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Will African Consumers Buy Cleaner Fuels and Stoves?

A Household Energy Economic Analysis Model for the Market Introduction of Bio-Ethanol Cooking Stoves in Ethiopia, Tanzania, and Mozambique

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LIST OF ACRONYMS

ASC	Alternative Specific Constant
COPD	Chronic Obstructive Pulmonary Disease
CSA	Central Statistics Authority
DALY	Disability-Adjusted Life Year
DCA	Discrete Choice Analysis
DFID	UK Department for International Development
EAC	East African Community
ETB	Ethiopian Birr
FAO	Food and Agriculture Organisation of the United Nations
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Development)
HHEA	Household Energy Economic Analysis
IAP	Indoor Air Pollution
LDC	Least Developed Country
LPG	Liquid Petroleum Gas
LRI	Lower Respiratory Infection
MDG	Millennium Development Goal
MME	Ministry for Mines and Energy
MNL	Multinomial Logit
Mt	Mega Tonne
MWTP	Marginal Willingness To Pay
MZN	Mozambican Metical
NORAD	Norwegian Agency for Development Cooperation
PISCES	Policy Innovation Systems for Clean Energy Security
PCIA	Partnership for Clean Indoor Air
RP	Revealed Preference
RPTES	Regional Program for Traditional Energy Sector
SEED	Strengthening Energy Environment and Development Processes
SIDA	Swedish International Development Cooperation Agency
SP	Stated Preference
SSA	Sub Saharan Africa
TZS	Tanzanian Schilling
UDSM	University of Dar es Salaam
UNDP	United Nations Development Program
USAID	United States Agency for International Development
USD	United States Dollar
WHO	World Health Organization
WWF	World Wildlife Federation

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EXECUTIVE SUMMARY

Switching from traditional biomass to cleaner, safer and more efficient fuels for cooking can enhance the welfare of the 2.5 billion people worldwide who currently do not have access to modern energy sources, while helping to reduce the negative health and environmental impacts associated with traditional biomass use. Despite the numerous benefits associated with cleaner alternatives, the transition to improved cooking stoves and fuels has largely stalled in Sub-Saharan Africa (SSA). In order to design effective policies and programs to promote the use of cleaner cooking alternatives, the barriers to improved cooking technologies must be understood at the household level. To date, research regarding the determinants of stove choice at the household level has focused mainly on socio-economic attributes, such as income, age, gender and education, while the role of product-specific attributes, such as safety, indoor smoke, usage cost and stove price, has been disregarded or given less attention.

This report presents a study conducted by the Stockholm Environment Institute to address this knowledge gap by empirically assessing the role of socio-economic attributes and product-specific attributes as determinants of cooking stove choice at the household level. The study involved a stated preference survey to investigate household-level preferences of cooking fuels and stoves; the survey included 200 households in Addis Ababa, Ethiopia, 564 households in Dar es Salaam, Tanzania, and 402 households in Maputo, Mozambique. The research team applied an alternative methodology, discrete choice analysis, which is commonly used in transportation studies, to assess the trade-offs among attributes affecting household cooking choice. The research methodology included focus group discussions with key stakeholders as well as individual interviews, to validate the model and to identify any significant social, cultural and local attributes that may have been overlooked in the application of the model.

The findings of this study illustrate the respective roles of socio-economic and product-specific attributes as determinants of stove/fuel choice and permit estimation of the relative strengths of product-specific attributes in determining stove/fuel choice at the household level. Such information is crucial for stove producers, policy-makers and programme developers interested in targeting particular markets since it tells them not only which stove characteristics are important to the consumer, but also by how much the consumer values one stove attribute over another, or how trade-offs are made at the individual level. This type of market information can be used to accurately target different market segments and design stoves that consumers will actually buy and use. The study argues that product-specific attributes are as important as socio-economic attributes to create a market for clean cooking stoves, and that future research should strike a balance between both types of attributes. In a near-term perspective, product-specific attributes are more important, as socio-economic attributes tend to change slowly, in line with longer-term patterns of economic growth and human development. The study results demonstrate the insights that can be gained from detailed consumer choice analysis, and how these insights can support policy makers and cooking stove programme designers interested in evaluating markets for new stoves and cooking fuels.

1 INTRODUCTION

This research report presents a household energy economic analysis study conducted by researchers at the Stockholm Environment Institute between 2008 and 2010 in three locations in Sub Saharan Africa: Addis Ababa, Ethiopia, Dar es Salaam, Tanzania and Maputo, Mozambique. A novel methodology based on discrete choice theory was designed to investigate consumer choice for fuels and cooking stoves and this methodology was then applied in each of the three locations. To the best of the authors' knowledge, this is the first time such a methodology has been applied in an experimental setting to analyse consumer decision-making around cook stoves and fuel choices in a developing country context. The aim of the analysis was to address gaps in the literature regarding the consumer-level determinants of stove and fuel choice and to demonstrate a methodology that can support practitioners and policy makers in designing new programmes, products and policies in the household cooking sector.

Strengthening energy, environment and development processes

The Household Energy Economic Analysis model (HHEA) was developed as part of the SEI programme on Strengthening Energy Environment and Development Processes (SEED), an initiative aimed at new approaches for improving energy access and enhancing livelihoods. The programme also included support in policy processes for improving energy access; evaluation of modern bioenergy options for socio-economic development; and rural and renewable energy enterprise development.

A special focus has been on developing evaluation methods for assessing the transition away from traditional fuels such as wood and charcoal to clean cooking fuels such as bio-ethanol. Traditional biomass provides only low quality energy services and raises significant environment, health and socio-economic welfare concerns. The HHEA aims for a better understanding of the market opportunities for households to adopt clean cooking fuels by evaluating consumer response through a fuel/stove choice experiment in several case study regions in sub-Saharan Africa.

Choice of case studies

The first case study was carried out in July 2008 in Addis Ababa, Ethiopia. Ethiopia was chosen as an initial study site, since the introduction of clean cooking stoves has been identified as a priority. Moreover, deforestation is a severe environmental problem in Ethiopia and it is acknowledged that reducing firewood and charcoal consumption can reduce resource pressures that contribute to deforestation. Also, a local NGO—Gaia Association—has been planning for the production and use of an ethanol stove in Addis Ababa; therefore, in terms of policy relevance, Addis Ababa offered a highly appropriate initial location to carry out the choice experiment.

It was decided that additional HHEA studies would be conducted in Dar es Salaam, Tanzania, and in Maputo, Mozambique to build upon and strengthen the approach that was used in the Addis Ababa case study. By applying the same methodology in additional sites and by maintaining the same research parameters, it was possible to make comparisons across all three studies. To ensure consistency, similar sites to those in Ethiopia were selected, that is, urban/peri urban neighbourhoods. The study is also of strategic relevance for the countries in question: both Tanzania and Mozambique have been investigating biofuels options as a contribution to a more sustainable energy supply, to improve energy security and to stimulate rural development and the agricultural sector. The main purpose of the three case studies is to analyse a switch to the bio-ethanol stove/fuel based on the specific choice experiments that were used, rather than a more general exploration of the different alternatives that are available, or could be made available, in these three locations.

Structure of the report

Given the study objectives presented above, Chapter two sets the policy context for the HHEA by exploring the energy access-development-environment nexus and describing the household energy crisis currently affecting many developing countries, particularly in Sub Saharan Africa. The potential role of clean fuels such as bio-ethanol for addressing this problem is discussed and the policy relevance of the HHEA for each of the case countries is presented. Chapter three introduces the Discrete Choice Analysis methodology applied in the case studies and the idea of choice determinant attributes, upon which it is based. The stated preference survey tool is then described and an overview of the experimental design process is given. There follows, in Chapter four, a detailed description of each of the case study sites in terms of policy background and household energy profile. This is followed by a description of the stated preference survey design process in each of the case countries in Chapter five, highlighting particular local factors influencing the study design and implementation.

The main findings of the study are expounded in Chapter six, with particular attention given to the results across various socio-economic strata in each case country and the trends observed in terms of trade-offs made by households between different product-specific factors when selecting a cooking stove. In Chapter seven, the potential of the methodology for simulating fuel switching, under given market scenarios is explored taking the case example of Ethiopia. A number of methodological issues emerging from the HHEA are discussed in detail in Chapter eight with particular attention given to possible improvements that could be made in future applications of the model. Different approaches to understanding the relative strengths of attributes affecting stove choice are evaluated and the importance of analyzing both product-specific and socio-economic factors affecting stove choice is explained. Several policy relevant findings are then discussed. Finally, Chapter nine summarizes the main findings and offers some recommendations in terms of the future development and application of the methodology for making similar assessments.

2 ENERGY ACCESS AND HOUSEHOLD COOKING: BACKGROUND AND POLICY CONTEXT

This section looks at the central role of household energy for human development, highlighting the health, environmental and socio-economic consequences of not having access to clean and safe energy services at the household level. The potential of clean cooking fuels for addressing the household energy problem in sub-Saharan Africa is outlined and the policy relevance of the HHEA study is described for each case study country. The HHEA is placed in the context of regional and national policy goals related to household cooking, and some background is provided on the development of the methodology from the initial case study in Ethiopia.

Household energy access and development

Although there is no Millennium Development Goal (MDG) specifically related to energy, access to energy is intrinsically linked to poverty reduction and plays a crucial role underpinning efforts to meet the MDGs (UNDP, 2005). For poor households in Least Developed Countries (LDCs), cooking often accounts for 90 per cent or more of total energy demand. Without a massive scale-up of access to modern energy services in the coming years, it is unlikely that the MDGs will be met (DFID, 2002). In the year 2000, indoor air pollution from solid fuel use was responsible for more than 1.6 million annual deaths and 2.7 per cent of the global burden of disease (in Disability-Adjusted Life Years or DALYs), making indoor air pollution the second biggest environmental contributor to ill health after unsafe water and sanitation. Therefore, cooking stove and energy are often quite relevant to MDG policies, such as MDG4-Child Mortality; improvements to cooking stoves and household energy use can support achievement of the MDGs.

In SSA alone, an estimated 500,000 people die each year from diseases caused by exposure to indoor air pollution (IAP) from burning biomass. Without systematic changes, household biomass use will result in an estimated 8.1 million Lower Respiratory Infection (LRI) deaths among young children and 1.7 million COPD deaths among adult women in SSA between 2000 and 2030 (Bailis, Ezzatti, and Kammen 2007 p.6). Since a large number of deaths from illnesses caused by exposure to indoor air pollution occur among women and children, biomass use for cooking is related to multiple MDGs and has been identified as a key focus area in poverty reduction efforts.

In addition to the act of cooking itself, the task of gathering fuelwood also falls mainly on women and children and comes with a high socio-economic cost, typically not accounted for by government policies. For example, there are significant socio-economic impacts due to the opportunity costs of spending several hours per day gathering fuelwood. The possibility to use that time to engage in income-generating and educational activities contributes to the stability and advancement of households and communities (UNDP, 2005). There are also safety risks for women and girls that must travel long distances by foot alone or in small groups. Where fuel is purchased, spending money on large quantities of fuel due to an inefficient stove constrains household budgets (WHO, 2006).

Finally, there is a growing body of knowledge linking household use of traditional biomass to emissions of black carbon, which is a significant contributor to climate change. Residential biomass burning is responsible for an estimated 18 per cent of global black carbon emissions (Bond and Sun, 2005). The combination of climate and health benefits creates even greater impetus to address the household energy problem.

Clean cooking alternatives

Modern or clean cooking fuels are considered to be those used in stoves that have high energy density, high combustion efficiency and high heat-transfer efficiency with sufficient heat control characteristics. Biogas and LPG are common gaseous cooking fuels, while ethanol and kerosene are the main alternative liquid cooking fuels (Schlag and Zuzarte, 2008). Efficient stoves are also available for wood or charcoal, sometimes relying on prepared fuels such as wood chips or pellets. A progressive shift to cleaner fuels and technologies for basic energy needs is a cost-effective means of creating new development alternatives, reducing health impacts and mitigating environmental degradation. Despite the many advantages of clean cooking options over traditional biomass, their use remains limited in SSA. The failure of clean fuels to achieve widespread dissemination in households is the result of a combination of economic, political and social attributes (Goldemberg *et al.,* 2004).

At the same time, new market opportunities are emerging for developing countries to improve access to modern energy sources through the domestic use of locally produced biofuels while reducing reliance on imported fossil fuels. This has led to renewed optimism regarding the feasibility of programmes to address household energy access in developing countries. A number of African countries are currently producing ethanol at significant scales, including Ethiopia, Kenya, Malawi and Zimbabwe. The ethanol is mainly used as an additive in transportation fuels but as the industry continues to expand, ethanol could offer the prospect of meeting household cooking needs (Schlag and Zuzarte, 2008).

Ethanol is among the cleanest of household fuels when burned in proper appliances, and is widely cost-competitive compared with electricity, LPG, and kerosene. It can be distributed through existing infrastructure and markets; and it has a high efficiency, low smoke/soot level, and high ‘cleanliness’ compared to those fuels most prevalent for cooking. The use of alcohol fuels in the household results in greatly improved air quality in the kitchen compared to firewood or charcoal, safer handling with reduced danger of fires, burns, and explosions compared to kerosene, and reduced environmental impacts compared to traditional stoves and fuels (Kassa, 2007).

