerosene) and **101 µg/m^3** (LPG) contrasted with **1500 to 2000 µg/m^3** for wood and animal dung.
- Personal (cook) 24-hour exposure to respirable PM was **132 µg/m^3** with kerosene and **1300 to 1500 µg/m^3** for wood and dung.

[78] H. Rollin, A. Mathee, N. G. Bruce, J. Levin and Y. E. R. von Schirnding. 2004. Comparison of Indoor Air Quality in Electrified and Un-Electrified Dwellings in Rural South African Villages Indoor Air 14: 3 208 – 16).

2.4.5. What reductions in household air pollution are required to make a health impact?

It is proving very difficult to achieve the WHO air quality guidelines (annual average of 20µg/m^3 for PM_{10}) in most developing country homes, and will remain so for some time for the following reasons;

- It is not currently possible to obtain very low emissions with low-cost solid fuel stoves.
- The International Energy Agency (IEA) estimates that the absolute number of people depending on solid biomass fuels will increase to 2.6 billion people by 2030.
- There are contributions to personal exposure from the outdoor environment which include vented household solid fuel emissions.

2.4.6. Health benefits obtained from a partial reduction in household air pollution

Will a 50% reduction in 24hr kitchen PM_{10} from 500µg/m^3 to 250µg/m^3 have an impact on the health of the household? Studies from Kenya and Guatemala have provided information to help answer this question for child pneumonia. The conclusion is that technologies currently available (such as woodstoves and smoke hoods) in developing countries deliver a useful reduction in childhood pneumonia, even though post-intervention pollutant concentrations still exceed WHO guidelines.

2.4.7. The relationship between alleviating exposure to household air pollution and health

There are very few intervention-based studies of impact on the most important health outcomes (child pneumonia, COPD and lung cancer).

The only completed randomised controlled trial involved a total of 514 homes in rural Guatemala. Each home was randomised to receive either an improved *plancha* chimney stove or continued to cook on an open fire.

Child exposure was assessed using CO, previously shown to be an adequate proxy for PM in this setting. Preliminary results show that the *plancha* reduced kitchen pollution by around **90%** and child CO exposure by around **50%**.

ALRI incidence among children <18 months was determined through a combination of weekly home visits by fieldworkers and physician examination. The *planchas* resulted in a modest reduction in pneumonia incidence (whether assessed by fieldworker or physician) of around **10-20%,** with larger reductions for more severe cases of around **30%**. Exposure-response analysis showed that halving exposure (**50%** reduction) reduced physician-diagnosed cases by **25%** and severe cases by **33%**.

For chronic obstructive pulmonary disease (COPD), adult pneumonia and lung cancer, three cohort studies have reported the impact on these outcomes following introduction of improved stoves as part of the Chinese National Improved Stove Programme. For lung cancer, the adjusted hazard ratio[79] for men using improved coal stoves compared with traditional open coal fires was **0.59** (95% CI: 0.49 to 0.71), and **0.54** (0.44 to 0.65) for women[80] .

- For COPD, in a similar type of study, use of improved stoves was associated with hazard ratios of **0.58** (95% CI 0.49 to 0.70) in men and **0.75** (0.62 to 0.92) in women[81] .The reduction in risk became unequivocal about 10 years after stove improvement.
- The most recent retrospective cohort study showed that 'stove improvement' was associated with a **50%** reduction in adult pneumonia[82] .
- For headache and eye irritation the randomised trial in Guatemala found **52.8%** of intervention women reported improvement in health, compared to **23.8%** of control women ($p < 0.001$). Among 84 intervention women who reported reduced kitchen smoke as an important change, 88% linked this to improvement in their own health, particularly for non-respiratory symptoms such as eye discomfort and headache[83] . There was also a large and statistically significant reduction in frequency and strength of headaches after the introduction of smoke-alleviating interventions in Kenya during the Practical Action Smoke Health and Household Energy project (Bates, 2007).

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[79] In this case hazard ratios give an estimate of the relative 'event' rates in the two study groups taking into account the time to event (age). A hazard ratio of one =no difference between the two groups. A hazard ratio greater than one = the event is happening faster for the 'treatment' group than for the 'control' group. A hazard ratio less than one indicates that the event of interest is happening slower for the treatment group than for the control group.

[80] Lan Q, Chapman RS, Schreinemachers DM, Tian L, He X. Household stove improvement and risk of lung cancer in Xuanwei, China. J Natl Cancer Inst. 2002 Jun 5;94(11):826-35

[81] Chapman RS, He X, Blair AE, Lan Q. Improvement in household stoves and risk of chronic obstructive pulmonary disease in Xuanwei, China: retrospective cohort study. BMJ. 2005 Nov 5;331(7524):1050. Epub 2005 Oct 18.

[82] Shen M, Chapman RS, Vermeulen R, Tian L, Zheng T, Chen BE, Engels EA, He X, Blair A, Lan Q. Coal use, stove improvement, and adult pneumonia mortality in Xuanwei, China: a retrospective cohort study. Environ Hlth Persp. 2009 Feb;117(2):261-6. Epub 2008 Sep 19.

[83] Díaz E, Bruce N, Pope D, Díaz A, Smith KR, Smith-Sivertsen T. Self-rated health among Mayan women participating in a randomised intervention trial reducing household air pollution in Guatemala. BMC Int Health Hum Rights. 2008 Jun 5;8:7.

2.5. Summary of health benefits of household energy interventions

Because only a very few studies have been done looking directly at the health impacts of various energy interventions, it is necessary to compare the various interventions in terms of their capacity to reduce smoke, but this makes a serious assumption that people will have enough money to purchase them, and having purchased them, will use them.

Switching from wood, dung or charcoal to more efficient modern fuels, such as kerosene, LPG, biogas and ethanol, brings about the largest reductions in household air pollution. In many poor rural communities access to these alternatives is limited and biomass remains the most practical fuel. Biomass improved stoves that are adequately designed, installed and maintained can reduce household air pollution considerably. Stove location, housing construction and better ventilation are partial remedies. Changing behaviours can contribute; drying wood improves combustion and lowers emissions, using pot lids cuts cooking time, and exposure of young children can be reduced by keeping them away from polluted kitchens (if this is safe).

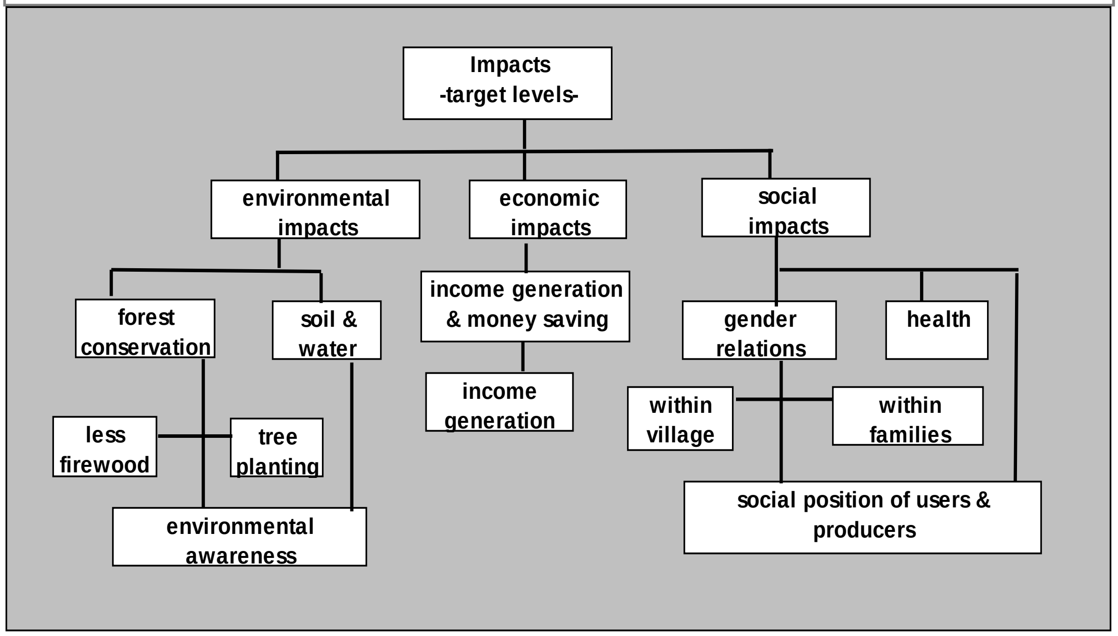
2.6. Non-health impacts of exposure to household air pollution

The inter-related complex impacts of household energy involve not only 'disease' and other health related issues, but also issues related to personal injury, time and income generation, gender empowerment, education and the environment.

2.6.1. Socio-economic factors

The German international NGO, GTZ, has created a table (Table 2.4) highlighting the expected impacts of improved household energy provision. This highlights impacts that should be expected of any stoves programme.

Figure 2.2: Which impacts are achieved through energy-saving stoves?



It is unlikely that health alone will convince people that the use of clean technologies is an important part of their well-being. A GTZ study in Zimbabwe noted; 'Respondents indicated that health related benefits have largely been brought to the fore by scientists and other outside experts but they currently do not constitute locally-recognized incentives that influence decision-making' (University of Zimbabwe).

Examining the issues that are important *to the cook* is vital, as she is the person who will choose either to use the stove, or to revert to her previous cooking methods. The very best technology, if it is not acceptable to the cook, has an efficiency of 0%. There are countless examples of good technologies lying unused as they do not fulfil the needs of those using them. Those living in poverty do not have the luxury of adopting goods or services which do not address their needs. From this it follows that a key factor in sustainability is to get this fundamental requirement correct if a technology is to success.

Over a five year study, Practical Action identified many of the important issues around adoption of household air pollution alleviation technologies. The key factors, other than health issues, that emerged through interview with the cooks during the study comprise;

- time saved
- money saved
- smoke reduced
- kitchen / home / pots & utensils / clothes / stove are cleaner.

A study in India indicated very similar findings for key benefits; fuel savings, time savings, less smoke produced, longer product life (Anderson 2007).

In a paper on the role of gender in household energy and household air pollution, the authors describe how women in Cambodia select stoves based on; less heat while cooking, fuel and time saving, better combustion and attractive[84] .

Time saving as a major factor is observed in several studies around household infrastructure. An economic analysis of water and sanitation interventions indicates that time saved is again the most important benefit (Hutton, 2004).

Time is identified as a key factor in a study in Bangladesh; 'However, there are many other reasons for improving the poor's access to clean household energy such as addressing deforestation and air pollution, saving people money, labour and time-saving, and making people's use of energy safer and more convenient'[85] .

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[84] San You and Sulpya, K. M., Gender's role in household energy and household air pollution in Cambodia http://www.sea-uema.ait.ac.th/formal/SNP/Gender6/MrSanyou.pdf [accessed May 2010]

[85]Rouse, J. 'Household air pollution: Issues for Bangladesh' *Renewable Energy Policy Project paper*, 2006

Box 2.1 Improving quality of life

Quality of life benefits emerging from the Practical Action study in Kenya showed that where the technology was chosen by the women, and therefore used all or most of the time, women found that they had:

- An improved sense of well-being
- Less smoke, so easier to work
- Opportunities to do other things
- Improved status
- Better family life / relationships
- They were happy to welcome visitors
- They could produce timely meals

The Practical Action study identified quality of life factors (Box 2.1) from three very disparate communities; a peri-urban community in Kenya, a displaced community in Sudan, and a community living at high altitude in Nepal, requiring space heating as well as energy for cooking. These 'soft' benefits should be used for promotion as they are less likely to be measured, but appeal to the target 'customers'.

Stoves must provide the product attributes required by the cook if they are to benefit her life. Consequently, if one is to promote their use, these technologies must address the factors which matter to the cook and her family.

2.6.2. Sustainability issues for the cook

In this section, the problems associated with sustainability are considered from the perspective of the cook.

2.6.2.1. Initial cost of stove

The upfront cost of the stove is often mentioned as the main reason why people do not buy stoves. In many countries of Africa, women do not have access to as much money as men, and although they are responsible for the cooking, they may not have money to buy stoves.

Revolving finance or ***soft loans*** can be useful in overcoming this barrier. However, many households are reluctant to take on financial commitments, particularly if their income is seasonal (such as crop growing or processing) and the type of loan does not have the flexibility to put off payments during lean periods. It is useful to involve both husband and wife in this decision, as the husband may be in charge of the finance, and if loans are taken up by the wife without his knowledge, and she is unable to cover the payments, this can lead to domestic disputes. This situation was reported during the Practical Action study in Sudan (Bates, 2007).

Carbon finance is a new and powerful way in which the cost of stoves can be subsidised completely or partially, provided that the right technology is used, and there is a competent organisation to set up and manage the monitoring required to access the funds. Key to the success of this form of finance is the stove itself. Not only does it have to be technically sound, but people have to be found to be using them for a very substantial part of their cooking needs. This goes back to the need to provide a stove which is not only acceptable, but *desirable*, to the cook. If carbon finance is part of the funding of a stove programme, *one cannot claim the funds* if the independent audit required by carbon finance companies show that the stoves have not been used and that they are therefore not preventing greenhouse gas emissions.

2.6.2.2. The cost of fuel

Fuel substitution among those on low incomes is most likely to work where there are shortages. Where people can gather fuel 'for free', they are unlikely to opt for a fuel that costs them money. This has already been demonstrated in Madagascar by the Andrew Lees Trust [personal correspondence][86].

Those for whom subsistence is the norm rarely have choices on how they spend their money, or on how to save for goods at a later date. They will buy whatever is most essential for them at any one time as soon as they have money. Fuel is often bought on a daily basis, even when it is more expensive bought this way than in bulk. Bottled gas is problematic for this reason, unless savings groups accompany an intervention to install gas stoves. Ethanol can be an ideal substitute for other fuels, such as charcoal or purchased wood, insofar as it can be sold in daily amounts. However, for daily purchase to be successful, the fuel has to be as easily accessible as for traditional fuel purchases (eg local markets, street sellers etc.).

2.6.2.3. The cost of time

Where households collect fuel, the time spent varies considerably but is not infrequently (on average) one to two hours per day, and can be considerably more as fuel resources become scarce and fuel-gatherers have to travel further. This takes the person away from other activities that potentially could include income generation. Inefficient stove combustion and design may result in more time spent cooking and cleaning off soot from pots, clothing, and the house itself.

In many societies, children (particularly girls) will not attend school as they need to collect fuel and assist in cooking and cleaning. This has a long-term detrimental effect on their education.

The reasons why women will opt for cleaner technologies will be governed by time and access to employment. As described earlier, time is often quoted as one of the

[86] www.andrewleestrust.org.uk

key impacts reported by women when they install a new technology. What seems less common is for the time saved collecting fuel, cooking, cleaning pots etc. to be consciously translated into money-earning potential.

Many women earn their income through home industries that use the stove, including street foods, soap manufacture etc. Providing clean and affordable stoves can assist them in increasing their income.

In the Practical Action study, several women in Kenya reported spending more time on household chores, farming, small enterprise, and on resting and leisure and their children. However, of the 131 respondents, only 12 identified 'time savings used for enterprise' as a cost benefit, whereas 80 respondents highlighted reduced fuel costs. This despite 67 saying they had 'a lot more time' and the remainder saying they had 'a bit more time' and the vast majority saying they felt either a lot better off, or better off.

In Kassala, Sudan, where women only work if they really have to, spending more time at work was only mentioned by one woman in around 87 households. For the remainder it was time spent on household tasks, visiting friends, with children, and making coffee.

Thus, in some societies, the immediate cost of the stove can be translated into the increased income that can be generated, and the cost of the stove can be offset by additional earnings. In other communities, this is less meaningful in the short-term, although it seems likely that if improved energy provision was widespread, more of those living in poverty would be able to use their time earning income.

2.6.2.4. Societal pressures

In many societies, women seldom have a voice when it comes to household energy provision. Decisions on the use of forest products are usually made by men. Thus even where trees are grown, all may be sold for timber for building or carpentry. Household woodfuel is 'women's business' and is therefore not part of their concerns.

Box 2.2: Alternative household energy approaches based on the status of women (Cecelski – 2005)

Level of commercialisation of fuel	Labour input into the subsistence economy by women	
	Low	High
Low	Integrate household energy and indoor air pollution components into sectoral programmes targeting women's development (e.g., Ethiopia – GTZ)	Provide information and technical assistance in stoves construction and kitchen design (e.g. Kenya-ITDG)
High	Household energy and indoor air pollution programmes include components to improve women's status/quality of life (employment, education . . . e.g. Nepal REDP, Kenya-Mandaleo, Mali)	Provide access to affordable improved fuels and stoves (Thailand, China)

Box 2.2[87] iillustrates that one relevant measure of gender equality may be the value of women's labour to the household, and that identifying the value of her labour could be the key to predicting the type of household energy intervention that will be successful in a given area. If this is true, then the successful introduction of ethanol to Madagascar may depend on the status of the target group. Efforts will be needed to promote the fuel, particularly where women's labour is not highly valued, and where time saving for the woman is not valued in terms of increased quality of life.

Whether or not a woman will adopt cleaner technologies will depend very much on her status within that society and on government action to ensure that the importance of her labour is valued. Case studies in the next chapter examine successful supply-side initiatives.

[87] Cecelski, E. 2005. Is gender a key variable in household energy and indoor air intervention? Boiling Point, 50:17–18.

3. Approaches to scaling up and sustainability

This chapter is based on a set of case studies of real organisations and reflects good practice demonstrated by high levels of demand, expanding businesses and good entrepreneurial practice.

Note: Although both Practical Action and Project Gaia are part of the research team compiling this report; every effort has been made to be objective in these case studies

3.1. Case study 1: Practical Action

This case study looks at issues around scaling up and commercialisation, with project finances targeted at awareness raising, infrastructural support and very small seed funding (~US$ 5000 per country) for revolving finance rather than on subsidising stoves.

Key findings in Kenya:

Revolving finance with a network of women's groups can be **successful but slow**. The project would benefit from **some ongoing support beyond project end**. LPG is the fuel of choice despite only being used some of time. Levels of repayment high, so money is in bank, but there is a lack of skills in managing funds by those now running the network. Low cost interventions proved as successful in reducing pollutant levels, but they are less convenient.

Key findings in Sudan*:*

LPG is the 'desirable' fuel in Sudan but with little history of savings, it is **difficult for women to repay the cost of the stove and save for the bottle**. Many hundreds of stoves sold and adoption is growing, through women's groups supported with skills by Practical Action. Most issues now resolved. Gas distributor providing more local access and supporting finance packages for gas bottle sales – **profits are in the sale of gas**, not in the initial bottle sale.

Key findings in Nepal*:*

Smoke hoods work excellently at both cooking and space heating. Small subsidy needed – continues to be available through local government. Ownership of revolving finance has led to near 100% repayment. Activities now all locally driven, **support coming from local government development offices**, whilst National Household air pollution and Health (set up by the project) keeps HAP issue prominent nationally.

Practical Action has worked for around 15 years in alleviating household air pollution. A recent project identified sustainable and effective kitchen smoke alleviation for very low-income communities. Working with one or two communities in three countries – Kenya, Sudan, and Nepal – to determine what methods they would adopt to alleviate smoke, the project adopted a 'technology neutral' approach, to find ways to achieve the demands of the households and make substantial HAP reductions. Ending in May 2007, the findings have been updated for this study by discussion with each country manager.

The most critical factor identified for sustainability throughout this case was the transfer of ownership of the problem of smoke alleviation from the project itself to the community, and the creation of a framework that continues to allow people to access the interventions they desire. Revolving finance systems were created to overcome the barrier of up-front costs. Smoke interventions were designed that reduced fuel costs; repayments could be set against savings, time savings could be monetised by additional employment or growing food.

Kenya dance / drama group demonstrating chronic chest pain caused by household air pollution

3.1.1. Kenya

Households adopting very low-cost interventions, such as fireless cookers (insulated boxes), and cooking outdoors, reduced their levels of emissions by almost as much as those purchasing the more costly technologies – an indicator that awareness-raising with small changes can help people reduce the pollutant levels in their homes.

Time-savings, convenience and modernity priorities most favoured bottled gas (LPG), but it was not used all the time, and polluting fuels were often used to slow-cook main meals. Fireless cookers linked to LPG were popular to reduce fuel costs.

The team set up a network KHAPNET (Kisumu Household air pollution Network). Members were trained during the project so that the activities could be handed over by the end of the intervention study. They also developed theatre and drama groups thereby raising awareness, and raising the status of the community members.

CURRENT STATUS KENYA – post project (April 2010)

Since the project ended, Kisumu has undergone periods of serious civil unrest. Some groups stopped functioning without project support, while some businesses are thriving. An example of the latter is sales of fireless cookers where the entrepreneur sells through schools, supports many organisations with training on their manufacture, and this year sold over 500 fireless cookers.

Upesi stoves being manufactured

Another has opened her own bank account to manage LPG gas refills, while another group has made their gas bottle collection point a sales outlet for biomass stove purchase. They trained a community installer to create eaves spaces in homes when installing stoves.

Five members of KHAPNET are active in stoves installation with eaves spaces, making links with different community organisations. They have installed around 600 stoves, 350 fireless cookers and 36 LPG sets. They continue to supply filling services for the LPG stoves.

An Upesi partnership project, run by Practical Action, adopted eaves spaces when it installed over 4000 stoves.

The organisation SWAP, funded by WHO, invited the team to train over twenty vendors to install stoves with eaves spaces. They are doing pre- and post-intervention monitoring of particulates, with very positive findings (not yet available).

A KHAPNET member has taken up stoves cladding, giving up her small vegetable business and focusing on it.

The main smoke hood manufacturer during the project has been involved in training artisans on the production and installation of smoke hoods, and there have been enquiries about them from different parts of Kenya and from Uganda.

These case studies were reported by Hellen Owala, of Practical Action, in Kisumu, in response to the request for updated information. She notes that the construction manuals published during household energy projects are knowledge products which encourage sustainability. On kiln construction: 'when a need arose that I needed to do it, I followed the manual step by step and got it right'.

Case study 1: Nyadiga Women's group

Nyadiga Women's Group nearly collapsed, and the kiln for firing the stove fell into disrepair. The former secretary of the group started her own production of *upesi* stoves. With two other employees, they made and sold several hundreds of Kenya Ceramic Jikos and some Upesi stoves, using their own moulds, but firing the stoves in the open. With some encouragement from one of the former smoke project's field staff, they purchased all the materials for a new kiln. Workshop space and moulds to make the upesi stoves, as well as training, were facilitated through local private donation to the group. The group sell stoves and saves and donates some of the income to support the orphans of HIV/AIDS. A small Energy Shop is currently being set up at the market centre close to this group to sell the stoves commercially. This whole initiative is being led and driven locally within Kisumu.

Case study 2: Technology transfer

As women move to a different part of the country, they bring skills with them. One woman, trained in the early smoke project, moved to Migori (a small town towards the Kenya Tanzania border) where she formed and trained a group called the Upesi Women's group in cladding and selling *upesi* stoves. The lady gets her stoves from the Wise Women producer group in Kisii.

3.1.2. Nepal

Taking records of payments at revolving fund meeting

The smoke hood designed in collaboration with the community removed over 85% of the CO and included several desirable attributes– including a hinged front flap to allow easy access for distilling alcohol, and conveniently sited bars within the hood for smoking meat. A sense of ownership of the revolving seed capital led to high repayment levels of revolving finance; it was no longer ‘NGO money’ and therefore had to be repaid. Levels of repayment in the early stages rose to over 95% in all groups.

Some subsidy was needed, for which engaging local government and other NGOs was found to be vital. Because of the cost of making the stoves, and providing a small profit for the manufacturers, the community have paid more for the smoke hoods than they had indicated in the original marketing survey, and no subsidy at all would have led to complete failure of the initiative, rather than the 500 hoods installed so far in the 3-4 years since the start of dissemination. By engaging local government, the project has worked to get longer-term subsidies for smoke hoods. Lower-cost hoods and less transport costs in the lower regions are already designed and planned. These are unlikely to need subsidy, but the design is inappropriate for high cold regions such as that of the original project location.

CURRENT STATUS NEPAL: post project (April 2010)

Although this project officially ended in 2007, some small Trusts wish to continue to support the communities with the modest sums of money which provide seed funding for revolving finance to be available over a larger geographic area, train new entrepreneurs, and provide awareness-raising within new communities. There is virtually 100% repayment on the revolving finance, as it is run by local community members, supported by local government, and is based on trust between neighbours and friends.

Local hood manufacturer now employs others to make hoods

Five out of the ten trained manufacturers are still active today. One of them has helped to provide training in two nearby districts for smoke hoods manufacturing and installation. Twenty four local artisans are now actively involved in smokehoods manufacturing and installation works.

The total cost of a smokehood is around Rs.5,400 US$73). Families can take a loan from a revolving fund and pay back the cost over two years, in monthly instalments. In total, 785 smokehoods have been installed (which includes improvements to traditional stoves) since project end. Between October 2009 and March 2010, 387 hoods were installed.

In 2009, the SGP/GEF UNDP financed the National Household air pollution and Health network (a network set up by the project) to scale-up activities in a new area in Rasuwa (project district). The project received a PCIA award to scale up in two new districts. The local District Development Committee has recognised indoor smoke alleviation as a priority and instigated a programme.

Two Village Development Committees have allocated money for poor households to install biogas. All revolving funds are still active and mobilise their funds for income generating activities, and repair and maintenance of the installed hoods, supported by the District Household air pollution Alleviation Fund.

Since the end of the project, over 4,000 households (including an additional 900 in the last six months) have been educated about household air pollution and safer alternatives through ongoing awareness campaigns – funded by Trusts since the project end.

Nepalese radio stations have featured a series of programmes in local languages, dedicated to the issue of indoor smoke pollution and a video documentary has been made and screened for various high hill communities. Additionally, home to home visits were carried out with a newly designed awareness booklet, to create awareness on the negative health impacts of indoor smoke.