Policy relevance

Although the approach used in this study is broadly applicable, this research used as a case study the option of bio-ethanol stoves as a clean cooking alternative. Other solutions such as using more efficient traditional wood or charcoal cooking stoves are also important, especially in peri-urban areas; however, these options are beyond the scope of the application chosen in this research and will not be discussed in detail in this report. Nevertheless, the methodology itself is general enough to be applied to basically any type of household cooking option.

In addition to alternative cooking fuels based on renewable energy such as bio-ethanol, there are also non-renewable options such as LPG (Liquefied Petroleum Gas) that would have immediate benefits with respect to indoor air pollution as well as reducing other environmental and social impacts. However, a renewable option offers additional benefits in the form of climate mitigation, development opportunities for new domestic agro-industries and improvements in foreign exchange. Many SSA countries currently produce some biofuels and several countries are in the process of drafting national biofuels development strategies to outline the targets and sustainability criteria for the growth of this industry. There appears to be potential for locally and sustainably produced biofuels as an alternative source of clean energy for the household sector; it is nevertheless important when designing policies and programmes to consider potential conflicts related to food security, water use and socio-economic impacts on land and livelihoods. This study focuses on the demand side of the equation for clean cooking fuel, although in the broader policy context it will of course be important to address the supply side as well.

In Ethiopia where the production of ethanol is being rapidly scaled up, the government has developed a biofuels policy that includes the use of ethanol for household cooking, in addition to its use in the transport sector. Both Tanzania and Mozambique have been investigating biofuels options as a contribution to a more sustainable energy supply, to improve energy security and to stimulate rural development and the agricultural sector. A biofuels task force has been established in each country to assess the various options for the development of policies and strategies to increase the use of biofuels in the transport sector.

However, there has been little analysis on the role of ethanol and other renewable cooking fuels in the household sector. One concept to be explored is to use the transport fuel market, which is much larger in volume, to support the creation of a household fuel market. In this manner, the household-level or energy access benefits of a biofuel program can be extended to many households and not just to those few that have access to vehicles. Policy makers, programme developers and stove producers will benefit from a more accurate picture of the potential market for ethanol as a cooking fuel. The HHEA (Household Energy Economic Analysis) methodology can be used to generate detailed information on fuel and stove market segmentation, which is vital for expanding the market for improved stoves and for designing mechanisms to increase access to improved fuels and technologies for lower income households, e.g. through subsidies or micro finance programmes.

In order to reach energy targets for improved cooking options, such as the targets established in the East African Community (EAC), policy makers and stove programme designers need to have a clear understanding of the attributes that influence a households' choice of cooking fuel and stoves. However, accurate knowledge in this area has historically been lacking and, as a result, a large number of improved cooking stove programmes have failed (Barnes *et al.,* 1994). The HHEA methodology applied in this project was developed specifically to address this knowledge gap and thus be of practical use to policy makers and stove programme designers.

3 APPROACH AND METHODOLOGY

This section begins by reviewing research on cooking stove choice over the past three decades and highlighting some major omissions in terms of the lack of academic focus on product-specific factors as determinants of choice. The importance of studying both product-specific and socio-economic factors to gain an accurate picture of household decision making is discussed and the methodology applied in the three case studies, discrete choice analysis, together with the stated preference survey technique, is introduced. A more detailed description of discrete choice analysis is provided in Appendix one.

Attributes influencing cooking stove choice: gaps in the literature

Since the early 1970s, academic research and theoretical models have generally viewed income as the single most important attribute responsible for variation in cooking fuel and the associated stove choice at the household level (Briscoe, 1979; Davis, 1998; Hosier and Dowd, 1987; Pachauri and Jiang, 2008). At the same time, much research has in fact considered non-income attributes affecting cooking stove choice at the household level (Gupta and Köhlin, 2006; Heltberg, 2004; Hosier and Dowd, 1987; Narasimha Rao and Reddy, 2007). A review of 20 academic journals indicated that 47 non-income attributes have been identified as accounting for some variation in stove choice, with the most commonly reported attributes being age, occupation, education, household size, and gender (for example, read Gupta and Köhlin, 2006; Heltberg, 2004; Ouedraogo, 2006).

The acknowledgement in the literature of many non-income attributes affecting cooking stove choice combined with a common assertion about the lack of understanding of those attributes at household level raises questions about the methodological approaches use in previous research on stove choice analysis. A close examination of the identified attributes and the methodologies adopted indicated a number of major shortcomings. One of the fundamental shortcomings in the published literature is that the research focus is highly skewed towards socio-economic attributes and consistently fails to distinguish between the different roles of product-specific-attributes and socio-economic attributes. This is a major omission because failing to consider product-specific attributes is tantamount to ignoring the agency[1] of household consumers in fuel and stove selection, a key attribute in predicting the market for improved stoves. From a fuel-switching perspective, it is especially important to distinguish product-specific and socio-economic attributes, as discussed further below.

1 Agency is a term from economic theory, and in this case refers to the role of the (household) consumer as an economic decision-maker (i.e. an economic agent).

Types of determinant attributes: socio-economic and product-specific

In theory, all determinant attributes of household cooking choice fall into either individual socio-economic characteristics or product-specific characteristics. These two types of attributes can be distinguished based on variations “between” and “within” individuals. The former type are characteristics between individuals as these attributes are different between different individuals and do not change for an individual over a short period of time. The latter is the variation that an individual faces while making a choice. For a given individual at a given moment, socio-economic characteristics are always fixed; hence the attributes responsible for variation in choice ‘within’ individual (for a given individual) are product-specific. It is important to cluster all determinants of stove choice into the two categories, since the usages and roles of these attributes are different in each category. It is instructive to note here that this categorisation is analogous to short-run and long-run costs in production/consumption theory, i.e. that some attributes of individuals are fixed in the short-term but variable over the long-term, just like different attributes of production are fixed or variable.

Theoretically, a socio-economic attribute that determines cooking stove choice could be anything that defines and describes people and has a correlation with variation in stove choice. A socio-economic focused analysis seeks to identify individual or household characteristics and assess if stove choices differ across the specified socio-economic variables. Commonly reported socio-economic attributes such as age, income, gender, and education do not vary within individuals in the short term, i.e. the variation is “between” individuals. These attributes are useful in identifying the target market and understanding the profile of its consumers.

In contrast, product-specific attributes refer to attributes or characteristics of the cooking stoves (and the associated fuel or fuels) themselves. As an individual can test or evaluate different stoves within a short period of time, these attributes change “within” the individual. Among the relevant product-specific attributes are stove price, usage cost, convenience and level of smoke. Previous research on the determinants of cooking stove choice lacked a focus on product-specific attributes. This biased approach and limited understanding of product-specific attributes is a significant constraint for the successful design and/or promotion of fuel/stove switching. Only product-specific characteristics can be easily modified in a relatively short period of time to develop an appropriate stove design with a high probability of acceptance in a target market.

As summarised in Table 1, the product-specific and socio-economic attributes have different characteristics and roles in the promotion of modern energy efficient cooking stoves; therefore, an innovative approach and method is required to categorise and study each. Furthermore, the quantification of these attributes is necessary to provide guidance for practical project implementation.

Table 1: Summary of product-specific and socio-economic attributes

	Product-specific attributes	Socio-economic attributes
Specific to:	Product	Person
Characteristics:	Universal in nature	Specific to context
Variation in choice:	Within individuals	Between individuals or groups
Change in short-term:	Relatively easy	Difficult
Useful for:	Product design, demand forecast, policy formulation	Market segmentation/profiling and policy formulation

Choice experiment and analysis

Accurate demand predictions are vital for the uptake of innovative clean cooking alternatives such as ethanol or solar cooking stoves; without this information, stove producers cannot risk producing new stoves and policy makers are unable to give suitable support to the projects. In order to make such accurate demand predictions for household fuels and stoves in Ethiopia, Tanzania and Mozambique, the project team developed a fairly novel approach based on a stated preference Survey and the use of Discrete Choice theory (see Appendix 1 for a detailed discussion). Choice analysis has been successfully applied as an approach for making economic assessments in various market research and transportation studies.

The research team applied a discrete choice analysis model, in this case using a multinomial logit model (MNL), in order to evaluate the trade-offs inherent in household choice of cooking stoves and fuels. This model was selected as it allows for the quantitative assessment of both socio-economic and product-specific factors, and because the research team was interested in knowing not only whether a particular product-specific factor is important, but also, how important it is in relation to other factors.

Consumers derive utility not from a cooking stove as such, but from its specific characteristics/attributes such as heat energy delivered, smoke level, safety, convenience to use and so on. Hence, the strength of the factors affecting a stove choice is derived from the weight of the utility that an individual derives from each attribute of a stove and how much they are willing to pay for those attributes. The relative weight of each attribute can be estimated by designing a choice experiment.

Stated preference survey

Central to the DCA methodology is the *Stated Preference* (SP) survey technique. In a SP survey, an analyst asks people to choose alternatives with stated attributes in a hypothetical situation using questionnaires, cards, telephone interviews, web, etc. For example, preference between ethanol and firewood stoves can be asked using cards as shown in Figure 1.

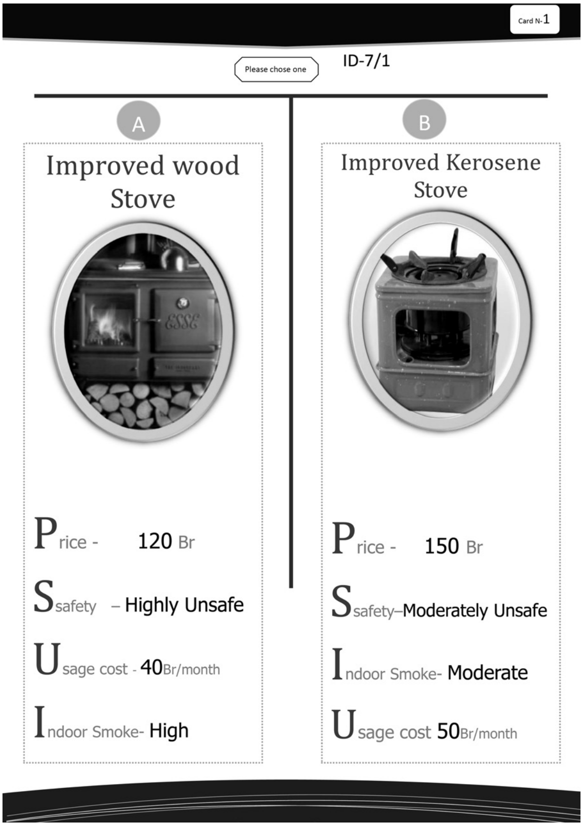

Figure 1: Example of Stated Preference (SP) survey

In this situation, an individual is asked to trade-off between the prices and smoke levels of two stoves. If s/he is willing to pay extra $50 to reduce the smoke level from "High" to "Low", he/she should choose an ethanol stove; otherwise, it is better to choose a firewood stove. An analyst may ask multiple questions in different combinations of attributes; therefore, SP technique is considered more efficient than conventional questionnaires, in that a number of questions can be asked to one person, and thus, more than one sample is generated from a SP survey.

Moreover, real observed choices, i.e. *Revealed Preference* (RP), give only a limited variation of data due to technological constraints and competition between similar products. For example, a producer cannot make stoves that are much more expensive than similar products due to market competition. For the same reason, one will not find good quality (low smoke level) products at cheap price. In other words, in RP, an analyst cannot control the selection of attributes and attribute levels. In contrast, using a SP survey, the analyst is free to choose any combination of attributes potentially affecting choice behaviour. Therefore, a choice against a non-existing situation can be tested with this technique. An analyst can obtain a much wider range of data with SP than RP. In the first indifference curve example, potentially observed smoke level and

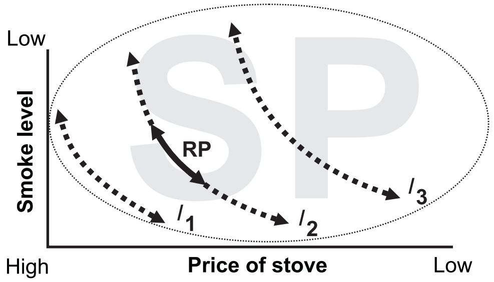

Figure 2: The ranges of attributes included in SP and RP techniques

price combination of a stove will be a fraction of I2. In contrast, the analyst can test any combination on I1, I2, and I3 as in Figure 2.

Experimental design process

The SP survey is a core of the choice analysis as an empirical experiment. According to Hensher, *et al*., (2005), an appropriate design process is summarised as Figure 3. The choice analysis should start with a refinement of the study problem. Then, an analyst is required to identify and refine alternatives and attributes through feedback loops as in verifying the attributes, ranges, etc. before completing a choice experiment and constructing an actual survey.

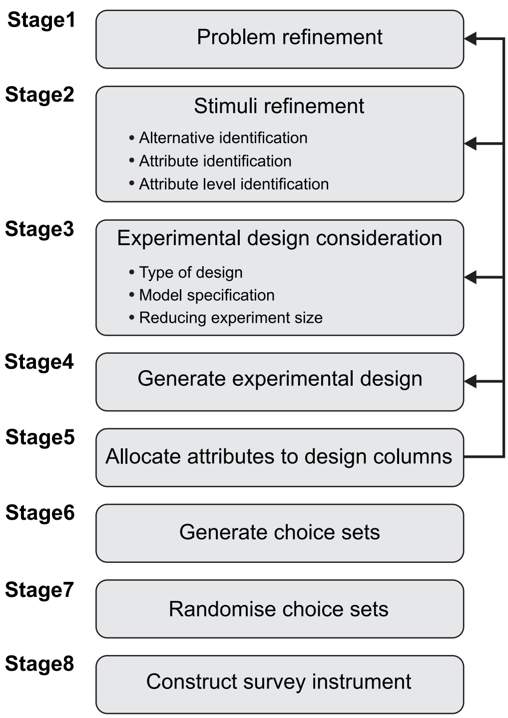

Figure 3: Design process of choice experiment

4 CASE STUDY DESCRIPTIONS

The following section provides background information for each case country including the policy relevance of the HHEA study, household energy consumption patterns and trends in each city (Addis Ababa, Dar es Salaam and Catembe), and other case specific relevant data such as, for example the status of national biofuels strategies and ongoing clean stove programmes.

Ethiopia

In July, 2008, the first of three Household Energy Economic Analyses was conducted in Ethiopia to estimate the relative importance of product-specific and socio-economic determinants of cooking stove choice at the household level. The study was conducted in close cooperation with Gaia Association, a local NGO engaged in the promotion of ethanol and ethanol fuelled stoves as a clean and safe alternative to traditional biomass and kerosene for household cooking in Ethiopia.

Background and policy relevance

Ethiopia currently produces eight million litres of ethanol annually and plans are in place to scale up production to 130 million liters by the year 2012/13 (Heckett and Aklilu, 2009). Because of this great potential, in 2004 Dometic AB (a major Swedish producer of alcohol appliances) introduced the ethanol-burning CleanCook Stove and in partnership with Gaia Association, conducted a pilot study among 500 Addis Ababa households. The study confirmed the stove's popularity among users, who cited a number of benefits including improved health and savings in time and income (Kassa, 2007; Lambe, 2006; Stokes and Ebbeson, 2005). The Government of Ethiopia has been receptive to the idea of developing the household cooking market for ethanol and has included legislation to this effect in its draft biofuels policy. The CleanCook stove is an adaptation of the leading alcohol stove in use in niche applications in the Developed World for three decades. It is established technology and thoroughly consumer-tested. Since it is non-pressurized, there is no risk of explosion. The stove is constructed entirely of stainless steel and is durable and long lasting with an estimated 10-year life. It is currently available either with one or two burners; each burner provides 1.5kW of heat output and has its own fuel canister that holds 1.2 litres of fuel sufficient for 4.5 hours of cooking. It has heating power equivalent to an LPG stove and a turn-down capability that allows users to conserve fuel and simmer food. Moreover, it has an efficiency rating of 55 per cent or more, which is comparable with typical efficiencies of LPG stoves. The stove has been redesigned for the Ethiopian market to be more cheaply manufactured, to be stronger, hold larger pots, and hold round-bottomed pots (Stokes and Ebbeson ,2005). The low emissions result in lower indoor air pollution and thus fewer health impacts.

Household cooking in Addis Ababa

The most widely used cooking fuel in Addis Ababa is kerosene (42.2 per cent of households) followed by fuelwood (29.4 per cent). Electricity, LPG, charcoal and

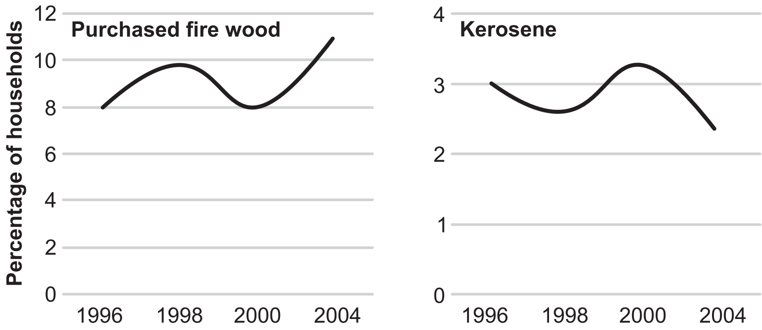

Figure 4: Trends in source of primary fuels for cooking in Addis Ababa between 1996 and 2004 (CSA 2004)

residues are used by a much smaller share of urban households. The primary cooking stove used in Addis Ababa is the single burner kerosene wick stove, which is used in 98 percent of Addis Ababa households (Kassa, 2007; FAO and PISCES, 2009).[2] Fuelwood cooking is typically done over an open, three-stone fire. Charcoal cooking is done with the Lakech, which is a type of improved stove, and other types of metal stoves. LPG is used by the highest income group in the city and this group usually owns multiple burner LPG stoves. However, LPG is often difficult to purchase due to unstable supply in Addis Ababa. The most widely used electric stove is a single-burner hot plate.

Cooking fuel use in the urban areas fluctuates frequently due to changes in prices and availability of fuels. A significant change took place between 1996 and 2004 where the number of households reporting kerosene as their primary cooking fuel declined in both relative and absolute terms (Figure 4). Besides the potential additional usage in fuelwood due to migration into Addis Ababa, the reduction in kerosene use was accompanied by an increase in the number of households cooking with fuelwood which suggests that a large proportion of kerosene users may have shifted to fuelwood or moved from using mostly kerosene to using mostly fuelwood. Such a shift towards a less convenient and less efficient fuel suggests that price may have been the main driver. Indeed, the price of kerosene increased steadily between 1996 and 2004 (see Figure 5).

Increased cost to the consumer of energy acquisition eroded household welfare (Figure 6). More than 75 per cent of households in urban areas have an annual income of less than ETB 6,000. The average household spends 10 per cent of its income on energy. For urban households with more income, the average expenditure is about 6 per cent of total income. Households in the lowest segment spend as much as 16 per cent of their income on energy and those at the highest segment about 4 per cent (Figure 6) (Kassa,

2 Households may have multiple fuels, since wood or charcoal may be needed for cooking injera (bread) and the traditional coffee ceremony.

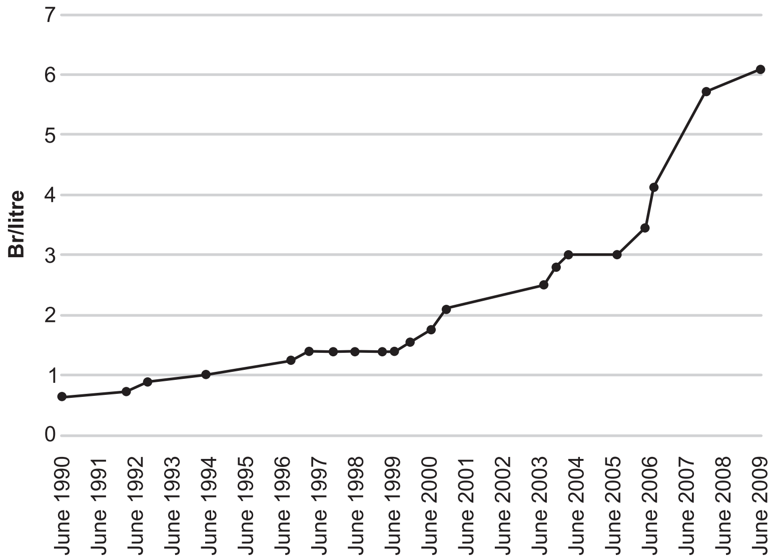

Figure 5: Kerosene price increase Birr / Litre in Addis Ababa, 1990-2009

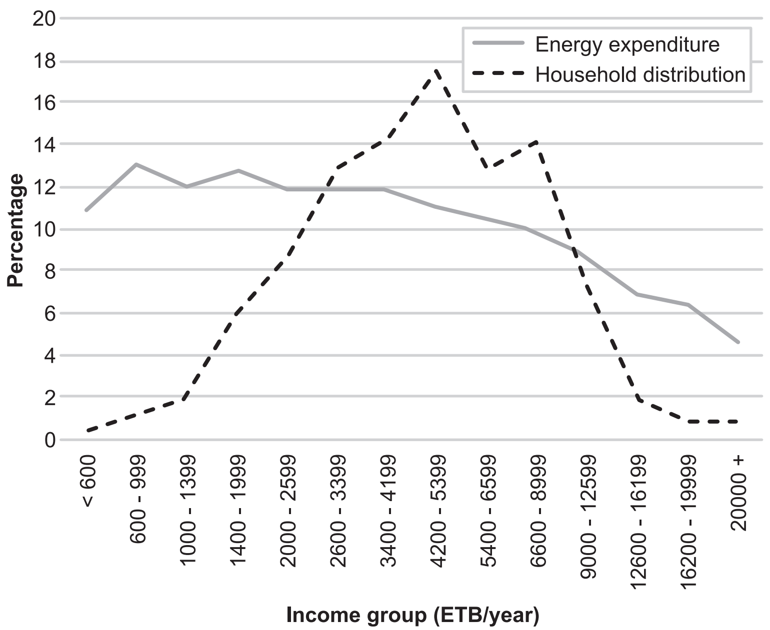

Figure 6: Histogram of energy expenditure in Addis Ababa in 2000

2009) The proportion of income spent on energy may have increased even further (than that shown in the figure) because prices have increased significantly since 2000 whereas incomes have not. Thus energy expenditure is clearly eroding the incomes of poor and middle income households in urban areas.

Tanzania

The Tanzanian Household Energy Economic Analysis was conducted in Dar es Salaam between September and October of 2009. The purpose of the study was—as with the Ethiopia case study—to estimate the relative importance of product-specific and socio-economic determinants of cooking stove choice at the household level.

Background and policy relevance

By 2010, the Tanzanian Ministry of Energy and Minerals aims to increase the number of grid-connected households by 20 per cent and to decrease charcoal and firewood usage by 80 per cent. At present, 14 per cent of urban and 2 per cent of rural households are connected to the grid.[3] Of total energy consumption in Tanzania, 90 per cent is still derived from firewood and charcoal, and less than one percent of the national energy balance is generated from sustainable renewable energy sources. The Joint Energy Sector Review state in their 2009 (final draft) report that: "The main energy challenge is to reverse the reliance on firewood and charcoal as the source of energy as this is unsustainable." [4]

Household cooking in Dar es Salaam

As can be seen in Table 2 below, Charcoal is the dominant source of energy in Dar es Salaam. It is the primary cooking fuel for almost 75 per cent of households. Fuel use is more diverse than this number would imply, however, with the majority of homes using more than one kind of cooking fuel (Sanga, 2003).

Charcoal is used by all income levels in Dar es Salaam, and in addition to being the most affordable type of fuel, it is also a part of Tanzanian culture and tradition. Households are by far the largest consumer of the fuel (Varmola, Valkonen, and Tapaninen, 2008). Use of charcoal is also favorable due to very low stove prices. The number of households using efficient charcoal stoves has increased from 49 per cent in 2002 to 72 per cent in 2007. Charcoal is commonly used in combination with kerosene, or less frequently with electricity. High-income groups generally only use electricity (Yahya, 2000). The increase of charcoal users compared to the early 1990s is at least partly an outcome of the decrease in its price, compared to alternative fuels (Ghanadan, 2004).

The trend in cooking fuel usage patterns over the last fifteen years in Dar es Salaam has been towards increasing use of solid fuels, despite government targets to reduce their use. Firewood usage has increased from a 1991/1992 level of 1.2 per cent to being

3 Joint Energy Sector Review final draft report 2009, p. 15

4 Joint Energy Sector Review final draft report 2009, p. 15

Table 2: Distribution of households by energy source for cooking (% of households) in Dar es Salaam

	1991/1992	2000/2001	2007
Electricity	9.7	4.8	2.2
Gas-industrial	1.2	0.4	2.2
Gas- biogas	N/A	0.2	0.1
Paraffin/Kerosene*	33.7	43.0	12.4
Coal	1.1	0.6	0.4
Charcoal	52.1	46.2	74.9
Firewood	1.2	4.6	8.0
Wood/Farm residuals	N/A	N/A	0.0
Other	1.0	0.3	1.1

Source: National Bureau of Statistics Tanzania[5]
** Only paraffin in 1991/92 and 2000/01*

the third most commonly used primary cooking fuel today at 8 per cent, and charcoal has strengthened its dominance from being used by one in two households in the early 1990s to being the primary choice of 75 per cent of households by 2009. Conversely, electricity has declined over the last 15 years from 7.5 per cent to today's level of a modest 2.2 per cent.

Mozambique

The Mozambican Household Energy Economic Analysis was conducted during September and October of 2009.

Background and policy relevance

The Human Development Report highlights that 18.6 million people are without access to electricity countrywide (UNDP 2008 p. 305) in Mozambique. This accounts for about 90 per cent of Mozambique´s 20.5 million population. To satisfy household energy needs, Mozambicans largely depend on traditional biomass, such as firewood and charcoal, for cooking and heating, as seen in Figure 8; firewood and kerosene are used for lighting purposes, as demonstrated by Figure 9. With 69.4 per cent of the population living below the national poverty line and largely dependent on the country's forestry resources for their energy needs, there is a need to introduce alternatives that mitigate this trend, while remaining economically viable for the poor.