Scaling up and Sustainability Conclusions

This approach has been shown to be sustainable in the high hills of Nepal. Through involving the local authorities in the activities from the start, installations are ongoing, and the geographic scope is increasing. In lowland areas, a similar approach to revolving finance can be used for less expensive intervention options that would be appropriate where space heating is not needed. Raising the profile nationally through a smoke forum has kept the issue on the national agenda. Creating ownership of the funds locally means that the money must be used *within that district* and this in turn means that some flexibility should be built into the system as smoke hoods will not always be required. By requiring interest on loans for other purposes, whilst providing finance at no interest for smoke hoods, has retained the prime purpose for this money. Skills are locally available when needed to repair or move the smoke hoods.

3.1.3. Sudan

Sudan produced mixed findings during the project, with revolving finance leading to nearly 1500 households with LPG stoves, and an ongoing buoyant demand for finance to buy LPG appliances at the project close. Usually, LPG is slightly cheaper than charcoal, and promoted by government. Women aspire to use LPG and like using it.

Women Development Organisations

Over several years, Practical Action has promoted Women Development Organisations (WDAs), to empower displaced women through engaging in productive activities. These WDAs were chosen to run the business-side of the scaling up, including microfinance. This allowed a rapid response during the early part of the project, but also caused problems due to lack of experience in dealing with the high demand.

However at project end, a peace treaty enabled many households to return home leading to a glut of charcoal, reducing prices below that of LPG. Many households reverted back to charcoal.

The mindset required for 'saving' for a new bottle was identified as a big hurdle. Suppliers needed convincing that a successful market for LPG sales could be maintained among low income households.

Support to the smoke activities was continued through the Women's Development Associations supported by Practical Action Sudan.

Coffee-making at Wau Nur displaced persons camp

CURRENT STATUS SUDAN – post project (April 2010)

Stoves being delivered to WDA Kassala headquarters for distribution

Demand for LPG sets using revolving finance remains high, and a loan is available for gas stoves, ovens, cookers, and gas. There is a large increase in demand for LPG in the local market. A gas shop established during the project continues to sell gas appliances (ovens, stoves, etc.), and this business is active.

The WDNA network that has grown out of the WDAs is now managing the work, using the system developed by the project. They have a good reputation in many villages and neighbourhoods in Kassala state. Two new gas businesses have been started, managed by WDNA staff. The ACORD organisation has launched a new project modelled on the project.

The gas supply company now recognises that company profit is in the fuel, not the sale of the gas bottle. Recognising the size of the market from low-income households, it has established a system for LPG marketing that allows local people to have LPG bottles on loan, paying back in affordable instalments. A small workshop makes gas appliances, co-ordinating the marketing with the WDNA central office.

As a direct result of this project, a further project, operating in El Fashir town, North Darfur, supports a conflict-damaged community of nearly 200,000 residents by providing LPG stoves to replace traditional three-stone fires, through carbon financing. Carbon Clear Limited has worked with Practical Action, to enable poor households to afford the upfront cost of LPG sets. The programme is administered by local women's legalised & registered groups - the project is carried out by the community for the community. Over 2,416 stoves have been disseminated, with positive results. Greenhouse gas emissions have been reduced, and reduced household air pollution is improving health and quality of life. It is contributing to environmental conservation by saving woodfuel and to reducing the vulnerability that women face while collecting fuel wood outside of town[88] .

Scaling up and Sustainability Conclusions

Ongoing support has seen this project develop into a sustainable operation over the last six years. The price of fuel, and its local availability, was seen to be critical in this study. People will use what is cheapest and most convenient. Charcoal, for the short period of time around the end of the study, was both cheaper and could be bought 'just down the road' every day. This study has shown that it is vital that **fuel is competitively priced and easily accessed.** It demonstrates that a successful approach, particularly where coupled with carbon finance, can create strong demand and support many hundreds of households.

[88] http://www.hedon.info/UsingCarbonFinanceToIntroduceLPGStovesIntoSudan?bl=y

3.2. Case study 2: EnterpriseWorks/Vita – Ghana

This case study looks at a highly successful ongoing international NGO which funds strengthening of local organisations. Funding is used to support training, promotion, management skills, whilst the businesses make sufficient profit for the day-to-day running of the factory. The NGO keeps a very low profile resulting in the brand name and brand image being that of a commercial stove, rather than an NGO activity. At the same time, skills and businesses within the country are strengthened.

The organisation

EnterpriseWorks/VITA (EWV) is an international not-for-profit organisation working to combat poverty through sustainable, enterprise-oriented economic development programmes. EWV has worked with local businesses and organisations for more than 40 years in 100 countries.


Selling Gyapa stoves

Status 2009

In 2008-09, by supporting profit-making enterprises to create employment and increase productivity and profits, EWV helped close to 2.3 million people generate more than $112 million in income, improving life quality, health care, education and nutrition.

CURRENT STATUS - April 2010

In 2009–2010 EnterpriseWorks sold, on average, 7,500 stoves per month in two geographic areas - Greater Accra and Kumasi. They are planning an expansion to take place in August 2010 which should boost sales to 10,000 per month and then around 12,000 per month by the end of 2010.

Stove manufacture

In Ghana, EWV has spearheaded the manufacture of the Gyapa stove in five urban centres, comprising 5 ceramicists, 111 stove manufacturers and 329 retailers. Most entrepreneurs have their own businesses, and are paid by the central stove factories on a piecework basis. A few stovemakers are employed by the main factory on a piecework basis. Most businesses are independent 1-3 person operations; although some of the manufacturers of the metal components employ up to 20 staff.

Box 3.1: Success factors for Gyapa stove

- Conduct substantial market research to find out what people want. Unless the product is right it will not sell, however well promoted.
- People will not buy unless the technology is at the right price, and unless the fuel is affordable.
- Be aware that opportunity cost is more important if people can find employment as 'time is money' for them.
- Promote where it will work. If biomass is abundant, stoves to save it will not be of interest, particularly if they are less easy to use than a three-stone fire
- Find a local brand name that *means something* and is catchy to the target consumer base
- Mentor the business. A quality safe product will sell itself by word of mouth.
- Initiate lots of brand promotion – use an advertising agency; it is their expertise
- Use the right production method for the product – some may be locally made, some may need a purpose-built factory. Work out what is most cost-effective for the given technology

The stove is manufactured in various sizes; a medium model retails at around $6.5US - a readily affordable price in Ghana, and pays for itself in terms of savings in around six weeks. All but one of the stoves burns charcoal. Although there is a woodfuel model available, it has not proved as popular, as most of those using wood only incur a time cost in gathering it, and as wood is still abundant, the time saving is insufficient to make the stove popular.

The businesses are self-supporting, and donor funding to EWV enables the organisation to provide important services which might well be outside the budget of individual entrepreneurs; sourcing raw materials for bulk purchase, mentoring in business skills and manufacture, promotion, and quality control.

In the early days, EWV supported massive promotion, particularly radio broadcasts and branding, so that the Gyapa stove is now a well-recognised brand. Some promotional work is still done, demand is high, the market is growing, and two new centres in different parts of Ghana have been set up over the last year.

The original Gyapa stove has led to spin-offs – including the Coalpot, made by one of the distributers forming a new company - Toyola – this will be discussed in the case study on E+Co and the role of available finance.

Role of private sector

The reasons for the success of the Gyapa stove are based on strong, well-defined good commercial practices shown in Box 1. The role of the private sector is clear, as the whole initiative is based on an affordable product being made available on the commercial market. EnterpriseWorks describes itself as a 'stove promoter' – assiduously avoiding calling itself an NGO, which could create a dependency culture, damaging the commercial operators. Its role is to facilitate good practice and provide an environment conducive to success for the entrepreneur.

Role of public sector

The government is not involved in any way with the running of the activities, but is supportive of the work. It plays a strong and useful role in promoting clean energy, providing financial support for social marketing and promotion through health centres, schools etc. It is useful for the long-term success of stove dissemination for the government to be seen to be supportive of these activities.

Scaling up and Sustainability Conclusions

The Gyapa stove provides an excellent model, developing management skills through external finance, whilst supporting the local entrepreneurial skills. There is competition (see Case study 3 below), but despite this, the high level of marketing and promotion in the early days has provided a strong brand image, and the geographic scope of the initiative is increasing.

3.3. Case study 3: Toyola and E +Co

This study examines the role of a non-profit investment company in facilitating rapid growth of a small company to develop a innovative product – selling stoves using mobile shops to enable them to be distributed at village level. To protect its investment, E&Co has developed a carbon financing mechanism, and also provides management and marketing support.

Toyola Energy Limited (TEL) was started by two artisans who were originally trained by EnterpriseWorks in Ghana to manufacture Gyapa stoves. Although they had the technical know-how to create high quality efficient stoves, they lacked the financing and formal business skills required to create a profitable business.

E & Co is a non-profit company that invests in small and medium enterprises in the developing world. In 2006, it invested in TEL with the goal of significant scale up and structuring a carbon finance project. TEL uses the name Toyola Coalpot to reflect some small design changes and to differentiate its product from others in the market.

As with all its enterprises, E + Co couples its investments with business development support. The loans are offered to enterprises that would otherwise require very high interest rates through local bank loans.

The plan includes a strategy to take the stoves to the people – a mobile stove delivery system. To assist with the implementation of the business, E+Co has invested US$70,000 for the purchase of a truck and supplies.

There has been a second and third loan, and although the repayment has not been realised yet, the business has grown from 1000 stoves per annum 2006 to 30,000 per annum over the last year. The business has become successful through;

- investment
- quality salesmanship
- added value with distribution and sales
- end user financing
- Toyola works with entrepreneurs on a commission basis.

Carbon Finance

The stove is believed to last for 2 to 4 years, so to maintain a conservative approach, carbon offset calculations are preliminarily adjusted on a 20% pa loss, with write-off after three years. Future aging tests reveal the actual useful life of the product, and future offset calculations are adjusted accordingly. Carbon offsets will, in the future, allow the loan to be repaid.

UPDATE April 2010

E+Co, with Toyola, is about 1 month away from selling the first tranche of offsets after three years of the initiative. As a result, the local company and end users have not benefited financially from carbon revenues directly. In the meantime, E+Co have continued to extend credit to the company, collateralised against future carbon revenues, allowing them to continue to grow. In 2009 Toyola sold about 55,000 stoves. Another carbon finance/stove project in the same market has reduced prices, leading to a price reduction for the stove despite not having the carbon revenues to fill the gap. Thus, end users have seen lower prices even though carbon revenues have not yet arrived. E+Co expect prices to drop further as both their finance company and the competing carbon finance project become more mature.

As of **February 2011**, the first tranche of credits have been sold, and a second tranche is currently being audited.

Scaling up and Sustainability Conclusions

By using carbon finance coupled with an up-front loan, Toyola (with E+Co) has implemented an innovative business model that includes delivering stoves to rural areas, giving stoves on credit to local market vendors who earn a commission from selling the product, and training artisans to bring the manufacturing process in-house.

3.4. Case study 4: Project Gaia and Gaia Association

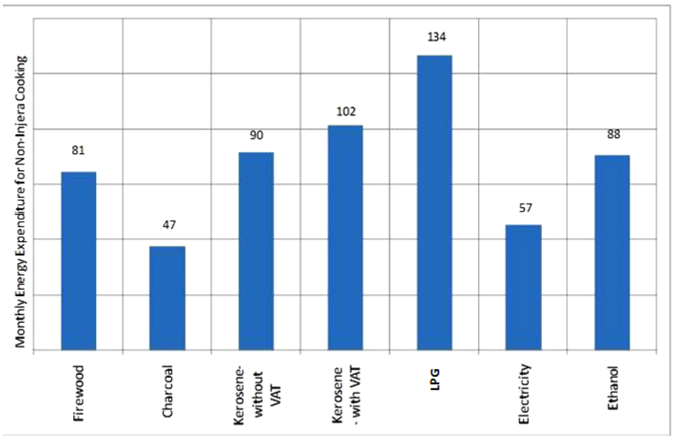
This study examines the potential for ethanol to be a major player in alleviating smoke and gaseous emissions through a well-designed, locally-manufactured stove in a region where fuel is also available locally. Key to its further dissemination will be the active involvement of the government in facilitating the sale of sufficient ethanol for household use as well as to the transport sector. This could include selling the fuel at the same price for transport and household use, removing or reducing taxes, easing import duties, etc. Currently stoves are not being sold commercially but are being funded through the UNHCR for displaced communities. Access to ethanol for stoves was interrupted in May of 2009 but is expected to resume within six to eight months (January 2011) when a second state-owned distillery is completed.

Project Gaia, an NGO based in the United States, is part of a global initiative for the development of clean-cooking fuels. It seeks to establish and promote the use of alcohol fuels for household energy for all who have limited access to clean energy, including disadvantaged and marginalised people who suffer the added burden of being energy poor.

Cooking using a CC stove

Project Gaia oversees the Project Gaia Research Initiative, which currently has programs in Brazil, Ethiopia, and Nigeria. To date, around 6000 stoves have been distributed in Ethiopia.

The Ethiopian organisation, Gaia Association, has a mission to improve household indoor air by introducing smokeless, odourless and safe alcohol-fuelled stoves to Ethiopia, thus benefiting women through reduced dependency of fuelwood, charcoal and kerosene and improving women and children's health. The stove is called the CleanCook (CC) stove,



and has been shown in independent testing by Aprovecho[89] to be clean, safe and efficient.