As a large majority of the population directly depend on traditional biomass for their energy needs, the National Energy Policy dedicates Section 3.6 to the promotion of sustainable use of the country's biomass resources. The policy calls for a

5 Household Budget Survey 2007, Dar es Salaam January 2009, Ministry of Finance and Economic affairs, National Bureau of Statistics, Tanzania

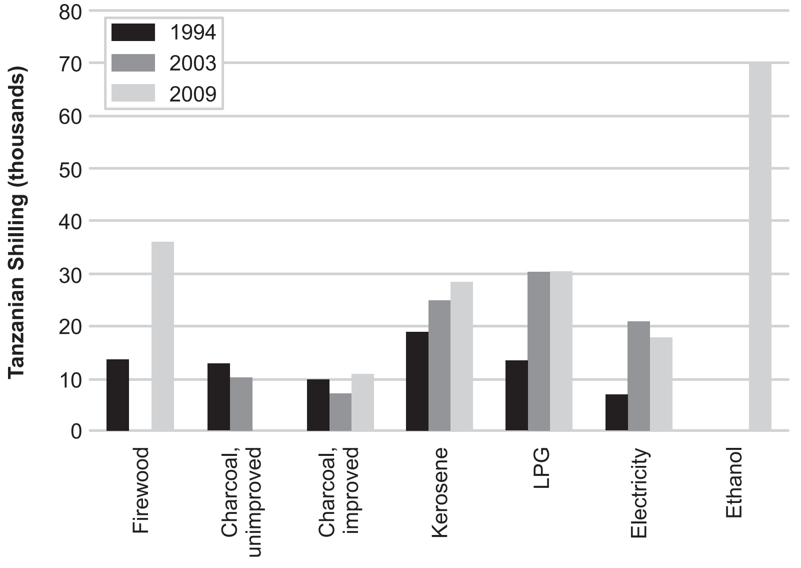

Figure 7: Illustration of price development by primary cooking fuel in Dar es Salaam.

Comments: The 2009 costs are based on an investment time of ten years.
Source: (Ghanadan, 2004) and SEI survey of fuel prices in Dar es Salaam, September 2009.

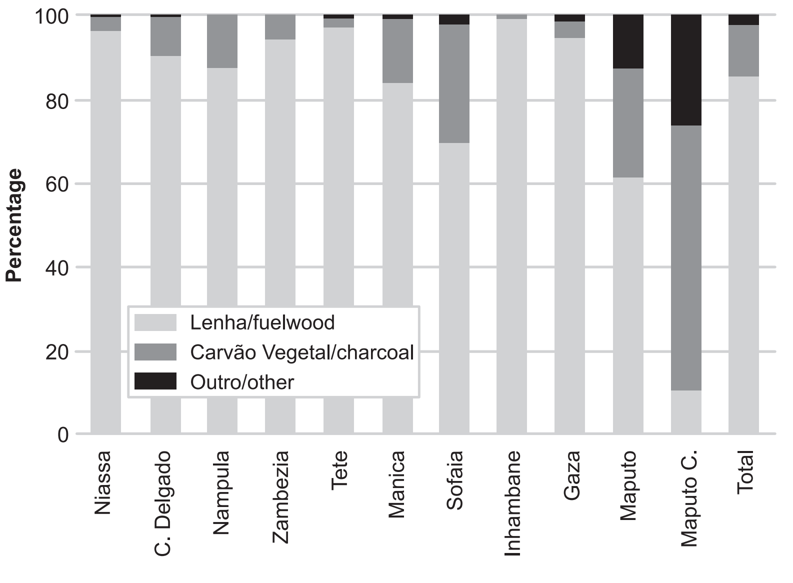

Figure 8: Household energy use for cooking in Mozambique

Source: Ministerio de Energia, 2005, Estatistica de Energia, pp. 34

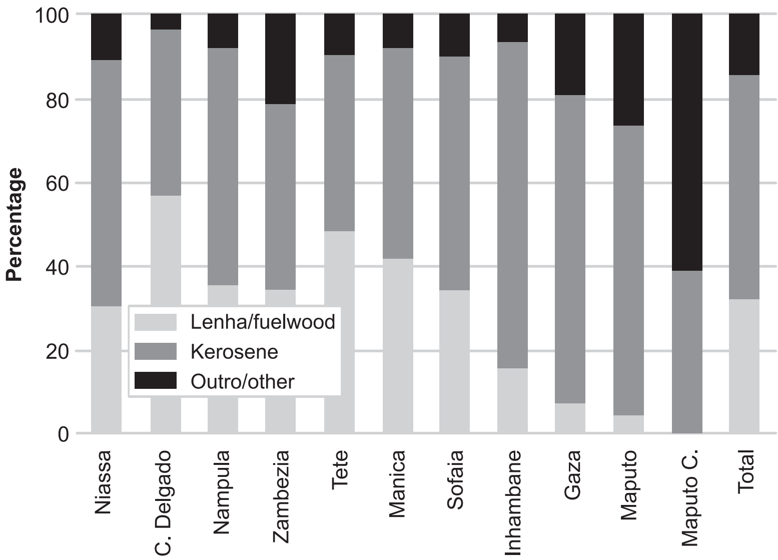

Figure 9: **Household energy use for lighting in Mozambique**
Source: Ministerio de Energia, 2005, Estatistica de Energia, pp. 34

gradual reduction in traditional biomass consumption and advocates environmental sustainability through reforestation programmes and the promotion of more efficient and environmentally considerate means to produce and consume biomass products.[6] Furthermore, the national strategy on climate change and adaptation focuses on deforestation as a result of fuelwood extraction. According to the document, 18 million cubic meters of forest are exploited annually for biomass collection, with no clear sustainability measures in place. Obstacles highlighted include the lack of community level involvement, weak institutional capacity in protecting and controlling forest areas, lack of demarcations on protected regions, as well as the lack of a clear strategy for forest management.[7]

The government of Mozambique has recently introduced its Biofuels Policy and Strategy with the core aims of ridding the country of its dependence on fossil fuel imports, promoting socio-economic development, and contributing to the global initiative of greenhouse gas reduction.[8] Mozambique is considered as one of the African countries with the largest biofuel production potential, with the capacity to produce around seven Exajoules of biofuels sustainably–a figure that assures full energy independence, with surplus to supply international markets (WWF, 2008). Furthermore, the policy promotes the use of ethanol gelfuel as a means to reduce the

6 Governo de Mocambique, Estrategia de Energia, 3 de Outubro de 2000, electronic copy: http://www.portaldogoverno.gov.mz/docs_gov/estrategia/energia/estrat_energia.pdf

7 Ministerio para a coordincao da accao ambiental, 2005, Avaliacao da vulnerabilidade as mudancas climaticas e estrategias de adaptacao. Electronic copy: http://www.portaldogoverno.gov.mz/docs_gov/estrategia/agricultura/avaliacao_vulnerab_mud_climat_estrateg_adapt.pdf

8 Governo de Mocambique, 2009, Politica e Estrategia de Biocombustiveis, 21 Maio 2009

mass use of firewood and charcoal. The focus on gelfuel, in contrast to liquid fuels, can be understood to be influenced by the Millennium Gelfuel Initiative, pioneered by the World Bank´s Regional Program for Traditional Energy Sector (RPTES).

Household cooking in Maputo

In Maputo, around 75 per cent of the population rely on charcoal and firewood for their cooking energy needs. Electricity and LPG accounts for the rest and are generally used by middle and higher income groups. Charcoal is by far the most prominent fuel, and it is used by 63 per cent of the city's population.[9] As a means to estimate household expenditures on charcoal, a baseline survey was carried out in September 2009. The results show that an average family of five requires around 70 kg of charcoal monthly. A 70 kg sack of charcoal is sold at the local market for an average of 480 Mt (17 USD). This figure is equivalent to a third of the national minimum wage (1480 Mt, equivalent to 53 USD).[10] It was also noted that many people purchase small quantities of charcoal at a time to satisfy their daily cooking needs. This occurs because they are either unable to afford a single payment for a large sack or to transport the 70 kg sack from the market. In this instance, a household spends on average 25 Meticais (0.84 USD) for about two kg of charcoal daily. The resulting monthly expenditure is 64 per cent more than it would cost to buy the 70 kg sack of charcoal.

9 Ministerio da Energia, 2006, Estatistica de energia 2005, pp 34

10 http://www.meusalario.org/Mocambique/main/salario-minimo/salario-minimos-em-mocambique

5 STATED PREFERENCE SURVEY DESIGN

This section describes how the stated preference survey for each case study was designed and pilot tested to ensure that the alternative choices and attributes selected were relevant for each site. Particular attention is given to explaining how somewhat subjective attributes such as “smokiness” and “safety” level of stoves were incorporated into the design. The survey process at each study site, including focus group discussions is then described.

A combined stated preference and discrete choice analysis, namely the multinomial logit model, enables a researcher to quantitatively study the two categories (socio-economic and product-specific attributes). A stated preference-based choice experiment survey was conducted in Addis Ababa, Ethiopia in June 2008, and in Dar es Salaam, Tanzania and a suburb of Maputo, Mozambique in September 2009. For a statistically sound representation of respondents with mutually non-exclusive socio-economic strata (e.g., age, income, education and gender), a stratified cluster random sampling technique was adopted. The sample size for the household survey was 200, 564, and 402 households in Ethiopia, Tanzania, and Mozambique, respectively, and for each stratum, a minimum of 30 samples was ensured.

The choice experiment design involved eight repeated games or treatments per respondent, in order to collect data about purchasing of eight different stoves. In addition, one experiment was randomly repeated for each respondent in order to verify consistency; thus, the total sample size for the choice experiment was, for example, 1800 in Ethiopia, and each featured three different alternatives choices. The experiment required respondents to choose between various cooking stove attributes or characteristics which were represented pictorially, rather than textually (see Figure 1). The pictorial approach allowed respondents to visualise the various choices and avoided potential confusion and fatigue which can occur when respondents are asked a series of similar questions. Using pictures also eliminated the risk of misunderstanding due to illiteracy which is prevalent in each project site. However the use of pictures in such surveys can also lead to biases. In the case of Ethiopia, to eliminate the biases, the researchers used several stove pictures and ensured that they were randomized; in Dar es Salaam and Catembe, illustrations of fuels, rather that pictures of stoves were used.

A structured household questionnaire survey was also distributed to collect socio-economic information and the respondent’s revealed preference for cooking energy choice, in an attempt to gather individual perceptions of the health and environmental impacts of firewood and charcoal use. In Maputo, 105 households were asked to indicate their opinions on these issues.

In the Ethiopian case, based on the literature review and discussions with energy experts, several attributes were considered for the stated preference (SP) and later discounted, such as start-up time, durability, fuel availability and ease of use. Only four attributes were ultimately selected: stove price, monthly usage costs, indoor smoke level, and risk. Since monetary attributes are the most important factors for the decision making on stove purchase, we include both stove price and monthly usage cost. The smoke level was chosen because the reduction of indoor air pollution is one of the main study purposes and the local NGO, Gaia Association, requested that the attribute "risk level" be added to this study. Hensher *et al*., (2005) state that it is appropriate to choose attributes based on a study purpose and a request from a stakeholder. The selection of attributes does not affect the valuation of trade-offs between the attributes, which is the primary objective of this research (McFadden, 1987).

Originally, fuel types were considered as an attribute; however, since each stove burns just one type of fuel, the fuel type became the label of the stove, and one of the objectives was to assess fuel switching. Fuel price, efficiency, and fuel quantity attributes affect the usage cost at the household level; therefore, these three attributes were combined into a single attribute, termed 'usage cost'. The level of indoor smoke depends not only on the smoke emitted by the stove, but also on the kitchen size, shape/layout, the kitchen's window size, other ventilation attributes and the duration of cooking (Heltberg, 2004). This resulted in a number of measurement complications. For example, a given quantity of smoke as such has no consistent meaning for scientists because the same level of smoke could have a varying composition of many gases and particulates (Naumoff ,2005). On the other hand, smoke level has no consistent meaning among different respondents. For example, the level termed 'highly smoky' is very subjective. Hence, it was decided to treat the smoke attribute as a pseudo-categorical variable, which assumed linear distance between each categorical response, i.e., No smoke = 1, Very little smoke = 2, Moderately smoky = 3, and Highly smoky = 4. It is acknowledged that the linear assumption is a simplification and is unlikely to represent the reality of peoples' perceptions or the real impacts (e.g. dose/ response relationship between health impacts and level of smoke). Dependent on the real perceptions, the smoke attribute will therefore tend to be under or over-estimated and this is the same for the risk attribute. These linear assumptions could be improved in the future study.

Safety/risk is another highly subjective term and often elicits varying interpretations (of same risk level or label) among respondents; therefore, we treat risk as a pseudo-categorical variable, like smoke: Highly unsafe = 1, Highly safe = 4, etc. The categorical numbers in smoke and risk were used only for modelling purposes; therefore, respondents were informed of only the description and the titles of attribute levels in the Ethiopian case. Risk and smoke thus have similar measurement problems. In order to minimise the measurement problem associated with pseudo-categorical variables, a case description approach was applied for the defined labels of smoke and risk attributes (e.g., Table 3 for the Ethiopia case study). Before conducting the experiment, each of the pseudo-categorical variables was defined for the respondents– for example, the label "moderately smoky" was defined as a situation when the smoke level inside the kitchen is so high that it causes some discomfort to the eyes and irritation to the throat. Likewise, the label 'highly smoky' was defined as a situation when smoke inside the kitchen is such that the respondent cannot stay inside kitchen without opening the kitchen windows or doors. Similarly, the following case situation was used for the risk attribute: i) Highly Safe: zero risk of burn and explosion; ii);

Moderately Safe: no risk of explosion, but risk of burn; iii) Little Unsafe: risk of both burn and explosion; and iv) Highly Unsafe: high risk of burn and explosion (specified as one burn and minor explosion every two months). These specifications were used to describe the case because people could not differentiate between minor risk and high risk.

In the Tanzania and Mozambique case studies, we improve the pseudo-categorical situation by displaying actual numbers to the respondents, i.e., “0: No”, “3: A lot”, etc. Therefore, the equal distances between levels are no longer implicitly assumed, but explicitly indicated. In addition to improving the modelling process, this also responds to the remembered levels of smoke and risks between alternatives, as many respondents could read numbers but not the alphabet. Moreover, in these two cases, the attribute that had been presented as “safety” in the Ethiopia case study was presented as “risk” to make the nature of the attribute consistent with the smoke attribute, i.e., the greater the level, the worse the attribute.

At the end of the experiment, the respondent’s understanding of the labels and levels of smoke and safety/risk attributes was tested by asking each to match the above-defined different labels and levels of risk and smoke attributes with some of the commonly used stoves, which have similar features. For example, if a respondent understood the term “moderately risky” correctly, in the questionnaire, the respondent should match moderately risky with the wood stove option, since the wood stove has a burn risk, but not an explosion risk. The test was done for all labels of risk and smoke attributes. Although this sub-project does not address the perception about issues such as indoor air pollution and deforestation, these concepts are evaluated at the same time as the conduction of the SP survey.

Using an orthogonal design technique, the number of treatments was reduced to 32, or four blocks with eight treatments per respondent in the Ethiopia case study, and 16 or two blocks of eight treatments in the Tanzania and Mozambique case studies. The blocking design divides the overall treatments into two or four groups of eight treatments and a different set of the eight treatments are asked to a different household. The number of treatments asked to a respondent should not be more than eight to avoid the fatigue of the respondent. The experiments were carried out in two steps as pair-wise comparisons, i.e., first, a respondent compared existing stoves, such as a wood stove and a kerosene stove, and then a selected stove was compared with an ethanol stove (Figure 10) in Ethiopia. When the two-step-pair-wise data were entered into BIOGEME software, this experiment was treated as a one-step-three-alternative choice. The experiments were conducted in one-step-three-alternatives in Tanzania and Mozambique, as the pair-wise approach in Ethiopia took excessive amounts of time. Cooking stove and fuel choice literature stressed income as the single most important attribute responsible for variance (Heltberg, 2005; Pachauri and Jiang, 2008). Hence, for the purpose of the study, income-based strata were used.

Finally, soft attributes like comfort, user convenience, associated status or brand also play an important role in choice, but are difficult to objectively assess and quantify.

Figure 10: Photograph of choice card and survey in Ethiopia case study

Hence, a 'labelled experiment' was used for each alternative, so that the 'alternative specific constant' (ASC) captures the cumulative strength of this attribute and its effect on choice (Hensher, Rose, and Greene 2005 p.113; Louviere, Hensher, and Swait 2000 p.220).

Ethiopia

Pilot testing of the questionnaire and choice experiment was conducted in two stages in Addis Ababa, Ethiopia. The first and second pre-tests were conducted by the staff of the Gaia Association between the 25th and 28th of June, and between the 9th and 10th July, 2008. The main survey was executed between the 10th and 20th of July 2008. To design the choice experiment, initial data analysis was carried out on a baseline data sample collected in 2005. Furthermore, a focus group discussion was conducted in Stockholm on 31st May 2008 with four energy experts, two of whom were from Ethiopia. Upon the completion of the household survey, one more focused group discussion was held in Addis Ababa with 18 cooking fuel consumers, representing different socio-economic groups and parts of Addis Ababa. This meeting was used to gather qualitative information about cooking stove and fuel choice. Since many respondents consider ethanol to be unsafe due to the K-50 problem[11] in Ethiopia, the risk label was used with this fuel.

Alternatives for the cooking stove choice experiment were evaluated based on four criteria: (1) number of users; (2) distribution across different income groups; (3) usage

11 In 2005, a local company produced kerosene and ethanol blend as cooking fuel and termed it as K-50. It developed a reputation for being explosively volatile due to poor blend and bad quality stoves; now, many respondents associate ethanol with explosions and consider it unsafe.

level; and (4) relevance to the study objectives. For example, the local energy experts suggested that almost every household uses charcoal primarily for the traditional ‘coffee ceremony’ in Ethiopia. We do not address the problem that some households may prefer to use only charcoal over other alternatives (e.g. because of the coffee ceremony). Since forecasting is not a major objective of this study, it is reasonable to exclude the dominant alternative in this choice experiment, namely the charcoal alternative. Whichever the level of attributes in an experiment, some respondents may stick with the dominant alternative. For example, no matter what the prices and the hardware specs of PCs, many people may buy a Windows PC, but not a Mac or Linux PC. If the purpose is to evaluate the monetary value of hardware specs, it is good to exclude Windows alternative to make respondents consider price and hardware attributes. Thus, on the basis of the above criteria and discussion, kerosene and wood were selected as relevant cooking fuel alternatives. In order to understand the switching pattern from traditional to a newer modern fuel the ethanol alternative was added. The allocation of levels and labels of the four attributes amongst the three alternatives is a critical part of the choice experiment (Table 3). The levels of price and monthly cost were determined based on the literature reviews and interviews with experts. For example, the range of kerosene stove was found between 30 and 150 Ethiopian Birr (ETB), so that we tested three levels such as 30, 70, and 150 ETB in the experiments.

Tanzania

Prior to the main survey, a pre-pilot survey in focus group format and pilot survey were carried out at the University of Dar es Salaam (UDSM). Focus group discussions were held in order to evaluate the applicability of the cooking stove choice experiment design, as well as the survey questionnaire used in the Ethiopian study, and to fine-tune the pilot survey. The pre-pilot study took place in focus group format during three sessions over the 27th and 28th of August, 2009. The groups were composed of 11 participants selected to represent low, medium and high-income levels. In addition to discussions about cooking stove/fuel choice and the evaluation of fuel attributes and adoption of the model to Tanzania, a more open conversation about fuels and stoves was held. Focus group discussions were followed by a pilot survey on the 4th of September. The main survey was carried out between the 14th and 18th of September 2009 by twelve research assistants from UDSM. The survey period was preceded with one day of training for the surveyors. Four areas–Mikocheni, Bunju, Temeke and Kigamboni–of Dar es Salaam were selected as the main survey areas, as they included low, medium and high-income groups. Additional survey areas included Changombe, Tabata Segerea, Kijitonyama, Mwenge, Karakata, Makumbusho, Yombo vituka and Tabata.

In Dar es Salaam, charcoal is, as presented earlier, by far the most commonly used fuel for cooking, with approximately 75 per cent of the population using it as the primary cooking fuel. Charcoal was not included as an alternative due to its dominance and risk of bias as explained above on the discrete choice model applications and also to make the case study consistent with the Ethiopian case. Having excluded charcoal,

Table 3: Allocation of levels and labels for the four attributes in the Ethiopian case study

	Ethanol	Kerosene	Wood
Stove price (ETB)	{500, 250, 100}	{150, 70, 30}	{120, 50, 20}
Usage cost (ETB)	{60, 120, 160, 320}	{50, 100, 150, 300}	{40, 80, 140, 250}
Indoor smoke	{No smoke, Very little smoke}	{Very little smoke, Moderately smoky}	{Very little smoke, Highly smoky}
Safety risk	{Little unsafe, Highly safe}	{Highly unsafe, Little unsafe}	{Moderately unsafe, Highly safe}

firewood was selected instead. Firewood is becoming a less common cooking fuel in Dar es Salaam and other urban areas, but is still widely used in rural locations; thus, it was chosen to represent a traditional fuel with many similar properties to charcoal. In addition to firewood, kerosene was selected as an important fuel (second after charcoal in Dar es Salaam), and ethanol, as a representation of a modern fuel.

Ranges of prices for stoves and monthly costs were obtained from Internet research and confirmed by a field survey in Dar es Salaam in August 2009. The findings are presented in Table 4 below. In comparison to the Ethiopian study, stove prices included four levels instead of three, and indoor smoke and safety risks also featured four levels, both uniformly on a 0-3 scale.

Mozambique

The stated preference-based survey was administered in the municipal district of Catembe, an extension to the city of Maputo, with a distinct blend of urban, peri-urban and rural characteristics. The region can be seen as a representation of the country at large. Catembe has an estimated population of 21,000 inhabitants, of which 85 per cent Is engaged in agricultural activities, and 10 per cent in fishing. The survey team covered four neighbourhoods–Guachene, Chali, Incassane and Inguide. Each neighbourhood offers a different setting: Guachene and Incassane are commercial centres inhabited by mostly lower and middle income people, Chali is a more affluent area, and Inguide has a distinct rural aspect with straw and thatch housing. The model design used for the choice experiment corresponds to those used for the Ethiopian and Tanzanian studies. One difference, however, was the choice of alternatives, as charcoal replaced kerosene (Table 5). Due to a lack of published and updated data on fuel and stove price ranges, it was necessary to carry out a study prior to the survey to determine the price ranges for the model. The study covered three marketplaces in Maputo and one in the district of Catembe. In addition, a focus group discussion

Table 4 : Allocation of levels and labels for the four attributes in the Tanzania case study

	Ethanol	Kerosene	Firewood
Stove price (TZS)	{20 000, 30 000, 40 000, 50 000}	{5 000, 10 000, 15 000 20 000, }	{100, 10 000, 20 000, 30 000}
Usage cost (TZS)	{30 000, 50 000, 70 000, 90 000}	{1 000, 10 000, 20 000, 30 000}	{10 000, 20 000, 30 000, 40 000}
Indoor smoke	{0: No smoke, 1: Little smoke, 2: Moderately smoky, 3: Very smoky}	{0: No smoke, 1: Little smoke, 2: Moderately smoky, 3: Very smoky}	{0: No smoke, 1: Little smoke, 2: Moderately smoky, 3: Very smoky}
Safety risk	{0: No risk, 1: Little unsafe, 2: Moderately unsafe, 3:Highly safe}	{0: No risk, 1: Little unsafe, 2: Moderately unsafe, 3:Highly safe}	{0: No risk, 1: Little unsafe, 2: Moderately unsafe, 3:Highly safe}

amongst household cooks in Maputo served to confirm the choice of alternatives and levels of attributes chosen.

Training of the survey team took place on the 17th and 18th September 2009. Five surveyors were recruited. A pilot survey was carried out by the survey team on the 19th September 2009 and allowed for the fine-tuning of the choice model and socio-economic questionnaire. The implementation of the choice experiment and socio-economic questionnaire took place between the 21st September and the 1st October 2009.

Table 5: Allocation of levels and labels for the four attributes in the Mozambique case study

	Ethanol	Charcoal	Firewood
Stove price (MZN)	{100, 500, 1000, 1500}	{ 50, 200, 400, 600}	{1,50, 100, 150}
Usage cost (MZN)	{400, 700, 1000, 1300}	{ 300, 600, 900, 1200}	{1, 200, 400, 600}
Indoor smoke	{0: No smoke, 1: Little smoke, 2: Moderately smoky, 3: Very smoky}	{0: No smoke, 1: Little smoke, 2: Moderately smoky, 3: Very smoky}	{0: No smoke, 1: Little smoke, 2: Moderately smoky, 3: Very smoky}
Safety risk	{0: No risk, 1: Little unsafe, 2: Moderately unsafe, 3:Highly safe}	{0: No risk, 1: Little unsafe, 2: Moderately unsafe, 3:Highly safe}	{0: No risk, 1: Little unsafe, 2: Moderately unsafe, 3:Highly safe}

6 RESULTS

This section begins by presenting the utility functions for the three stove choices in each case study. The general model is then examined and some trends across the three cases are identified. There follows a examination of the results in terms of the importance of product-specific attributes across the various socio-economic strata for influencing choice of stove in each case study. The relative strengths of product-specific attributes for different market segments across socio-economic strata are then discussed and some significant findings are presented, both in terms of stove preferences but also the trade-offs made between attributes at different income levels. Trends in decision making across the socio-economic strata in all three cases are highlighted.

Utility parameters

The following utility functions have been specified for the three alternatives across the different socio-economic strata without an error term, i.e., U = V + ε: A U represents, unobserved utility and an ε represents errors in observation, so that a V represent observed utility. A β represents a weighting parameter of a relevant attribute and an α represents partial utility associated with a type of a stove which is not captured by other βs. i.e. Alternative Specific Constant (ASC).