In Ethiopia, the household sector accounts for around 91% of all energy consumed, and 84% of this is in rural areas. Cooking and baking are the most energy intensive end uses, each requiring about 2.6 GJ/household-year.

More than 75% of households in urban areas have a monthly income of less than ETB 500 (US$ 46) and on average they spend around 6% of their income on household energy. This figure rises to 10% for all households, rural and urban. Households in the lowest segment spend around 16% percent of their income on energy.

The most widely used fuel for cooking in Addis Ababa is kerosene (42%), which until recently was subsidised but which is now market based, followed by fuelwood (29%). Electricity, LPG, charcoal and residues are used by a much smaller section of city households. Electricity is subsidised but it remains expensive to cook with. There are frequent service interruptions. The primary cooking stove used in Addis Ababa is the single burner kerosene wick stove, but as the price of kerosene increases, there is an erosion of use to wood and charcoal.

CURRENT STATUS - April 2010

Commercialisation Plans

Produced locally, the major cost of production of the stove is the cost of dies and stove materials (steel sheet). The material cost per stove produced will remain more or less constant until a sufficient manufacturing quantity is reached. The unit cost associated with the cost of dies is a function of the quantity of stoves produced within the total lifetime of the dies employed. With a higher production volume, the steel will be imported, most likely from India. However, with small quantities, the steel would be sourced in the Mercato (Addis market); adequate numbers of stoves must be produced to justify importing the steel. The potential manufacturer has been in negotiations with Indian suppliers for both for the steel and the machinery, and also to attract investment. Finchaa Sugar Factory is producing ethanol at present with an annual output of eight million litres. During 2004-2006, Project Gaia was supplied by Finchaa with approximately 200,000 litres of ethanol at 1.65 ETB per litre ($0.19 US) for its pilot studies in Addis Ababa and UNHCR refugee camps spread widely in Ethiopia. Between 2006 and 2009, Gaia and UNHCR purchased over 1.5 million litres of ethanol from Finchaa to run stove scale-up projects in three refugee camps, Kebribeyah, Awbarre and Sheder, located in the Somali Regional State. The

[89] Orbrink, T. Results of Standard 5 Liter Water Boiling Test Conducted at Aprovecho stove-testing lab http://www.google.co.uk/search?hl=en&q=Aprovecho+CleanCook&btnG=Google+Search&meta=&aq=f&oq=

purchase price for this ethanol ranged from $0.35 to $0.65 per litre. Since May of 2009 the Ethiopian Government has interrupted the supply of fuel to the stoves and allocated this ethanol to a gasoline fuel-blending pilot project being conducted by Nile Petroleum under government auspices, leaving the stove project temporarily without ethanol.

The Government (Ministry of Mines and Energy) has developed a policy that prioritises both fuel blending and stove fuel ahead of export for the ethanol produced by the state-owned sugar factories and it says that it intends to resupply the stove project when more ethanol is available. Prime Minister Meles has confirmed this in a statement to Milkyas Debebe of the Gaia Association. The Government plans to expand ethanol production to reach 130 million litres by 2012 through new factories, and a new plant at Metahara Sugar Factory is currently being commissioned, with an initial capacity of 16 million litres per annum. This capacity should become available by January of 2011. Project Gaia is negotiating for a supply of 4 million litres of this ethanol.

Project Gaia in Ethiopia has had to compete for ethanol with fuel blending. Sugar factory and Ethiopian government officials travelled to Brazil in 2007 to see the progress with fuel blending there. Although Ethiopia's gasoline-powered automobiles are older and have not been equipped to handle gasoline-ethanol blends, the government desired to test fuel blending as a use for its ethanol. Gasoline blending has two primary attractions for policy makers. It is a large use of ethanol. Eventually approximately 30% to 40% of Ethiopia's 120 million litres of ethanol could be absorbed into a fuel blending market. Secondly, the use of ethanol in a 5 or 10% blend would reduce the amount of gasoline to be imported and would thus reduce the trade deficit, which is substantially affected by the cost of importing petroleum fuels.

Project Gaia's response to the Ethiopian Government has been that ethanol stove fuel will displace kerosene imports and that from a cost, technology and infrastructure standpoint it is easier and cheaper to burn ethanol in stoves than to blend it with gasoline. Hydrous ethanol is sufficient for stove fuel while anhydrous ethanol is required for fuel blending. Project Gaia also argues that the benefit of using ethanol as a clean cooking fuel outweighs the benefit derived from fuel blending, and that the beneficiaries would be largely women and children, making the stove fuel use is more responsive to Ethiopia's Millennium Development Goals.

Since Project Gaia's strategy has been to develop Ethiopian SME capacity to produce stoves and distribute fuel, there may be a concern on the part of the government that the Project Gaia effort does not have the capacity or finance behind it (e.g. a large domestic company or a large foreign investor) to succeed or to succeed on a scale and with the rapidity that may be desired. This is a concern that the Project Gaia team is currently evaluating as they meet and negotiate with the government for an ethanol supply agreement. Project Gaia believes it can succeed with an SME strategy provided that the government agrees to (1) a guaranteed supply agreement, (2) a sensible pricing policy for the ethanol (possibly including suspension of or holiday from VAT and/or other market distorting taxes), and (3) a reasonable take-down schedule that allows the private sector SME to limit its fuel storage capacity to about 25% of projected annual fuel sales volume.

Project Gaia is about to embark on a World Bank BEIA-funded project to examine the potential of micro-distilleries to provide locally-sourced ethanol for stove fuel and small-scale power generation. Project Gaia may acquire and build its own micro-distillery to provide sufficient ethanol for an on-going stove demonstration in Addis Ababa (1000 operating stoves in a geographically centered community), in order to keep the ethanol stove in public view and as a functioning alternative to fuel blending or other uses for the government's ethanol. It is hoped that if the micro-distillery can be built and operated cheaply enough, using an efficient boiler and distillation/rectification unit, it could serve as a replicable project for cooking fuel production on a distributed basis at community scale.

3.5. Case study 5: Millennium Gelfuel Initiative

> Gelfuel is ethanol to which a thickening agent has been added to make it easier to store and distribute than liquid ethanol. Although studies have shown very positive user findings, due to the low-cost stove and ease of use, within the development context the price of the fuel is not competitive, and the basic stove does not give heat output flexibility. Currently, it is finding a role as a niche product, being sold as a second stove for cooking during power outages etc.

Gelfuel is based on ethanol produced through the fermentation and distillation of sugars (derived from molasses, sugar cane, sweet sorghum, etc.) or starch crops (cassava, maize, etc.). Ethanol is mixed with a thickening agent (cellulose) and water through a simple technical process, resulting in a combustible gel. The gelfuel is thus renewable and can be locally produced in most countries in Africa.

Between 2000 and 2003 the Millennium Gelfuel Initiative (MGI) was set up; a public-private partnership aimed at adapting and disseminating an existing ethanol-based cooking fuel 'gelfuel' for the African household sector.

The then Regional Program for the Traditional Energy Sector (RPTES) of the Africa Region Energy Unit (AFTEG) of the World Bank teamed up with a Zimbabwean company, Millennium Gelfuel Company (MGC) to undertake a research and development initiative to re-engineer MGC's existing "Greenheat Gelfuel" into a renewable, low-cost, safe and clean household cooking fuel. The project was financed through a $130,000 Development Marketplace award, with MGC supplying an additional $100,000 and RPTES contributing $50,000.

The aims of the project included;

- Reduction in the production, packaging and marketing costs of Gelfuel.

- Designing appropriate stoves for it.
- Assessing commercial viability.
- Identifying potential follow-up investment projects.

'Greengel' gelfuel stove

Other tangible benefits aimed for included generating large economic growth opportunities in rural areas, creating rural employment, enabling rehabilitation of the ecosystem over large tracks of land and reducing oil import expenditures.

By 2004, the Millennium Gelfuel Initiative had achieved and/or completed;

- Reduction in gelfuel costs >50 % of the original cost.
- Development and marketing of five low-cost/high-efficiency efficiency gelfuel stove models and a gelfuel burner to be retrofitted into a wide range of existing African wood and charcoal cooking stoves.
- Studies the competitiveness and comparative environmental advantages of gelfuel and ethanol compared to other household fuels and in several countries in Africa.
- Market surveys conducted in Ethiopia, Madagascar, Malawi, Mali, Senegal, Mozambique, Senegal, South Africa and Zimbabwe.
- Private-sector gelfuel plants established and operational in South Africa, Malawi and Zimbabwe.
- Private-sector gelfuel or ethanol projects in preparation in Benin, Ethiopia, Madagascar, Malawi, Mozambique, Senegal and South Africa.
- Development and marketing of a low-cost high-efficiency, non-spill, direct ethanol stove (based on the adaptation of the standardized gelfuel burner).

CURRENT STATUS: April 2010

Gelfuel is an expensive option compared to most other household fuels. In Malawi, in 2004, gelfuel could only marginally compete with LPG, whilst ethanol itself was the cheapest option. At the same time, producer performance tests and consumer feedback indicated that the cost of cooking with a direct ethanol stove was 50% lower than with the gelfuel option, as the effect of the better stove efficiency gets further compounded by the lower cost of the direct ethanol (approximately 70% of the cost of gelfuel). Under this scenario, direct ethanol cooking is competitive even with fuelwood and charcoal in all countries studied whilst gelfuel is not.

In South Africa, gelfuel is becoming popular, but mainly as a secondary fuel used during the frequent power outages for those using electricity. The Alleviation of Poverty through the Provision of Local Energy Services (APPLES) project was implemented in South Africa and ran from for three years up to August 2008. This EU CO-OPENER project is implemented by ECN in the Netherlands, University of Oxford, UK, Risoe National Laboratory, Denmark, Parallax South Africa and the Energy Research Centre of the University of Cape Town. The main objective of APPLES was to understand the energy needs and energy priorities within the target communities, to determine and demonstrate the best practices for energy service provision to meet the needs of these communities, and to strengthen the embryonic networks of existing energy centres in South Africa (APPLES). From the data below, it can be seen that ethanol gel is an expensive option in urban South Africa, even compared to (subsidised) electricity.

Table 3.2: Comparative cooking costs for various fuels in urban South Africa

Fuel type	**Total cooking time (est.)**	**Energy consumed cooking meal**		**Typical costs of the food ingredients**		**Cooking energy costs as a % of food costs**	
	(minutes)	kWh used	Rands	Main ingredient	All ingredients	% of main ingredients	% of all ingredients
Electricity	41	0.45	0.27	3	5	9	5
Paraffin	44	0.84	0.93	3	5	31	19
LPGas	34	0.79	1.26	3	5	42	25
Ethanol gel	44	0.57	1.44	3	5	48	29

Source: Imizamo Yethu / S.Africa, 2008 circumstances & prices. Energy estimates are approximate, to within about ± 15%.

These estimates indicate the importance of providing cost-effective cooking energy options for lower-income urban households. Using electricity, the energy cost of cooking this staple meal is only about 5% of the cost of the food ingredients, at current prices. Using paraffin, this percentage rises to about 20%; using LPGas 25%; and using ethanol gelfuel nearly 30% of the food costs.

CURRENT STATUS: April 2010

The Millennium Gelfuel Initiative raised awareness among governments and biofuel producers of the potential of ethanol and ethanol gel as viable household fuels. The last publication from the 'APPLES initiative in January 2009, indicated that in mid-2008, it was cheaper to use an electric stove, where possible, rather than ethanol gelfuel, which cost around 30% of the food cost[90] .

The report stated that the main reason was that the energy-content of ethanol gelfuels (as tested in local laboratories) was very low in relation to their selling price. An obvious parallel can be drawn with the price of ethanol fuels, which would have to reflect the percentage of water in the mix, particularly if sold directly from artisanal sources.

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[90] http://www.applesonline.info/fileadmin/applesonline/user/docs/Deliverable17.pdf

Thus, current trends suggest that ethanol *gelfuel* is likely to remain a niche product. It is becoming popular in industrialised countries as a 'clean' fire, used more to give the appearance of a fire than for its heat output where chimneys and emissions are banned.

3.6. Case study 6: GTZ biomass stove programme in Uganda

GTZ has worked for many years in Sub-Saharan Africa – mainly on reducing the amount of fuel used in stoves. 'Rocket' stoves comply with a number of principles that allow the stove to save fuel and reduce emissions. This case study examines the 'training the trainers' approach to mass dissemination.

In Uganda, the forests are contracting by two per cent every year. People have to walk miles for a couple of branches. Seven out of ten women do without a hot meal once a week for lack of fuelwood for cooking.

Since 1999, GTZ has worked with the Ministry of Energy and Mineral Development to support Energy Department through the Energy Advisory Project (which is now the Promotion of Renewable Energy and Energy Efficiency Programme), to develop and implement successful energy policies and strategies. One of the components of this project is the promotion of improved stoves.

The 'Rocket Lorena' is the name given to an energy-efficient stove made of earth with grass and water, or with bricks. The programme, financed by the Federal Ministry for Economic Cooperation and Development and the Dutch government, has provided training for well over 3,000 stove artisans, called 'village professors'. The stove costs about three to five dollars, depending on region, size and negotiation ability. It uses 60% less wood than traditional three stone fires, and emits minimal smoke.