Ethanol:	V_i^E	=	$\alpha^E + \beta^{cost}(cost\_e) + \beta^{price}(price\_e) + \beta^{risk}(risk\_e) + \beta^{smoke}(smoke\_e)$
Kerosene (Charcoal):	V_i^K	=	$\alpha^K + \beta^{cost}(cost\_k) + \beta^{price}(price\_k) + \beta^{risk\ (risk\_b)}(risk\_k) + \beta^{smoke}(smoke\_k)$
Wood:	V_i^W	=	$\alpha^W + \beta^{cost}(cost\_w) + \beta^{price}(price\_w) + \beta^{risk\_b}(risk\_w) + \beta^{smoke}(smoke\_w)$

This model is the basis of all three cases; however, one of the alternatives is charcoal instead of kerosene in the Mozambique case. In addition, α^K in the Tanzania case and β^{smoke} in the Mozambique case were removed. Each variable name represents a relevant attribute shown in Table 3, and its suffix represents alternative fuel used for the stoves. The α of firewood is fixed as zero. All alternatives use the same parameters, except the risk of firewood and charcoal, β^{risk_b}, because risk issues are different between liquid and solid fuels, i.e., firewood and charcoal do not present explosion risks. Hence, the logistic form of the fitted model for choosing the ethanol stove is:

$$P(\text{Ethanol}) = \frac{\exp\ (V_i^E)}{\exp\ (V_i^E) + \exp\ (V_i^K) + \exp\ (V_i^W)}$$

The logistic forms for the other two options are similar to the one above. P(Ethanol) is the probability of choosing an ethanol stove in a given situation. The model is based on the work of McFadden (1973), and it has been used to study cooking stove choice (Heltberg, 2004; Narasimha Rao and Reddy, 2007; Ouedraogo, 2006; Pundo and Fraser, 2006). BIOGEME software[12] was used for the parameter estimation of the discrete choice analysis.

The general model

P-values in Table 6 show that all two constants and five parameters are significant at 5 per cent levels in the three cases. The ASC of charcoal for the Tanzania case and the smoke parameter for Mozambique were removed, as these ASC and parameters are consistently insignificant in almost all social segregated models, to be explained in the next section. This indicated that these coefficients are most likely to be insignificant attributes in the context of the two cases. We retain the rest of the model components for the comparison between the three cases. A positive ASC signifies that the associated alternative generates utility for the respondent, while a negative parameter shows that any increase in the respective attribute level will reduce utility. All monetary values were translated into U.S. dollars; the exchange rates used are 12.5 Ethiopian Birr (ETB), 1,300 Tanzanian Schilling (TZS), and 26 Mozambican Metical (MZN).

The three cases may not be directly comparable, as monetary parameters may not correctly reflect purchasing power parity between the three countries, and risk and smoke parameters can be biased due to perception differences. Given the above, some interesting trends were observed. ASCs well reflect the actual situations of the studied regions. For example, in Ethiopia, people are negative about kerosene stoves due to serious explosion issues that arose several years ago. The negative α^K for the Ethiopian case reflects the unpopularity of kerosene stoves. In addition, charcoal stoves are the dominant stove in Mozambique, so the ASC for charcoal stoves is very strongly positive. An ethanol stove is more positively accepted than a firewood stove in all three cases. An ASC represents only relative utility, so the ASC of one alternative is fixed as zero. In this case, the ASC of firewood is fixed at zero.

In β parameters, the Ethiopia and Tanzania cases have more similar results than those of the Mozambique case, so the usage cost and stove price have similar coefficient values even in absolute terms. In relative terms, the effects of the usage cost are slightly higher than those of stove price in all three countries. Where they exist, all risk parameters have stronger coefficients than the corresponding smoke coefficients. The insignificant smoke parameter in the Mozambique case is confirmed by field observation and expert opinion. Unlike other cases, people in the Mozambique case study often cook outside, so they are not as concerned about smoke levels.

Specific models

This section analyses the relative strengths of product-specific attributes for different market segments, differentiated on the basis of socio-economic characteristics. Due to

12 http:// biogeme.epfl.ch/

Table 6: The general parameters derived from the BIOGEME model

		Ethiopia		Tanzania		Mozambique	
Parameter	**Description**	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeffi.**	**P-value**
α^{E}	ASC for Ethanol	.415	.05	. 666	<.01	. 427	<.01
$\alpha^{K/C}$	ASC for Kerosene or Charcoal	-.392	.04	--	--	. 558	<.01
α^{W}	ASC for Firewood	Fixed	---	Fixed	---	Fixed	---
β^{cost}	Usage Cost	-.029	<.01	-.024	<.01	-.009	<.01
β^{price}	Stove Price	-.024	<.01	-.022	<.01	-.008	<.01
β^{risk}	Explosion risk	-.272	<.01	-.296	<.01	-.357	<.01
β^{risk_b}	Burn risk	-.256	<.01	-.298	<.01	-.118	<.01
β^{smoke}	Indoor Smoke	-.101	<.01	-.214	<.01	--	--

the lack of a panel structure (mentioned above), the comparison of model coefficients for different socio-economic groups may underestimate the effects of other socio-economic characteristics in a particular model because such characteristics are not controlled in the models. However, this approach yielded clear outcomes, even when considering the inevitable "noise" or error in the SP survey due to low adult literacy rates (e.g., less than 50 per cent in Ethiopia) (Watkins, 2008), the un-computerised survey process, and related attributes. The results of the choice experiment in estimating product-specific attribute strengths across different socio-economic attributes are presented in Table 7, Table 8, and Table 9, respectively. The figures in square brackets represent insignificant variables at the 10 per cent level.

The Tanzania case has the most significant outcomes, as all parameters across all the socio-economic classes are significant, except the omitted ASCs of kerosene, which indicate that people in this case do not have significant preferences between kerosene and firewood stoves. Overall, the Ethiopia and Tanzania case studies show relatively similar results to explain the differences in parameters and ASCs amongst socio-economic classes. The results from the Mozambique case study also have significant values when compared with the other two cases. Although some estimated parameters in the Ethiopian and Mozambican cases did not show significant outcomes, all estimated parameters across the ten socio-economic classes in the three cases display negative coefficients, except the smoke coefficient for the low-income class in Ethiopia, which is statistically insignificant. The negative coefficients are expected, as higher usage cost, higher price, more risk, and higher smoke levels are expected to reduce the utility of a respondent, regardless of geographical location and socio-economic status. This simple but important result confirmed that these stove attributes as "product-specific characteristics" to some extent universally influence stove purchase decision-making.

Table 7: Specific model output of the Ethiopia case study

Models		**Coefficients**						
		α^{E}	α^{K}	β^{cost}	β^{price}	β^{risk}	β^{risk_b}	β^{smoke}
General:		.415	-.392	-.029	-.024	-.272	-.256	-.101
Income:	Poor	.508	[.119]	-.043	-.045	-.236	-.298	[.068]
	Middle	[.077]	-.71	-.035	-.030	-.340	-.253	-.155
	High	[.633]	[-.602]	-.015	[-.008]	-.336	-.310	-.322
Gender:	Female	.369	-.488	-.024	-.024	-.250	-.208	-.113
	Male	.479	-.280	-.031	-.023	-.281	-.300	-.089
Education:	Low edu.	[.405]	-.259	-.029	-.029	-.293	-.274	[-.020]
	High edu.	[.419]	-.531	-.028	-.019	-.257	-.246	-.198
Age:	Below 30	[.045]	-.618	-.043	-.019	-.262	-.184	[-.062]
	31-40 Yrs	.469	-.515	-.026	-.033	-.249	-.195	-.134
	Above 41	.672	[-.057]	-.019	-.016	-.300	-.381	-.102

Table 8: Specific model output of the Tanzania case study

Models		**Coefficients**						
		α^{E}	α^{K}	β^{cost}	β^{price}	β^{risk}	β^{risk_b}	β^{smoke}
General:		.666	--	-.024	-.022	-.296	-.298	-.214
Income:	Poor	.659	--	-.029	-.025	-.244	-.191	-.16
	Middle	.734	--	-				
023	-.025	-.345	-.371	-.274				
	High	.555	--	-.018	-.013	-.303	-.369	-.19
Gender:	Female	.742	--	-.024	-.027	-.392	-.382	-.275
	Male	.617	--	-.025	-.019	-.236	-.244	-.183
Education:	Low edu.	.953	--	-.033	-.037	-.304	-.219	-.241
	High edu.	.555	--	-.021	-.016	-.297	-.346	-.203
Age:	Below 30	.7	--	-.023	-.024	-.286	-.28	-.184
	31-40 Yrs	.919	--	-.026	-.034	-.235	-.204	-.295
	Above 41	.421	--	-.025	-.012	-.359	-.410	-.195

Table 9: Specific model output of the Mozambique case study

Models		Coefficients						
		α^E	α^C	β^{cost}	β^{price}	β^{risk}	β^{risk_b}	β^{smoke}
General:		.427	.558	-.009	-.008	-.357	-.118	--
Income:	Poor	.416	.557	-.008	-.007	-.336	-.0868	--
	Middle	.511	.476	-.009	-.009	-.245	-.132	--
	High	.37	.647	-.01	-.008	-.515	-.157	--
Gender:	Female	.412	.532	-.009	-.006	-.393	-.123	--
	Male	.531	.758	-.01	-.019	[-.144]	[-.0753]	--
Education:	Low edu.	.337	.43	-.008	[-.003]	-.347	-.0908	--
	High edu.	.535	.706	-.01	-.014	-.371	-.152	--
Age:	Below 30	.474	.514	-.008	-.012	-.338	-.142	--
	31-40 Yrs	.264	.501	-.007	[-.003]	-.362	[-.058]	--
	Above 41	.47	.705	-.011	[-.004]	-.401	-.122	--

The negative sign of the usage cost (β^{cost}) coefficient implies that increasing the usage cost generates negative utility for respondents. In addition, the stove price (β^{price}) coefficient, as expected, is similar to the usage cost coefficient, in that it is significantly negative for all socio-economic stratums, except the high-income class in the Ethiopia case study and some classes in the Mozambique case study. A given change in stove price will affect the low-income group utility more than five times that of the high-income group in the Ethiopian case, and the respective rate is approximately doubled in Tanzania. The negative indoor smoke coefficient (β^{smoke}) in the Tanzanian and Ethiopian cases indicates that increasing smoke levels reduces utility. However, the insignificant coefficients of some particular groups may also indicate that the decisions in these groups cannot be affected by smoke attributes, and hence, the respective coefficient value has no meaning. Some reported that indoor smoke played a role killing bugs; therefore, they might actually prefer to have indoor smoke. The explosion risk (β^{risk}) coefficient is, as expected, negative for all strata in the Ethiopian and the Tanzanian cases, and there is only one insignificant estimate in the Mozambique case study. This indicates that people prefer a safe stove to a risky one.

The ASC (α) coefficients reveal different trends between the three cases. In Ethiopia, all strata except the low-income group have the following preference order: ethanol, followed by wood, then the kerosene option. This indicates that, all things being equal, people prefer ethanol to wood and kerosene; furthermore, it demonstrates that except for the low-income group, people prefer wood to kerosene. Across many strata, the ethanol ASC coefficient is insignificant; such results are expected, given that these fuel options are presently non-existent or non-utilised for many people in Ethiopia.

In Tanzania, the ethanol stove is also the most preferred alternative, if all attribute levels are similar, i.e., ethanol ASCs always have high significant values, but kerosene ASCs do not. As a result, ASCs for kerosene were removed from the Tanzania case study. This indicates that people prefer an ethanol stove by a significant margin over a firewood or kerosene stove. In Mozambique, charcoal is by far the more dominant stove choice, and the results support this trend. Unlike the other cases, the preference order is always charcoal, ethanol, and then firewood for most social classes in Mozambique.

Socio-economic strata

The socio-economic specific model shows that in all three case studies, barring few exceptions, all product-specific attributes (usage cost, stove price, risk and smoke levels) affect choice decisions across the entire specified socio-economic strata, including age, education, income and gender. However, as indicated by the different coefficient values, the relative importance of attributes and trade-offs are different with each stratum. A brief but detailed discussion on the general pattern observed is warranted for each stratum.

The coefficient value of usage cost is highest for the low-income group and lowest for the high-income group in the Ethiopia and Tanzania case studies, but not in the Mozambican case. The trends in the first two countries indicate that a given increase in the usage cost will have the most negative impact on poor households and the least negative impact on the rich. The impact is more significant in the Ethiopian case than the Tanzanian case. In Ethiopia, the low-income group is affected nearly three times as much as the high-income group, while the Tanzanian low-income group is less than twice as much affected than the high-income group. The coefficients for risk are generally weaker in the low-income group across all cases. This indicates that with an increase in income level, people are to some extent more sensitive to safety or averse to the risk of explosion and burning.

The male group is more sensitive to usage cost than the female group in the Ethiopian and Tanzanian cases (Figure 11 and Figure 12), possibly because of the traditional household division of labour; women in these countries are responsible for cooking, while men are responsible for the household budget and for shopping. The unit of these figures is a partial utility in a relative term, so that these numbers do not have any meaning in the absolute term. The relative values show that men are more sensitive to budget affairs. Women are indifferent to the usage price and fuel price in the Ethiopian case and more significantly affected by stove price in the Tanzanian case, while men are more sensitive to usage cost than stove price in the Ethiopian and Tanzanian cases, which further substantiates the above observation. Focusing on smoke coefficients, the female group coefficient is higher than that of the male group in the Ethiopian and Tanzanian cases, suggesting that women are more concerned about smoke levels while cooking, so this result is consistent (Figure 13). The divergences between the three countries can be due to the cultural reasons or inefficiency in the statistical analysis. In either case, we need further studies such as in-depth social assessments and further statistical analyses to understand the real causes.

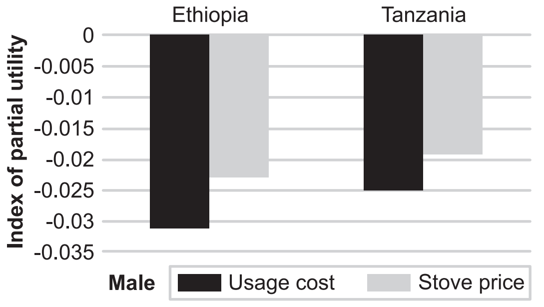

Figure 11: Comparison between usage cost and stove price of men in Ethiopia and Tanzania (in partial utility)

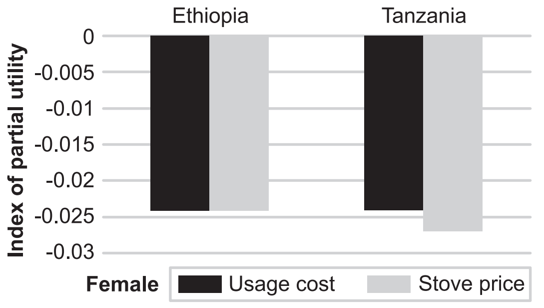

Figure 12: Comparison between usage cost and stove price of women in Ethiopia and Tanzania (in partial utility)

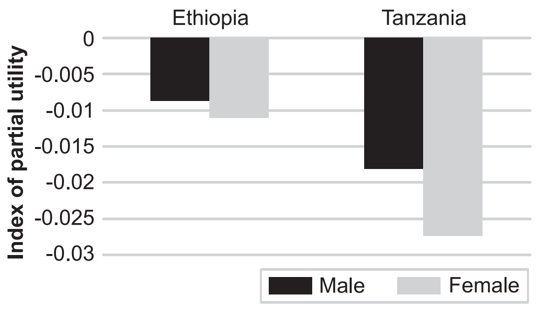

Figure 13: Comparison of smoke level coefficients between men and women in Ethiopia and Tanzania

Education is classified into two strata, namely “low” and “high.” A respondent is classified as having a low level of education if he or she has only received primary education or no formal education. Education and income-based strata result trends are similar, indicating a strong correlation between the two characteristics. For example, smoke is as insignificant to the low-income group as it is for the less educated group in the Ethiopia case study, i.e., the low-income group is more sensitive to burns than explosions, as is the less educated group. Moreover, like income classes, both monetary estimates are more negatively significant in low-educated households rather than high-educated households in the Ethiopian and Tanzanian cases. The highly educated group is more likely aware of fuel attributes and the dangers of indoor air pollution. Hence, some non-income attributes such as education could play a role in decision making processes regarding cooking stove and fuel. As aging respondents are less sensitive to price and cost, this indicates that the older population is generally less likely to switch stoves due to these attributes in the Ethiopian case, but not in the other two cases.

Trade-off between product-specific attributes

The trade-off between attributes is presented as a ratio of an individual attribute coefficient and the stove price coefficient (Table 10). The trade-off can be interpreted as the value (described in stove price unit, in USD) that a respondent would pay to receive one more or one less unit of another attribute specified in the model; therefore, this can be viewed as the Marginal Willingness to Pay (MWTP) based on the stove price. It may also be understood as an exchange rate between attributes based on the stove price.

The values in square brackets are insignificant values, as either a subject coefficient or a stove price coefficient was determined to be not statistically significant.

The trade-off trends are not universal, but some interesting trends are observed. For example, the first column of the figure shows how much households are willing to pay for one unit (1 USD) worth reduction in the stove price. In Ethiopia, low-income households want to pay only 0.956 USD, compared to 1.167 USD and 1.875 USD, which the middle and high-income groups are willing to pay, respectively. In general, with increases in the level of income, people in Ethiopia are willing to pay more for a unit reduction in the usage cost. This result is quite intriguing: it reflects the very high discount rate associated with the low-income group, and the capital cost constraint difference between the poor and other income groups, i.e., pay now or pay later.

It is also important to emphasise the trade-off between product-specific attributes, as this indicates relative importance and significance amongst attributes. As shown in Figure 14, the usage cost generally affects decision making significantly more than the stove price does because the usage cost of the general model is more significantly negative than that of the stove price. However, this does not universally impact all individuals. In the socio-economic specific models, the stove price is more significantly negative in low-income households than the usage cost, indicating that low-income people care more about the stove price than the usage cost. In contrast, as evidenced by the bar plots, usage cost is more significant than stove price for middle and high-

Table 10: Trade-off between attributes (MWTP) based on stove price

		β^{cost}	β^{risk}	β^{risk_b}	β^{smoke}
Ethiopia	General	1.208	11.333	10.667	4.208
	Low	0.956	5.244	6.622	[-1.511]
	Middle	1.167	11.333	8.433	5.167
	High	[1.875]	[42.000]	[38.750]	[40.250]
Tanzania	General	1.091	13.455	13.545	9.727
	Low	1.160	9.760	7.640	6.400
	Middle	0.920	13.800	14.840	10.960
	High	1.385	23.308	28.385	14.615
Mozambique	General	1.125	44.625	14.750	
	Low	1.143	48.000	12.400	
	Middle	1.000	27.222	14.667	
	High	1.250	64.375	19.625	

income groups. A lower usage cost reduces the overall cost of a cooking stove in the long term. Therefore, the low-income group considers an initial investment, such as stove price, to be more significant in the short term but less so in the long term.

This trade-off phenomenon between attributes amongst different socio-economic classes is even more important when non-monetary attributes such as smoke and risk are compared (Figure 15 and Figure 16) in the Ethiopian and Tanzanian cases. For

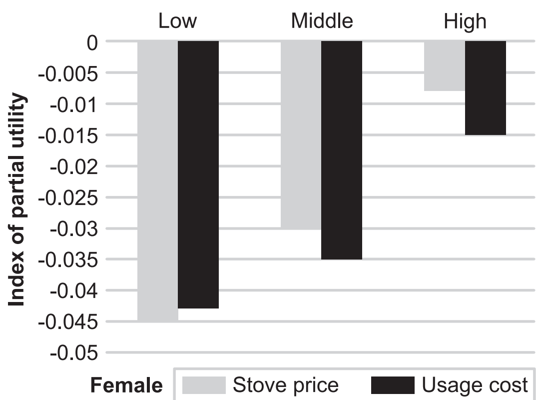

Figure 14: Comparison of Stove Price and Usage Cost Coefficients in the Ethiopia Case

example, it is interesting to note that for a unit reduction in the smoke level, the low-income group is willing to pay only 6.4 USD, while the wealthier group is willing to pay more than twice that amount (14.615 USD) in the Tanzania case study. As a whole, similar to usage cost, with increases in income level, the willingness to pay for a unit with reduced smoke levels and risk attributes increases significantly in the two cases.

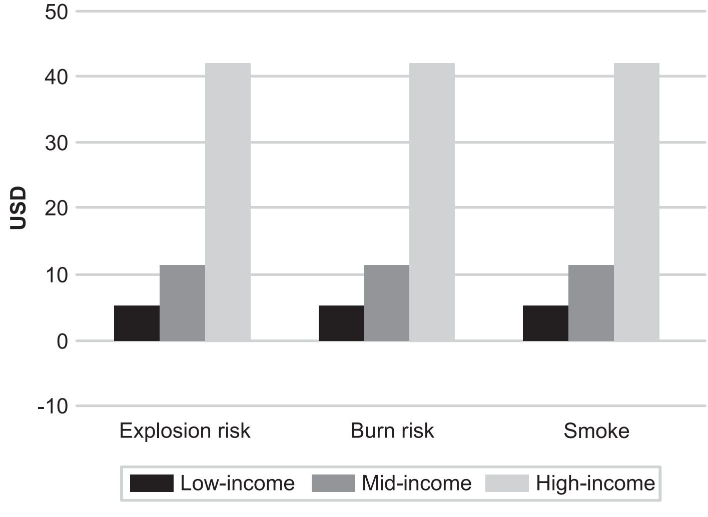

Figure 15: MWTP of soft attributes between income groups in Ethiopia

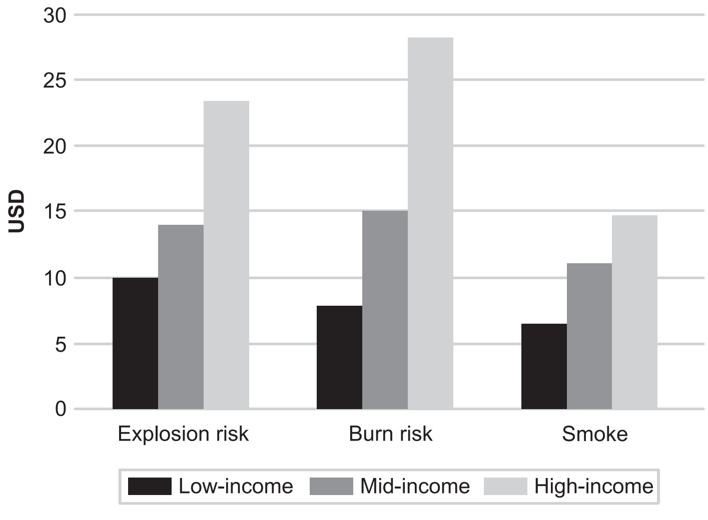

Figure 16: MWTP of soft attributes between income groups in tanzania

7 FUEL SWITCH SIMULATION

The following section examines the potential of the methodology for simulating fuel switching patterns under different scenarios. Given the trade-offs made between various stove attributes at different socio-economic levels, and taking existing market conditions in a given location (in this case, the example taken is Ethiopia), stove price and usage cost (fuel cost) of the ethanol stove are specified to estimate the market share under differing scenarios. From this, the demand for three stoves (ethanol, woodfuel and kerosene) under various ethanol pricing scenarios is simulated. In addition, the demand for the ethanol stove among three income groups (high, middle and low) under various ethanol fuel pricing scenarios is simulated.

Fuel switching patterns can be simulated based on the estimated coefficients and the application of extra measures described in the method section. This is derived from estimating the potential demand for the three alternatives in the different scenarios of attribute level–such as usage cost, stove price, smoke level, and risk level–within the observed range of the experiment. This scenario makes an attempt to simulate the demand for ethanol under existing market scenarios. The attributes/inputs of the kerosene and wood alternative have been specified on the basis of the current market scenario (Table 11). As the market for ethanol does not exist, the inputs were specified based on the following conditions: (i) the stove price of 500 ETB (i.e., 40 USD) is the likely imported price of the stove; (ii) the ethanol risk has been specified as moderately not risky, as some respondents have the perception of it being unsafe because of previous negative experiences with kerosene and ethanol blended fuels; and (iii) usage cost has been simulated in the observed range, namely between 60 to 320 ETB (i.e., 4.8 to 25.6 USD). In addition, a lowered ethanol stove price is tested to simulate the scenario of a subsidy applied on the ethanol stove.

PPlot (A) in Figure 17 shows demand curves for the three alternative stoves under different ethanol usage cost scenarios, with the most likely stove price of 40 USD. The slope indicates switching patterns for the simulated scenarios above. The graph shows that if ethanol fuel is provided at the minimum observed cost, it can secure only a third

Table 11: Simulation inputs: the stove price and usage cost of an ethanol stove vary and the remaining attributes are fixed

	Ethanol	Kerosene	Wood
Stove price ($)	{20, 40}	9.6	8
Usage cost ($)	(4.8, 25.6)	12	12
Indoor smoke	No smoke	Moderately not smoky	Moderately smoky
Safety risk	Moderately not risky	Highly risky	Moderately risky

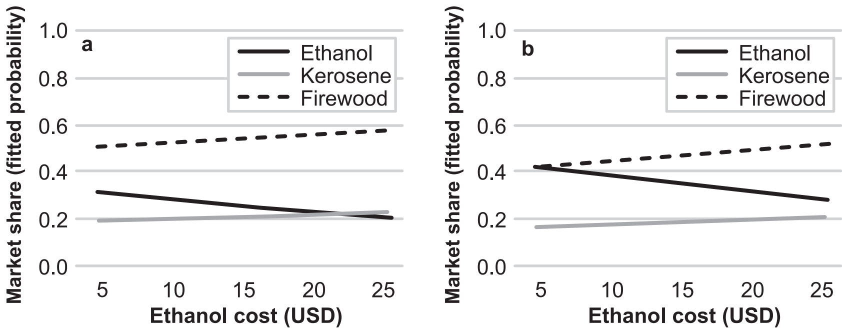

Figure 17: Demands for three stoves under changing ethanol fuel price scenario

of the existing market. If ethanol fuel is priced equally to kerosene (usage cost of 12 USD per month), *ceteris paribus*, the market share will be reduced to approximately 27 per cent, while (other things being equal) kerosene and firewood stoves will have a market share of 20 per cent and 52 per cent, respectively. Despite its advantageous characteristics, such as cleanliness and safety, the ethanol stove cannot dominate the market.