Besides the Rocket Lorena the projects also supports the dissemination of single-pot portable rocket stoves made of mud. By June 2009, over 500,000 household stoves were in use; each stove saves 1 tonne of fuelwood a year.

The last project phase (05/2005 - 06/2009) aimed to provide close to half a million people with a woodstove that was promoted as modern and efficient. As a result of the project, by June 2009, around 2.5 million people could access clean household energy.

UPDATE – April 2010

The current project phase (July 2009 to May 2011) aims at providing another 1,100,000 people with modern household cooking energy. A further 32,000 people will have access to food cooked on modern institutional stoves. Awareness campaigns, training of the stove artisans and quality management form part of a 'snowball' effect to increase skills and adoption. Along with training and construction, awareness messages about efficient cooking practices are disseminated so that the technology is adopted together with the techniques.

The project does not give direct subsidies on the stoves but supports producers with training, marketing activities and awareness raising (indirect subsidies).

In urban and semi-urban regions, GTZ supports commercial private companies to produce portable household (metal rocket and charcoal) and institutional (rocket type) stoves. One example of a business that has developed out of this work (but is not included in the data for this case study), and is now independent of GTZ, is the Ugastove, described in the next case study.

Scaling up and Sustainability Conclusions

The rapid expansion of stoves was facilitated through artisanal production of stoves with GTZ taking a role in training NGOs to train producers. The work was greatly facilitated through the positive attitude of the National Ministry of Energy of Uganda which supported the work with awareness campaigns, and through dissemination through schools, health, and agricultural extension services.

Lessons learnt:

Based on experiences from the first district, hierarchic levels between various co-ordinators were reduced, and fewer persons were trained in stove construction in the subsequent districts;

- The pyramid approach leads very quickly to a high number of producers and high numbers of disseminated stoves but can be challenging in terms of stove quality. Thus monitoring of stove quality must be very rigid, and should not be done exclusively by the executing NGO.
- Stove users must be aware of the features of a good quality stove.

It is necessary to raise user awareness of the need for the stove to work well, so that they are properly maintained and replaced when necessary. Often there is a gap between the technical aspects of the stove, and how the cook wants to use it; many users do not recognise cracks or other changes in the stove as possible reasons for reduced efficiency. Awareness campaigns can tackle this point. Once users are aware of the need for good quality, they may refuse to pay for a stove which is not of good quality, and once they have bought a good stove, they will keep it well maintained.

Planning for post-project dissemination

A certain decline in stove production and coverage is a normal phenomenon after project interventions have stopped. The challenge is to limit the decline to such a level that stove coverage remains considerably higher than before the intervention. It can be important to plan, from the beginning, a second intervention after withdrawal of the project from the area. This can help to adjust unforeseen developments on the production or the users' side and to offer a supplementary support to both of them. In Uganda, post-dissemination activities have been carried out in the first project regions. The creation of "production centres" was supported in order to highlight the profit making aspect in stove production in contrast to the "community help" motivation many producers had previously. Thus, providing a post-dissemination intervention from the beginning coupled with a good monitoring system that informs realistically on developments on the ground can improve the chances for a sustainable result.

3.7. Case study 7: Ugastove (formerly UCODEA)

Ugastove is the first cook-stove project to be registered by the Gold Standard Foundation which indicates that it will not only burn fuel more efficiently thereby curtailing greenhouse gas emissions, it will also delivering significant social and health benefits through lower family expenditure, mitigation of deforestation, and reduce household air pollution.

Selling the Ugastove at market

Ugastove started as a community-based organisation UCODEA operating in Makindye Division, Kampala District of Uganda. Now a business, under the name Ugastove, it supplies efficient charcoal-burning stoves and woodstoves to families and institutions in Kampala, and subsequently throughout the country.

The business works through stove promotion, developing business capacity to manufacture and market the stoves, creating jobs in retail and after-sales service, and establishing quality assurance procedures which include careful monitoring of the usage and effectiveness of the new stoves.

The Ugastove is one of the first projects to benefit from the carbon market. In 2005 UCODEA sold approximately 3,000 stoves through the year. In 2006 plans were made to secure carbon finance with a view to a major expansion effort which would allow high-efficiency models to be sold at affordable prices, and increase sales.

Upfront carbon finance has allowed the organisation to spend money on training staff, marketing and sales and credit facilities and is expecting to generate over 20,000t of CO_2 offsets per year. Operational stove-years are an important concept, since GHG emission reductions are dependent not on the sale of an improved stove for use in a kitchen operating an inefficient stove, but rather they are dependent on the number of months or years the improved stove is in daily use.

In the course of 2006 and 2007 the technical designs of the stoves were improved to achieve high levels of efficiency (reduces CO by 54%; PM2.5by 49%; Fuel consumption by 38-58% compared to traditional stoves) with expert help from the Centre for Entrepreneurship in International Health and Development (CEIHD), based at the University of California-Berkeley in the USA, with financial support from the Partnership for Clean Indoor Air.

UPDATE – April 2010

The total emission reductions from the project are estimated to be on the average 85,615 tCO2e per year over the first 7-year crediting period. This is based on statistical data about the number of households in Uganda, the distribution of cooking fuels and the distribution of cooking technology. It reflects predicted sales of domestic charcoal stoves of 173,000 pieces (~29 %) in urban areas of Uganda and 18 % in Uganda in total. The predicted sales figure of 6,700 pieces of domestic rocket wood stoves (~ 3 %) in urban areas of Uganda and 0.2 % in Uganda in total. There can be observed a slightly declining trend in the use of charcoal in urban areas (from 96 % in 1999/2000 down to 89.4 % in 2005/2006), but otherwise more charcoal use is observed in rural areas (from 20 % in 1999/2000 up to 22.9 % in 2005/2006).

In its summary of January 2010, the Bureau Veritas Certification confirmed that the project is implemented as planned and described in the validated and registered project design documents. The monitoring system is in place and the project is ready to generate GHG emission reductions. The GHG emission reduction is calculated without material misstatements.

Scaling up and Sustainability Conclusions

This project has led the way in showing how reductions in greenhouse gases can be 'paid for' by carbon reductions, whilst ensuring that other socio-economic benefits are also addressed. Carbon finance is relatively new – and considerable input is needed to access it. By demonstrating that it can be achieved, this organisation is demonstrating its potential for other stove programmes.

3.8. Case study 8: Andrew Lees Trust (ALT)

A project in Madagascar has shown proven success in disseminating improved woodstove through training-of-trainers and promotion through radio broadcasts – a dissemination tool promoted by the Trust. The need to address the right target community is highlighted in this case study.

The Andrew Lees Trust was set up in 1995 to develop and implement social and environmental education projects in Madagascar which aim to empower local communities to improve their self sufficiency and reduce the effects of extreme poverty. Funding from the Community Fund UK (1999 – 2005) and Climate Care (2004 - 2006) enabled the Andrew Lees Trust to run approximately 700 training sessions for villagers, teaching them to build fuel efficient woodstoves themselves. Using data provided by the Andrew Lees Trust, a total of 36,000 woodstoves were counted as completed by villagers in 2006, at project end.

Training trainers to make the Toko Mitsitsy

Where women had to collect the fuel, they were much more interested in saving it than in those areas where men did most of the fuel gathering. Thus, their approach was to train users as trainers in Androy, Mahafaly and Vezo regions where women collect fuel.

Nearly all the trainers were women, primarily to demonstrate that women could easily construct the stoves. In some villages men were engaged (decided by the president of the village) but usually women were selected as employing male trainers can be problematic, particularly in the rural villages where husbands might not allow their wives to be trained by men.

The project produced visual training materials for its largely non-literate target groups, and a radio marketing campaign had a significant impact on mobilising Toko Mitsitsy construction and ongoing use of the stoves. Women who heard the radio campaign were much more likely to use the stoves.

The project worked mainly in the dry zone where women collect wood and have to walk up to a day to find ever diminishing supplies of forest resources and wood fuel.

The Andrew Lees Trust trained a number of partners and NGOs in other regions, including in the capital (Antananarivo), but was unable to report on their success. The project recognised that where women were collecting the fuel, they were much more interested in saving fuel, and therefore time, than in those regions where the men collected the fuel. They appeared to be less motivated than the women by the prospect of reduced fuel collection.

The Trust has evolved its work on energy needs in the south over the past ten years. Currently it is implementing a Drought Mitigation Programme which addresses ongoing food security issues and environmental challenges in the south (funding from Big Lottery Fund and EC). Alongside sorghum reintroduction, the Trust has developed a tree nursery and is distributing trees for local associations and families –

in particular to provide fruit and fuel at family level. It continues to train women to build stoves within some target communities, but currently on a much smaller scale.

UPDATE: May 2010-05-10

Surveys by the Malagasy NGO, ALT Madagascar, reflect that over 37,000 stoves were constructed, mainly between 2001 and 2006. If they are well-maintained, they will last around five years, but if they are not well-maintained, they last about two years. To improve their life, the Andrew Lees Trust has concentrated more recently on repair and maintenance. The WFP has approached the Andrew Lees Trust about further stove dissemination through stoves for schools in the Tshiombe region; this is in the discussion phase.

Scaling up and Sustainability Conclusions

This ongoing work shows that the policy of 'training the trainers' is an effective dissemination strategy. It has also highlighted the need to target the consumer carefully - disseminating stoves where the need has been clearly identified by the user. There is an interesting gender issue with the time men spend collecting fuel not appearing to influence the woman's choice of cooking technology. The differences in the life of the stove indicate that awareness-raising on the need to maintain the stove can have a major effect on the stove life.

3.9. Case study 9: Envirofit

Shell Foundation worked with a number of NGOs and has used much of the socio-cultural information from these studies to design a stove with an engineering team and a university in the US. This stove will be modified to suit local needs. It is currently working in South India. The effort to date has cost several tens of millions of dollars. There are plans to disseminate more widely in the coming year.

Shell Foundation is working with 'Envirofit', a commercial partner described as an ' entrepreneurial, commercially-driven, independent, non-profit organisation'. Envirofit works through businesses that are already established, supporting product development, sales and marketing and technology transfer.

Several tens of millions of dollars have been invested by Shell Foundation into this overall effort during the past five years as the potential market is huge, and the roll-out plan is global. With Envirofit dealing with the commercial side (as of November of 2007) Shell Foundation continues to pursue its key mandate – monitoring and evaluating successful approaches to alleviating household air pollution.

Current situation – March 2009

The Envirofit brand produces a range of stoves from a basic one pot, chimney-free model to one that has a short chimney and allows two pots to be used simultaneously, with similar fuel-saving capabilities. Both stoves produce marked reductions in household air pollution, thus achieving the aims of the Shell Foundation.

The stoves have been designed to include an attractive appearance, ease of use and extended durability. The centralised manufacturing approach employed by Envirofit ensures quality control and economies of scale, reducing overall costs to the greatest extent possible. Continued investment capital is required as this business gains in-country sustainability within three years, and overall sustainability within 5 years.

Sales and service

The project itself has set up no new businesses to introduce the stove. Instead, Envirofit has worked with well-established enterprises, using their distribution networks, and thus improving their business profitability. Local retailers, already in the business of selling stoves, have an additional product to add to their range of goods.

Where NGOs have acted as an outlet, they have instigated demonstrations and support to users as part of the introductory package. A useful lesson learned through this approach found that stove demonstrations made people aware of good stove us practices, leading to improved information and demonstrations being incorporated into the selling strategy. Demonstrations also heighten awareness of its positive attributes, provide a talking point for dissemination, and allow people to see the stove in action first hand.

Another important learning is that significant investment is required in advertising/ awareness raising to bring attention to Household air pollution (HAP). This should be considered an ongoing effort / investment, required through-out market entry, and is needed to help create customer pull. Any business being built around addressing HAP/HAP needs to have this ‘awareness’ investment in a campaign pointing to specific product solutions in order to be successful. During 2008,over 30,000 stoves were sold. Projections for 2009 suggest that around 200,000 stoves will be sold per annum.

UPDATE April 2010

Note: No further data has been received from Envirofit – the data below is from the Envirofit website.

Envirofit charcoal stove

Envirofit has introduced a new charcoal stove for Africe - the C-3300. The new charcoal stove is being piloted within households for durability, emissions, and engineering design. Initial results on emissions and fuel-use are reported as very good. The stove will be launched in Africa in the second quarter of 2010.

Envirofit woodstove

Sales of the Envirofit G-3300 woodstove continue to be strong in India and in pilot programs in Africa. Emissions of pollutants are around 80% reduction, with up to 60% savings in woodfuel, and cooking efficiency improved up to 40%.

Scaling up and Sustainability Conclusions

Envirofit works closely with partners and firms local to the area of introduction to understand the needs of the customer base. They follow up with post-sale surveys to ensure customer satisfaction, and identify areas for product development. Already on their third generation of stoves, these show significant improvement over previous models). These attributes will effectively make the stoves more desirable, affordable and thus more marketable.

Currently, the stove is available throughout Southern India, where similar cultural cooking practices can be accommodated by the same set of Envirofit stoves. There are three clear markets identified for the stove within the next two years;

- whole of India
- West Africa – then East Africa
- Latin America – starting with Brazil.

Finance

Within the last year (2008-09), two pilot studies using micro-finance have shown positive results, with good rates of repayment, and more are planned. These are needed by customers, to make the product more affordable, and by various actors in the supply chain to access working capital for goods and services.

The stove has considerable potential for support through carbon finance, and this could either reduce the cost of the stove to the producer, or, with support from the government, could allow provision for social programmes to deliver stoves at very low cost to those on the very lowest incomes.

3.10. StoveTec

This is a short case study describing the rapid growth of a type of stove based on the reputation of the team promoting it. The stoves are relatively new, but sales have grown very rapidly, reflecting the positive feedback from users, and the reputation of the suppliers. Stoves are dispatched in crates either as complete stoves or as liners which can be built into stoves at a later stage. The stove benefits from low production costs in China, and mass production.

StoveTec is a spin-off from the Aprovecho Research Center. Having tested hundreds of stoves, the Aprovecho team designed a model that had all the characteristics it had found to be successful. A factory was found in China that could produce such stoves at an affordable price. The result is a range of stoves and liners known as GreenFire stoves.

Because the organisation is well-known, and the team running it have considerable expertise in knowing what is needed to produce a clean-burning stove, very little was needed to promote these stoves. In the first year, over 36,000 have been sold, dispatched in crates all over the world.

UPDATE 2010

The StoveTec stove won the 2009 International Energy Champion Ashden award, and has sold over 70,000 stoves in the past year, with a production capacity of 500,000 stoves per year[91] . Stoves are purchased by the container load, ready for distribution. A study undertaken by Berkeley Air for the USAID initiative in Dadaab refugee camp Sudan, in February 2010, indicated that this stove (together with the Envirofit stove) would be the stove of choice for this situation[92] .

[91] http://www.stovetec.net/us/resources/ashden-award

[92] http://www.stovetec.net/us/images/stories/USAID_DadaabFinal.pdf

4. Lessons learnt in scaling up and sustainability

4.1. Framework for successful scaling up and sustainability

Any initiative to initiate and scale up clean household energy requires an infrastructure that can support both supply and demand. Quality products that fulfil the needs of the customer will lead to increased sales and a growing market. Poor products, safety issues, accidents, lack of access to fuel, or lack of back-up where products fail will lead to failure.

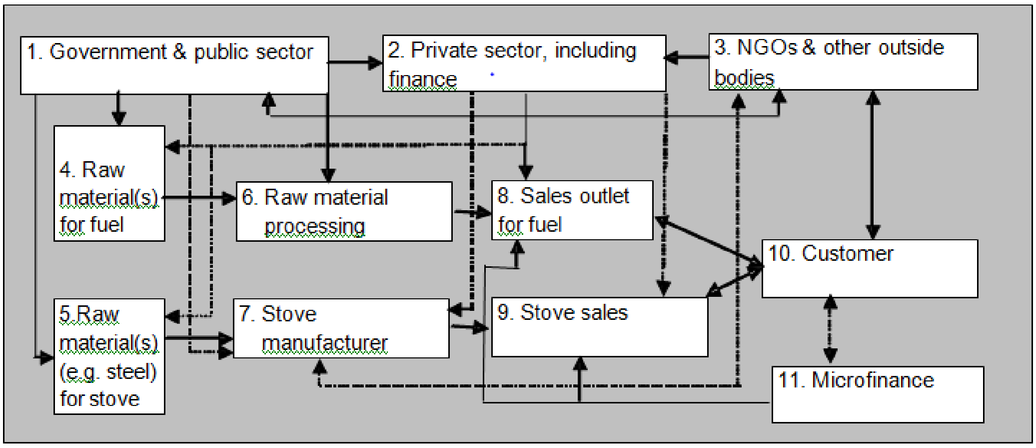
If the initiative is NGO-driven, a more commercial approach will need to be adopted. If profit-motive is the driver, the needs of those living in poverty must nevertheless be considered.

In every instance the needs and wishes of the customer must be addressed if a successful commercial operation is to be created.

4.1.1. Institutional arrangements

Table 4.1 outlines the institutional relationships and interactions between key actors that are needed to introduce a new fuel and technology successfully. This could be applied to ethanol, and also to, for example, LPG from oil products, or charcoal from renewably-sourced biomass.

Table 4.1: Institutional arrangements and relationships



The role of the key actors is discussed in Section 4.2.

4.1.2. Technical performance and acceptability

Getting the product right is paramount in the establishment of a new technology; unless the product is right for the customer, no amount of promotion will sell it. This requires ongoing development of technologies to improve their product attributes in response to customer feedback. Successful technologies will be copied, and although branding may help, improvements need to be ongoing where there is healthy competition in the marketplace.

Technologies should not only be promoted on the attribute which is important to the entity introducing it. Technologies need to be promoted according to the attributes the consumer feels is most important (cost, attractive design, speed of cooking) whilst retaining the efficacy of the product to alleviate a substantial proportion of the smoke. At the start-up of any business, very substantial promotion will be needed.

The technology must be safe, and must be used safely. This can be accomplished with cooking demonstrations, and ideally these should involve local government and other NGOs to change the culture where needed (eg mud-plastering inflammable wall materials, demonstrating safe handling of fuels). A serious accident could set back a programme for years as well as causing distress. Involvement of local government and local NGOs can help to make new technologies more sustainable between initial introduction and fully commercial involvement.

Investment in training in manufacture, marketing and sales to ensure quality products will improve product quality and availability. Product life is key if people are going to spend a substantial part of their savings. This is particularly true if carbon finance is being used and at start-up of a business. EnterpriseWorks (see Chapters 1 & 3) uses donor funding to support commercial businesses with business training and product development for their biomass stoves. This form of 'smart subsidy' is not evident to the consumer as all goods are sold on a commercial basis in terms of profit margin on manufacturing cost and overheads.

The most vulnerable time for any business is within the first two years, where up-front finance is needed for capital items, technology promotion, purchase of raw materials, components, sub-assemblies, premises, and transport. Money will also be invested in stock (work-in-progress), and required for loan repayment.

4.1.3. Promotional activities

Awareness-raising & behaviour change are key roles for NGOs, supported by local government and collaborating with other NGOs and private businesses. A very major roll-out of a technology over a large geographic area is expensive. The wood-fuelled Envirofit has received very substantial funding from the Shell Foundation, in order to launch a quality product over large areas of the globe. Customers now pay the full factory-gate price of the stove without subsidy, but promotion, and product development costs are still not covered.

Activies are useful in two scenarios – to engage local communities, and to influence policy-makers who may need convincing of the dangers of household air pollution. Each key group should be targeted; customers, local authorities, private enterprise (finance and entrepreneurs), other NGOs, health and education people etc. with messages tailored for each group.

4.1.3.1. Getting the message right

Messages must be locally appropriate. It does not matter whether it is to do with health or not, for example, promoting clean, modern kitchens. Reasons may include; better health, improved child health, time saving can be used for other things; fuel reduction, reduced smoke, improved family relations, cleaner possessions (clothes, pots & pans etc.) and food; greater hygiene (clean hair, face etc.), improved status and room temperature and more modern technology. Health messages, in particular, need to be accurate.

4.1.3.2. Community engagement

It is vital to engage people in making this life change, providing the information needed to understand and act upon the link between smoke and respiratory disease. Activities can be conducted directly through community groups, and indirectly by providing tools and information to health and education professionals, and to local NGOs, enabling them to continue sharing knowledge beyond project end. The type of media used will depend on what is best liked by the target audiences; radio, TV, large public meetings and rallies, dance and theatre, at schools and clinics.

Technologies, such as stoves, are often introduced by NGOs for a specific reason – for example, household air pollution. At this stage, the reason for the introduction belongs to the NGO, not to the consumer. For sustainability, it is necessary to create a sense of ownership of the problem in the consumer, so that they prioritise the issue and are themselves seeking ways in which this could be solved. Only when they recognise the whole range of benefits of cleaner fuels are they likely to adopt in large numbers.

It is the role of government to seek ways to improve the quality of life of the community. NGOs need to work with local government officials to encourage them to target health centres, schools, community centres etc. If health professionals are taught to link ALRI in infants with smoke in the same way as they associate diarrhoeal infections with poor water quality, they can share this knowledge with their patients. Awareness can lead to a greater prioritisation of the dangers of smoke, and can lead to increased sales. Schools are an important conduit as the students are the mothers and cooks of the future.

4.1.3.3. Engagement with policymakers

An ongoing forum for dialogue between community representatives, entrepreneurs and financiers with key policy-makers can be used to ensure that arguments for clean energy are kept high on the political agenda until a particular technology and fuel are well-established. Engaging key actors from the health, environment, energy, and industrial sectors in the process of introducing clean and efficient stoves and fuel will provide a solid basis for the future

4.1.3.4. Raising the profile of HAP internationally

Unless things happen at country and regional level, the numbers reached will be modest. Creating the infrastructure for policymakers and practitioners to discuss the real issues involved in smoke alleviation can lead to well-informed policies when major policy documents (such as PRSPs) are being revised. In Nepal, Practical Action (supported by Winrock) created an Household air pollution And Health Forum Nepal (http://practicalaction.org/nepal/region_nepal_HAP) to provide an interface for dialogue between policy makers and practitioners on alleviating kitchen smoke.

4.2. Roles of key actors

For the introduction of new fuels and technologies, governments and businesses need to work together to joint objectives. Indeed, it is not easy to present the roles of each separately, because they are reliant on one another.

Increases in fossil fuel prices in recent years have caused governments worldwide to invest in biofuels, sometimes resulting in them being accessible for household use.

In order to achieve viable production and a vibrant household energy market, key informants and literature generally indicated that the optimum combination of public and private-sector roles is as follows.

4.2.1. Role of government bodies

Government and the public sector have several important roles in establishing new initiatives for household energy, and for ensuring the ongoing success and consumer safety of growing markets.

4.2.1.1. Developing a biofuel strategy & policy

In developing a biofuel strategy and policy, clauses specific to ethanol and/or other new fuels (such as plant oil) need to be included, as new fuels together with new stoves have specific issues around them around the timing of the introduction.

The body responsible for developing the strategy should gather data which may be accessed by the private sector players, and also undertake a level of market assessment, for example differentiating between urban and rural communities[93] .

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[93] SEI, 2008. Market barriers to clean cooking fuels in sub-Saharan Africa: a review of literature. Working Paper, Stockholm Environment Institute, April 2008.

Case Study 4.1 - Developing a biofuels policy in Tanzania [94]

Tanzania has recently attracted considerable interest from the private sector for biofuels development; significant areas of the south have been given over to biofuel crops. The sector has suffered from a lack of regulation and control; the Tanzania Investment Centre, dealing with applications, had little insight, and uncontrolled, inappropriate land acquisition.

A specific biofuels policy will ensure that ongoing development in Tanzania will move forward and expand in a sustainable manner. It will clarify what can and cannot be used for biofuel development; ensure that water, land access and waste disposal issues are properly considered; that carbon sinks are not disturbed for biofuel plantations; and that user-issues, such as blending ratios, are regulated. There is also provision for the household energy market.

4.2.1.2. Setting safety and quality standards

Good stove and fuel quality for items being sold to the consumer can be achieved by setting quality standards, and by developing codes of best practice with industry to prevent poor copies being disseminated. The government needs to set quality standards, particularly for new fuels, including denaturing, storing, modes of transport. For stoves, the standards should include minimum product life and steel quality standards. Stringent safety standards are needed that reflect the very specific dangers related to fire within a household context. The high number of deaths from kerosene in South Africa is a reflection of the need for denaturing and adequate safety and storage facilities[95] .

For ethanol and other liquid fuels, particular attention should be paid to ensure that the fuel is neutralised (so does not rapidly corrode the stove), that it is denatured to prevent ingestion, and that it is of sufficient concentration to burn with a stable flame for the specific technology.

4.2.1.3. Creating a positive industrial environment

Creating an enabling environment for private sector investment through addressing major barriers that prevent an easy transition to new household fuels. Major barriers can include a lack of clarity of regulations and legislation, lack of security of investments, prohibitive cost of investments (including import duty on specialist technologies), lack of information, competition from subsidised alternative fuels, and difficulties in accessing carbon finance. Government can collaborate with banks and other financial institutions to establish financing for industry setup.

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[94] WWF, 2008 Exercise/situation analysis on the biofuel industry within and outside Tanzania. ESD, Tanzania.
[95] PASASA Paraffin safety Association of South Africa - http://www.pasasa.org/about-us/

Case Study 4.3: Creating an enabling environment for biofuel development in Kenya

The Energy Act 2006 in Kenya;

- Allows duty-free importation of energy hardware to promote widespread usage.
- Allows certain renewable energy systems to operate in any area of the country without a licence.
- Allows for the determination of energy prices by market mechanisms and regulates only where necessary.
- Empowers the Minister to promote development and use of renewable energy technologies such as biodiesel and bioethanol.[96]

Offering investors some level of protection against fluctuating fossil fuel prices into the future[97] and providing an environment conducive to donors and NGOs to support new initiatives. The case of EnterpriseWorks, in Chapter 3, is a good example of the collaboration between a supportive government, and an international NGO providing commercial know-how to new commercial businesses.

Removing barriers for the private sector to engage with carbon financing. If governments will support baseline data acquisition, this will reduce the set up/transaction costs of carbon projects, as currently these measures are made by each project, which is both expensive and difficult. This is particularly important for massive scale-ups using the clean development mechanism. This is described in more detail in Annex 1.

Government has a crucial role in regulating pricing, leaving as much as possible to market forces. This is particularly critical where a new household fuel is competing with subsidised household fuels (e.g. kerosene), and where it is competing with the motor fuel industry.

Investment in new technologies and fuels can be positively encouraged by setting low taxes or no taxes on new household fuels for a fixed number of years. This could support the creation of a positive policy environment for private sector and NGOs.

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[96] Adapted from PISCES Policy Brief number one. December 2008. Policies and regulations affecting biofuel development in Kenya.
[97] PISCES 2009. FAO - PISCES Case Studies: Small-Scale Bioenergy Initiatives. Final Report. http://www.pisces.or.ke/pubs/index.html [Date accessed: 6 Apr 09]

Case Study 4.2: Ethanol pricing for household use in Ethiopia

In Ethiopia, competition with the motor fuel market has been a challenge. Although the Finchaa sugar-cane factory distillery was mandated to provide 20% of ethanol produced to the household energy market, the price was set higher than the sale price to fuel blenders, and too high for the household energy open market. Fuel is not currently available to purchase, and ways to import fuel, despite the very stringent import regulations, are being investigated (April 2010). Micro-distilleries that make fuel locally in small quantities that are not attractive to the transport sector are being researched (April 2010).

4.2.1.4. Facilitating partnerships

The business of fuel production often involves a wide range of government bodies, including those relating to investment, the environment, forestry, energy and trade and industry (Stokes[98], Mfugale[99]). Partnerships involving information flow and financial flow from north to south, and between countries and organisations within the south, have been shown to be beneficial in some areas, for example within the Program for Basic energy and Conservation in Southern Africa[100] .

Providing 'champions': The commitment of influential individuals within key institutions (e.g. Minister of Energy) can have a profound impact on how fast and how far government support can go, in either supporting or hindering progress (Lambe[101] and Kees[102]).

4.2.1.5. Supporting the development of a reliable supply chain

By creating binding agreements with both agro-industries and refineries, governments can ensure a sufficient supply of raw materials for household fuel, and sufficient fuel output to cover the needs of the household energy sector. The failure to enact agreements to provide to the households sector in Ethiopia has set back the introduction of ethanol stoves.

4.2.1.6. Support to achieve socio-economic benefits

The government has an important role to play in education and raising public awareness. Social marketing and awareness-raising can help to create demand for household energy devices and fuels, particularly for unfamiliar clean fuels, and this can overcome a major barrier to private-sector involvement and to the success of NGO pilots.

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[98] Stokes, H. – personal correspondence
[99] Mfugale – personal correspondence
[100] ProBec, 2002 Economic Analysis of fuelwood saving technologies and systems in ProBec supported BEC demonstration projects, University of Zimbabwe.
[101] Lambe, F. Stockholm Environment Institute/ Project Gaia – personal correspondence
[102] Kees, M. GIZ – personal correspondence

The efforts of most domestic clean-energy programmes are focused in urban areas which enjoy a more accessible and wealthy market, leaving the 75% who lives in rural areas as-yet relatively unserved (SEI, 2008). Governments can assist all sectors by ensuring that people only pay for goods fit for purpose, as discussed in 'quality standards'. Increasing the life of the stove to five years or more, particularly if finance is being sought through the carbon market gold standard (see Annex 1), can make carbon finance very attractive, and make the stove more affordable.

4.2.2. Role of the private sector

The private sector is involved in all the commercial activities that surround the sustainable delivery of stoves through a reliable supply chain for either raw materials, such as steel, or the import of stoves ready for sale or assembly.

With purchased fuel, such as ethanol, consumers will revert to polluting fuels unless the fuel is locally available and affordable. For small operations, the fuel manufacturer may be the fuel seller – for example, a small distillery set within a farm complex. It is more likely that at least two private sector businesses will be involved – the fuel manufacturer and the fuel seller. In this case, the fuel seller will need to ensure a reliable fuel supply, including transport of fuel to the point of sale. Where a small distillery is only handling ethanol from one raw feedstock, the seasonality of the supply may be an issue. Where large industrial distilleries are supplying both the household and transport sectors, the support of the government may be needed in legislating for sufficient fuel to be made available for the household energy sector.

The initial cost of a stove may be the major constraint to people being able to afford to use clean fuel. Financial structures that enable households to pay off the cost of the stove over a fixed time period can resolve this constraint. If there is a monopoly on fuel, the price of the stove can be amortised through the price charged for the fuel. Other approaches are through micro-finance, soft loans, and revolving finance.

Bioethanol reduces greenhouse gases through cleaner burning and the reduction in deforestation. The private sector is well placed to develop the carbon potential of projects and leverage carbon finance, more particularly in collaboration with government through the CDM, or through the voluntary market (see Annex 1 and Case study Toyola – Chapter 3). Carbon finance companies could provide the key to large numbers of households being able to afford to cook using ethanol. However, to date, a methodology for ethanol fuel has not been approved – a major barrier to this form of financing.

The private sector may have more financial backing to provide choices of technology for households with different levels of income at affordable costs – making technology prices competitive in the market. Larger manufacturers may be in a position to develop technologies for easier production, improved supply chains and over a geographically wider market. Providing product information appropriate to the target population and warrantees can give confidence to the consumer in using the products safely, and can make the providers commit to their responsibilities.

Case Study 4.4: Private investment in ethanol production in Malawi and Kenya

The following contributed to the success of private-sector participation in ethanol production:

- Building on an existing industry –ethanol companies were 'built onto' existing sugar industries in both Malawi and Kenya.
- Government and private sector commitment – the Malawian and Kenyan governments created a conducive environment for the private sector to invest in production, distribution and marketing of ethanol.
- Long-term commitment - Key players in the Malawian energy sector demonstrated their commitment to biofuels through testing a car designed to run on ethanol blended fuel.

Pers comm., Robinson 2009

BlueWave Ltd is a Malawi company based in Blantyre (see Chapters 1 & 3). It is promoting the SuperBlue II stove. It identified a market, developed the prototype, and established anticipated market, environmental and health benefits to attract investment partner funding for upscaling. GSB, the UNDP's 'Growing Sustainable Businesses Program' has supported Bluewave in developing their business concept[103] .Over the past year, there does not appear to have been further activity within BluWave and the UNDP.

NGOs often find it problematic to make the transition from a donor/beneficiary relationship to one which is a seller/consumer one. In many instances a 'hand-over' will be more appropriate. The scale of the need for clean household energy requires that the majority of households access clean technologies through commercial and/or semi-commercial initiatives. Governments and civil society organisations do not have a good record of delivering sustainable, viable household energy programs at scale. Commercial approaches are proving to be successful as they are generally demand-driven, and those which involve the private sector to ensure a demand and profit-driven approach, are among the most successful. However, most of these organisations have the support of NGOs in the early stages, particularly training in business skills and financial management.

Applying a commercial approach to scaling up, often moving on from a donor-led or government-led initiative, can lead to more commercial solutions that are not well-known in the NGO sector, thus making it easier to make and market affordable goods and services attractive and long-term.

[103] UNDP. Growing Sustainable Business Initiative. Ethanol Cooking Stove SuperBlu II. http://www.undp.org/partners/business/gsb/projects/GSB%20Malawi%20project%20SuperBlu%20II%20Stove%20one%20pager%20(2).doc [Date accessed: 6 Apr 09]

4.2.3. The Role of INGOs and NGOs

NGOs can provide the link between the more formal sectors and communities and households who will be the consumers of improved cooking services. They are well-placed to support governments and businesses through awareness-raising, demonstrating technologies and promotional activities.

All the successful cases described in this document involve NGOs at their inception. Although governments can instigate social marketing, international and local NGOs can play a key role, particularly where they are already well known by the communities with whom they work.

NGOs can play a key role in facilitation, supporting services, enabling sector co-ordination, advocacy, piloting, linkage with community groups. Demonstrations of safe practices are not only essential from a health perspective but can also lead to a greater awareness of the intervention being promoted.

Where local businesses are set up for sales, distribution, and local manufacture, NGOs can often complement the larger businesses through business training at local level. This may take the form of ongoing support to new or established local institutions, supporting them to develop management skills, financial control, book-keeping skills etc. over a period of years. Local NGOs can provide information about community problems or issues that beneficiaries/customers might not wish to divulge to those outside the community.

Not all communities feel that they can work directly with outside finance institutions, such as banks. NGOs can help support micro-finance arrangements (revolving finance or soft loans) with community groups, and/or assist them in setting up relationships with banks and other finance institutions. They are often seen as an 'honest broker' who can act on behalf of a they serve.

Language issues are more easily resolved when applying questionnaires or group discussions. People are more likely to respond when discussing issues in their local language.

4.3. Impact experience and lessons for key policy areas

4.3.1. Public Health

Studies from all over the world, including the African region, show conclusively that household air pollution levels are extremely high in households that rely on biomass fuels or coal. The WHO recently outlined how improved energy services for the world's poorest communities could substantially contribute to all of the eight millennium development goals[104]. There are currently very few intervention-based studies of impact on the most important health outcomes (child pneumonia, COPD and lung cancer). However the evidence available does suggest that improvements in household energy practices, in particular the use of improved stoves and cleaner fuels, can reduce the incidence of childhood pneumonia and risk of adult COPD. Using clean fuels also removes the issues related to fuel procurement.

Many interventions can reduce the levels of household air pollution dramatically. However, even with these reductions, many technologies still produce levels that exceed the USEPA guideline limits. It is clear therefore that further study is required to identify the most efficient clean appropriate household energy solutions in the knowledge that it will make an impact on the health and quality of life of the poorest communities. There is consistent and increasing evidence that daily exposure to these levels of pollutants has dramatic consequences for health. It is also well understood that the fuel procurement and storage has a significant impact on the safety, and socio-economic well- being of all family members.

4.3.2. Deforestation

Every year people destroy 15 million hectares of forest all over the world[105]. Reducing the pressures on forests not only improves quality of life for those living close to them, but also helps to mitigate climate change. Stoves projects have been shown to work most effectively where pressures on forest are great, so that time and/or money must be spent to alleviate deforestation.

In Madagascar, the Toko Mitsisky is saving approximately 5,342 tonnes per annum for each 2500 stoves in use. In Ghana, the per capita consumption of charcoal is the highest in West Africa. Gyapa stoves have conserved the equivalent of more than 27,606 hectares of forest. In Ethiopia, the use of ethanol stoves has led to improved relations between refugees and local residents who felt angered by the deforestation of areas that had once been woodland, and who regarded fuel gathering by the refugees as theft from their land.

Programmes on household energy should require that both household air pollution and fuel demand are reduced. However, where biomass is replaced by ethanol, policy action needs to be taken to ensure that forests are not displaced by energy crops, and that food crops are protected.

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[104] Rehfuess, E. Fuel for Life: Household energy and health, WHO Press, 2006 www.who.int/indoorair/publications/fuelforlife.pdf

[105] http://www.gtz.de/en/aktuell/1822.htm

4.3.3. Food Security[106]

Global ethanol fuel production — over 90 per cent of total biofuel production — more than doubled between 2000 and 2005. Global biodiesel production nearly quadrupled in the same period. Producing biofuel source material, such as corn and sugarcane, accounts for most of biofuel production costs.

The International Food Policy Research Institute (IFPRI) has projected prices of biofuels for two potential scenarios up to the year 2020; one is based on current biofuel investment plans, and predicts that the international price of maize and oilseed will increase by 26%and 18% respectively. Scenario two assumes double the expansion of biofuels in scenario one, and suggests a price increase of 72% for corn and 44% for oilseeds.

In both scenarios, increasing crop prices go hand in hand with decreasing availability of, and access to, food. Poor people spend a much bigger share of their budgets on food than they do on energy, about 50%–70% on food and 1%–10% on energy. With high prices, they will likely spend less on food, exacerbating poor diets and malnutrition.

In general, biofuels that use food sources are costly to the poor and raise prices on the basic foods. Biofuels that do not use food as their source, such as converting cellulose to liquid fuels, can utilise waste biomass and use less land resources.

Comprehensive international and national policy frameworks can lay the foundation for pro-poor environmentally sustainable biofuels that also achieve energy security.

4.3.4. Climate Change and stoves

Emerging evidence links black carbon (soot) with high levels of global warming[107]. In testimony to the US House of Representatives, Dr Bond states 'Black carbon emissions can be reduced quickly by improving fuels or combustion'. The large emissions from developing regions are mostly from open biomass burning and from small-scale traditional combustion of solid fuels such as wood and coal. In some small-scale applications (such as domestic cooking in developing countries), health and convenience will drive such a transition when affordable, reliable alternatives are available.

On April 22nd, 2009, US lawmakers introduced a bill directing the Environmental Protection Agency to study the environmental impact of black carbon. Where biomass is burnt inefficiently in stoves, the sooty deposits have a much greater

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[106] *Adapted from* Msangi, S. Biofuel revolution threatens food security for the poor, International Food Policy Research Institute (IFPRI), December 2007 http://www.scidev.net/en/middle-east-and-north-africa/opinions/biofuel-revolution-threatens-food-security-for-the.html

[107] Bond, T. Testimony for the Hearing on Black Carbon and Climate Change, United States House of Representatives, October 2007

warming potential than the equivalent amount of fuel burnt at high temperatures – such as forest fires. Because of this, the smoke from traditional cooking fires and inefficient stoves is particularly serious in terms of global warming. The US bill means that substantially greater funds will be directed at black carbon. Evidence on its effect on climate already exists (Bond, 2008), and if black carbon is added to the 'basket of gases' eligible for carbon finance, this will make improved stoves an attractive option for those dealing in carbon.

4.4. Finance

Loans or grants will almost certainly be needed at start-up through banks and other financial institutions, donors, and international organisations, to establish the infrastructure needed for development, manufacture and uptake of a new product.

On the demand side, micro-credit or soft loans are likely to be needed for those with insufficient up-front capital to purchase goods. Carbon finance is one option, discussed in Annex 1. Revolving finance can work well, but where people are on a very low income, the payback period may be very long, so the funds revolve slowly, and it may not be viable approach in commercial terms. Within a community group setting, where livelihoods do not depend solely on profits, this can be a useful approach. Developmentally it is beneficial, as groups start using banking facilities and managing group funds.

4.4.1. Specific issues around ethanol stoves and carbon finance

Within Madagascar, low-income communities form the major part of the total population. If the upfront price of a stove is too great for the target market, insufficient will be bought to create that market. To reach this large potential market, a way must be found to reach the 'bottom of the pyramid' by making the ethanol stoves affordable to this market segment. Carbon finance (see Annex 1) could provide this additional finance stream.

A major current barrier to proceeding with this approach is the lack of an approved methodology for validation that the project activities generate emission reductions which are truly additional to business as usual, and will be sustained at least over one crediting period, i.e.7 or 10 years; that they can be measured, monitored and verified with reasonable certainty. Without such a methodology funds from the carbon market cannot be raised. No buyer in the market is currently providing up-front funding for the development of methodologies, although this is actively being sought by one of the consortium. Typically the terms of an Emission Reduction Purchase Agreement will state that funding will be contingent on the provision of documentary evidence to prove the applicability of the project activity to a methodology approved by the CDM Executive Board. This reduces the size of the potential market for high-quality stoves to a fraction of its true potential as the materials and manufacturing costs for such stoves puts them outside the reach of most of the population. It does mean, however, that the 'additionality' element for carbon finance is met.

As described in Annex 1, there is a lengthy process for approving a new methodology, including the (PDD) outlining an example of how the methodology would be used, and going through several cycles of scrutiny by the UN bodies. Methodologies are often restrictive in their use, and non-existence of an applicable approved methodology is a common barrier to developers of new types of emission reduction projects. Once a methodology is approved, it is publicly available and can be used by any entity that wants to develop a similar project. Other developers of similar projects can then use the methodology free of charge.

The Gold Standard process follows the CDM process quite closely but to achieve accreditation by the GS a number of additional requirements have to be met to ensure that there is a genuine development benefit arising from the project in overall poverty reduction or in specific areas such as improved health or education. GS uses the CDM methodologies for both voluntary and CDM markets.

PRACTICAL ACTION
Consulting

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5. Annexes

Annex 1: Carbon Finance

If carbon finance is properly directed towards stoves which have been proven to have a long product life, produce real and ongoing reductions in greenhouse gases, and are shown to be well-accepted by the users, it can make stoves affordable which would otherwise be too costly for those living in poverty. The addition of the Gold Standard ensures that there are substantial developmental benefits[108] .

Carbon finance provides a basis for maintaining a professional commercial relationship between the user and the stove provider, while also introducing a quality guarantee and a warranty system through which stoves will be repaired free of charge after one year and replacement stoves will be sold at a reduced price after three years. Stoves are continuously monitored, and it is in the best interests of those obtaining the carbon finance to ensure that the stoves work well, and that they are well liked.

Two routes can be used to access this finance. The first, the Voluntary Market, relies on the voluntary carbon sector which is not linked to the mandatory reductions required by the Clean Development Mechanism (CDM). The second route, using the CDM, requires the government of the country to approve the action.

The Clean Development Mechanism

It is a requirement of the Clean Development Mechanism that there is Government involvement to access these funds. The government would need to promote clean stoves on a very large scale to get the kind of substantial returns needed to make CDM viable. Clearly, where a free-market approach is adopted by the government, the aims of both industry and government are compatible.

A government led initiative to establish baseline data accepted by the carbon finance board for each country has been identified by some of the successful businesses mentioned in this report as a useful way to reduce the amount of investment needed by each company and project setting up carbon finance. These data would facilitate obtaining carbon finance for the country involved.

Where governments are more engaged in the way that industries are managed, working with them to access carbon finance may have potential if a sufficient part of the income generated can enable them to run social programmes.

Even with the support of government, there remain some potential challenges to large scale access to carbon finance. These relate to technological /methodological requirements on measurement, monitoring and verification, and issues of baseline data as described below.

[108] http://www.cdmgoldstandard.org/

Annex 1.1 Setting up carbon finance for stoves programmes

For both voluntary markets, and the CDM, a 'Gold Standard' ensures a best practice methodology and a high quality carbon credit label. Setting up a carbon finance project requires a number of factors to be researched and provided:

A project document (PDD) must be accepted that highlights how the project activities will be implemented; the types of stove distributed or sold and how this will be done – including motivation and awareness-raising, the numbers of each type that are planned during the crediting period, eligibility of households, the numbers employed by the project, and how randomness in the groups to be sampled will be achieved. The project boundary is the physical, geographical site of the renewable energy generation. A distinct geographical boundary of each project area must be clearly identified.

Audits must be prepared, which involve; monitoring baseline submissions, developing a database on project households, monitoring emissions, calculating fuel consumption, determining levels of renewable and non-renewable biomass within the project areas, and determining leakage. A database must be created showing all project areas, sample households, date of implementation, questionnaire results from baseline and project monitoring for each project household.

Baseline emissions are calculated on the fuel emissions for the non-improved stoves for cooking and space heating. Where stakeholder's energy services are insufficient to meet their human development needs (suppressed demand), the baseline emissions may include emissions that would result from meeting this suppressed. If a sample of the population is measured, an error margin must be applied. Baseline emissions may be calculated on the basis of the questionnaire results. Baseline emissions need to be calculated only in the first year

A project monitoring questionnaire is collected at the end of each monitoring period from the sample group. The mean and standard deviation of household project fuel consumption during the monitoring interval (the time period between two spot checks) must be calculated. Both baseline and project monitoring questionnaires must be performed by specially trained personnel with extensive local and technical knowledge. Quality control is conducted by re-visiting some of the households to verify the questionnaire.

Monitoring involves the collection of the following data:

- Ex-post identification of the actual number of households that took part in the programme at the beginning of the monitoring interval.
- Identification of the households that are randomly selected for the project sample.
- Ex-post collection of data on fuel use.
- Ex-post calculation of the mean and standard variation of baseline and project emissions and ex-post calculation of emission reductions.

- All monitored data, stored on an electronic database should be available for scrutiny with each monitoring report.
- All measurement equipment must be calibrated and regularly maintained and checked for its correct functioning.

Project fuel consumption is calculated based on sampling results and adjusted with the statistical margin of error at a 95% confidence level. The fuel savings as a result of the project are calculated as the difference of the mean household fuel consumption for the baseline and project situation multiplied by the total number of households participating in the project. Determining levels of renewable and non-renewable biomass and leakage

Wood is regarded as non-renewable if, within the project area the consumption of wood exceeds the renewable wood production, or where fuel wood consumption by households constitutes a significant share of total wood consumption. In this instance, the leakage would be the amount of non-renewable biomass that would be used outside the project area as a result of it not being used within the project area. This would be deducted from the total emission savings.

For carbon finance to be obtained, the actual values of usage and emission reductions are the basis for the carbon funds to be released. It is therefore vital that each stove reduces emissions substantially, that the stoves reach a substantial number of households (thousands rather than hundreds), that they are robust enough to work well throughout the product life quoted in the PDD, and perhaps most importantly - that the household wishes to use the stove and that a reliable fuel chain is established to ensure that the new stove can be used most of the time throughout the project period. All this information must be gleaned during the project period through questionnaires and quality review. Carbon finance is thus 'earned' by using the project stoves, so it is in the interests of the implementer to make sure that the stove is of high quality, and that the fuel supply is assured.

Annex 2: ToR for Component C

Component C: Review of SSA experience in Scaling-up Household Energy Interventions

1. Using secondary sources of information, the third component of the study will provide a synthesis of data from African household energy interventions, reviewing significant results from such initiatives undertaken since 1990. This will focus on data regarding the health benefits and cost effectiveness of interventions, including through the use of cleaner fuels, improved stoves, enhanced ventilation, and behavior change. The second element of this component will review success in scaling-up such interventions, with special attention to the division of roles between the public and private sectors, drawing lessons for potential future government and development partner support in Madagascar.

2. While HAP has yet to be integrated into the development agenda to a degree that reflects its significance as an environmental health challenge, many initiatives have been undertaken in SSA that aim to reduce exposure to biomass smoke, either as a primary objective, or as a secondary result of improving the efficiency of solid fuel use. Recent examples include:

- SMOKE Project (1999-2001), supported by DfID among others, which aimed to improve quality of life through reduction in household air pollution for households in SSA;
- An investigation of exposures and health status in households cooking with biomass in Kenya (2006 – ongoing), supported by the Millennium Villages Project;
- Smoke, Health and Household Energy Project (2000 – ongoing), supported by DfID, to reduce the major health risks caused by smoke from kitchen fires, through awareness of the dangers of smoke and interventions to alleviate it, in Kenya, Nepal and Sudan, including research on pathways to scaling-up;
- Rwanda improved stoves (2006 – ongoing), supported by USAID;
- Study of HAP and pneumonia in The Gambia (2007 – ongoing), supported by WHO and others;
- Household fuel use and HAP monitoring in Uganda, (2005 – ongoing), to assess the impact of the wood-burning rocket stove, supported by USEPA, GTZ and others;

- Evaluation of GTZ Rocket-Lorena Stoves in Uganda (2007 – ongoing) supported by the Millennium Villages Project;
- HAP monitoring in Ethiopia to evaluate the impact of an ethanol stove (2005 – 2007), supported by UNHCR and others;
- Upesi stove project in Kenya (1996 – 2000), supported by DfID and EC;
- Reducing health risks from HAP in Uganda and Tanzania (2002 – 2005), supported by the Health Foundation;
- HAP monitoring in Accra to assess the impact of the wood-burning rocket stove (2005), supported by Enterprise Works and the Shell Foundation;

3. More specifically, there are currently a few ethanol stove programs that attempt to address the rural energy problem claiming also environmental (avoiding deforestation) and human health (lower household air pollution) benefits. These include:

- Project Gaia is an Ethiopian based program which seeks to create a model by which a household market for alcohol based fuels can be developed on a commercially viable scale throughout Ethiopia;
- The Millennium Gel Fuel Initiative is a public-private partnership set up to adapt and disseminate an ethanol cooking fuel for use in the African household sector. The program developed a low cost combustible ethanol gel and more than five gelfuel and/or ethanol dedicated stoves;[109]
- Nari Ethanol Stove. The Nimbkar Agricultural Research Institute (NARI) of India has been developing both an ethanol stove as well as a sweet sorghum feedstock for ethanol production;
- The SuperBlu Stove. Bluwave Ltd of Malawi has developed a novel ethanol burner technology for use in a cook stove as well an industrial burner.

In addition, the private sector is beginning to make inroads into the commercialization of ethanol cookstoves. For example, Cooksafe, a South African company is designing, manufacturing and distributing ethanol stoves and fuel products. Lessons learned from other ethanol stove programs will be reviewed for their relevance to the proposed program in Madagascar.

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109 Utria, B.E., "Ethanol and gelfuel: clean renewable cooking fuels for poverty alleviation in Africa, in Energy for Sustainable Development, Volume VIII No. 3 l September 2004. pp 107-114.

Task C.1: Synthesis of data from SSA household energy interventions

4. The first task under this component will focus on synthesizing data on the health benefits and cost effectiveness of household energy interventions in SSA that reduce exposure to HAP either as a primary objective or secondary result, including through the use of cleaner fuels, improved stoves, enhanced ventilation, and behavior change.

Task C.2: Review of success in scaling-up SSA household energy interventions

5. The second task under this component will be a review of the success of initiatives aimed at scaling-up such interventions. This review will provide information on institutional arrangements, technological performance, promotion activities, and financing, with special attention to the division of roles between the public and private sectors, drawing lessons for potential future government and development partner support aimed at reducing the burden of disease associated with HAP in Madagascar, and more widely in SSA. Projects that have been completed within the past five years will be contacted to start to develop evidence on current usage patterns and to determine reasons for lack of use where this has occurred. The review of successes in scaling-up will also entail analysis of the findings to identify both best practice, and reasons for failure or reduced success, to mitigate such problems in the future.