The popularity of the ethanol stove can be achieved by a cut in its price. Plot (B) of Figure 17 shows that when the stove price is reduced to 20 USD (e.g., by governmental subsidy, technological innovation, carbon finance), the ethanol stove is the most popular stove, when its monthly usage cost is also set at the lowest scenario. This simulation showed that although it is still difficult to make the ethanol stove the most popular stove in the market it is not an impossible scenario if stove price and monthly cost are reduced at the same time.

When we look at segmented markets, the trend in market shares is more clearly explained. Plot (A) of Figure 18 shows the demands for the ethanol stove when the stove price is 40 USD as the plot (A) of Figure 17 . However, Figure 18 shows the segmented demands by different income groups such as low, middle and high income. As Figure 17 , all demand curves in Figure 18 have downward trend and the demand curve of the low income group is the steepest as the usage cost of the low income group has the largest negative coefficient (Table 7). Also at any points in the plot, demand for the ethanol stove by the high income group is the most and followed by the low and middle income groups.

Plot (B) of Figure 18 shows that the demand of ethanol stove increases when the stove price is reduced to 20 USD as explained above. The point of focus is the change in the demand of the low income group. If, for example, the usage cost becomes the lowest by the drop in the ethanol fuel price, the demand of the low income group becomes higher than that of the high income group. This means that the change in the demand

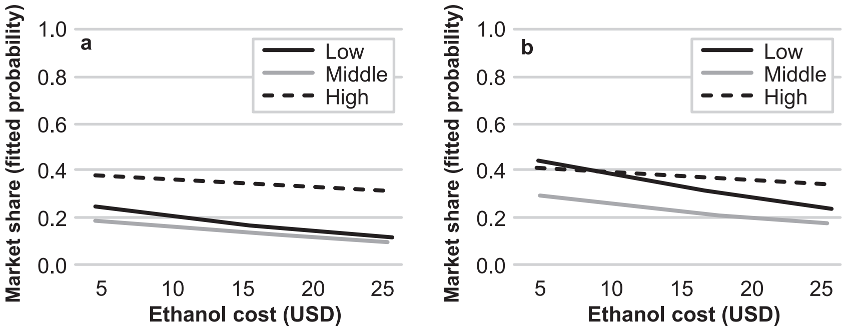

Figure 18: Demands for ethanol stoves in three income groups under changing ethanol fuel price scenario

of the low income group becomes a key driving force behind a movement in popularity of the ethanol stove in the plot (B) of Figure 17 .

This simulation demonstrated the effects of product-specific attributes such as stove price and usages cost to the market share of stoves and how the socio-economic attributes also contribute to the analysis in the simulation. Based on the estimated coefficients and trade-off among the product-specific attributes in different socio economic groups, simulation for stove switching patterns under different scenarios can be conducted for policy consideration to promote clean cooking stoves. This simulation taught that it is effective to reduce both usage and purchase costs to promote the ethanol stove especially if the low income group is its target market.

8 OVERALL DISCUSSION

This section opens with a reflection on the methodology used, focusing on some areas for improvement in future applications. Among the possible improvements discussed are the possibility of including additional attributes in future models and ways to improve the categorisation of the more subjective, "soft attributes" such as smokiness and safety. There follows a discussion on the advantages of using a "trade off" as opposed to a "wish list" approach in identifying attributes affecting stove choice. This leads on to a detailed discussion on the need to consider product-specific as well as socio-economic factors as determinants of cooking stove choice.

Suggestions on the modelling for further research

Although the model used in this study shows some interesting and significant outcomes, there could be some areas to improve–namely 1) additional attributes, 2) panel data structure, and 3) dummy variables for soft attributes. This short section discusses the possibility of these three improvements, while explaining the rationale for adopting the current model in this research.

First of all, like other regression-based models, the fit can be improved by including additional variables, such as income level, age, education, occupation or any other socio-economic attributes affecting variability. However, the inclusion of such attributes would defeat the study's purpose of separately assessing attributes that relate to product-specific and socio-economic variables. Furthermore, the main purpose of the model is the valuation of trade-off between attributes, but not to forecast; thus, no additional effort was made to improve the $\rho 2$ value which indicates model fitness. Having said that, in future research, additional attributes can be included if they help to formulate better clean cooking project designs or policies. For example, from the focus group discussion, usability–such as start-up time and finishing time–can be important to making a popular clean cooking stove. Although convenience is usually not the main purpose of a clean cooking stove project, if this attracts extra demand, stove designers should take the attribute into account. Another specific factor influencing stove choice that has not been assessed is the life-time of the stove, and hence the (medium-term) running costs, which the results show to be very important to users. Some improved stoves last only a matter of three to five years. In this circumstance, the medium-term running costs should take into account the stove replacement cost. Both time attribute will be quantified easily, so that further research regarding the new attribute will help to establish more realistic representation of hypothetical alternatives.

Second, theoretically, the panel nature of the data must be considered because the SP survey uses multiple observations from a given respondent (Revelt and Train, 1998). For example, a model could have a random coefficient, which will not vary across observations from the same respondent. That is, panel data could be addressed by using a Mixed Logit model, in which an individual specific error term is added to fix its mean value at zero, while its standard deviation is estimated. However, the panel structure did not work in the model, and as a consequence, the standard errors reported here are understated, i.e., the results in the model must be discounted (Wooldridge, 2002). As this model does not consider the effects of previous choices on subsequent questions, one of the potential problems is incorrect starting values for the parameter estimates. For future research, a jackknife method should be applied to the original results to estimate less biased and more conservative parameters, as discussed by Cirllo *et al*., (2000).

Third, for the risk and smoke attributes, dummy variables could have been more appropriate, as these are categorical attributes; however, as mentioned above, these are pseudo-categorical attributes in this model, while they are continuous in reality. These attributes differ from "age" categories, which, although also continuous in nature, may even change sign (+/-) across the age categories; the parameters for smoke and risk levels, in contrast, are unlikely to alter in sign across levels. Moreover, the risk and smoke variables were presented with level numbers, such as "0: No" and "3: Very high" in the SP of the Tanzania and Mozambique case studies; therefore, the linear assumption is more explicitly suggested in this study. Since these soft attributes are difficult to measure and estimate, future studies could adopt a more appropriate approach, such as ordinal variables using a latent variable framework, in which these values are indicators of a latent variable.

Wish-list approach vs. trade-off approach

Although research on the relative strengths of attributes affecting stove choice was lacking, a few studies have attempted to estimate the relative strengths of attributes (Gupta and Köhlin, 2006; Pohekar, Kumar, and Ramachandran, 2005). However, their adopted methodology is questionable; for example, the strengths of the attributes were estimated by asking respondents to rank/rate different product-specific attributes as the basis of their preference levels. Such an approach has the risk of people listing every positive attribute–such as safety, convenience of use and cleanliness–as highly preferred, while negative attributes–such as smoke, price and operating cost–are listed as least preferred. If there is a failure to check such biases, this results in the generation of a potentially unrealistic 'wish list' at the individual level, with the extrapolation of such data for a given population through aggregation resulting in a 'democratically expressed wish list'. Choices are therefore assessed in terms of a hypothetical collection of attributes, rather than analysing the trade-offs among choices available to consumers. Pohekar and Ramachandran's (2005) results showed such a tendency. Their study revealed that Liquid Petroleum Gas (LPG) for cooking is the most preferred alternative, while the study region in India is known for its use of biomass fuels and very little use of LPG.

In the ranking- and rating-based studies, respondents are not required to express preference in terms of trade-offs between the attributes. In choice experiments, the adopted methodology for this research, the strength lies in its ability to capture preference in terms of a trade-off between the attributes, which in turn can be used for the estimation of demand, price elasticity, income elasticity, the value of each attribute and trade-offs between them. Theoretically most product attributes will affect choices if the levels of the product attributes are raised or lowered beyond the trade-off range of an individual or group. For example, the result of this study indicates that the stove price is not significant to the high-income group, perhaps because the study tested a maximum stove price of 40 USD (i.e., 500 ETB). However, for the same income group, if the stove price is raised continuously, at some point the price will become higher than the highest willingness-to-pay price of the group (e.g., if a price is higher than income and savings, one cannot pay the price); hence, it would affect the choices made. Thus, it is important to design a product to meet consumer needs based on the trade-offs amongst attributes.

Product-specific attributes and socio-economic attributes

The previous studies on determinants of fuel/stove choice are highly skewed towards socio-economic attributes and lack a focus on product-specific attributes. As mentioned previously, socio-economic attributes are responsible for variations in choice between different individuals or groups. For example, the study results presented in Table 7, Table 8, and Table 9 show that the strengths of product-specific attributes–such as the coefficient of smoke, stove price, usage cost, and safety–differ across various socio-economic attributes like age, income, education, and gender. The product-specific attributes analysis assumes that people's choices are different because they have different tastes, as indicated by the coefficients of the product-specific attributes. For example, for the low-income group, the smoke attribute is insignificant, indicating that smoke does not affect the stove choice of a low-income household, while for the high-income group, the smoke coefficient is highest, indicating the high level of aversion to smoke within the high-income group.

The World Bank's research on 'attributes determining fuel choice in Guatemala' (Heltberg, 2005) found income, electricity connection, lifestyle, household size, and education to be the determinants of cooking stove and the associated fuel choice. As described above, the identified determinants of stove choice are socio-economic attributes, which are responsible for variations in cooking stove and fuel choice between different people, and fail to explain what determines stove choice in terms of the identified socio-economic attributes, such as income, lifestyle, household size and education. In other words, the study successfully identifies the characteristics of a target market, but it is silent regarding the description of stoves that best fit the needs and characteristics of that market. For example, many researchers have cited gender as an important attribute affecting stove choice. Attributes like gender are essentially two mutually exclusive categories–male and female. The identification of gender as a attribute in determining stove choice may help to explain how stove choice differs between individuals or groups belonging to either of the two categories; however, what determines cooking stove choice for either of the categories remains unanswered. Therefore, it is important that research includes both product-specific attributes and socio-economic attributes. The product-specific determinants of stove choice are likely to be limited in number and universal in nature. Hence, the important question may not be what determines stove choice for a given target market, but more importantly, what are the magnitudes and trade-offs between the product-specific attributes for a given target market, specified in terms of socio-economic attributes. This study (Table 7) illustrates that while product-specific attributes determining choices remain reasonably consistent across all other tested socio-economic attributes, the difference lies in the magnitude and trade-offs represented by the coefficients of the attributes.

Understanding the strength of each attribute and the trade-offs among attributes is a more practical, efficient, and effective approach. As such, reducing the cost of the stove (β^{cost}) is more "efficient" than reducing the price of fuels (β^{price}), as the magnitude of the former parameter is larger in the general model (Table 6). However, if the decision makers in the target market are women, relatively more attention must be given to fuel price, as this study indicates that women give more consideration to fuel price than men (gender-segregated models). Similarly, the trade-offs and magnitudes of other product-specific attributes can be analysed for different socio-economic attributes to identify efficient interventions. Furthermore, an "effective" implementation needs to consider information on market-specific profiles and preferences through various indicators, such as the variability of trade-offs and magnitudes of product-specific attributes across various socio-economic variables. In this way, both product-specific attributes and socio-economic attributes are important, each providing rather different information. Thus a clear distinction between the two must be considered.

A focus on product-specific attributes is as important as socio-economic attributes because in order to bring changes to energy usage patterns in the short-run, it is much easier to change products or product attributes than to change the socio-economic characteristics of an individual or a household. Transformation through changes in socio-economic attributes is tantamount to changing energy usage patterns by altering people or their circumstances, which is almost impossible in the short term and difficult even in the long run. For example, commonly reported attributes like age, income, gender, and level of education cannot easily be changed. At the same time, socio-economic attributes are important to identify target groups for long term policy changes.

The above discussion about the roles of socio-economic and product-specific attributes are summarised in Figure 19. Previous research has only focused on Quadrants 1 and 3 (Q-1 and Q-3), helping to identify target groups or market segmentation. This study has identified the importance of Q-2 and Q-4 and estimated the trade-offs among such attributes, which could help to design a cooking stove project with a higher probability of acceptance. The idea of balancing between socio-economic and product-specific attributes is strongly related to "pragmatism," as expressed by the philosopher Charles Sanders Peirce (Peirce, 1877; Peirce, 1878). Peirce claimed that the problem of social science, compared with physical engineering, is perfectionism and a lack of pragmatism. An engineer finds a solution and then designs approaches to move step by step towards the target or the perfect solution. In contrast, a social scientist sets up a perfect target and then skips intermediate processes and designing stages to

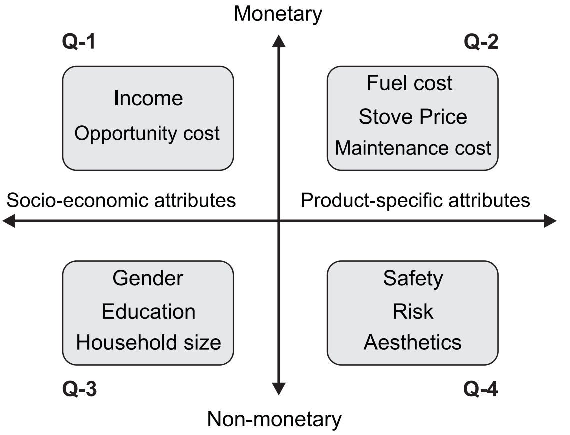

Figure 19: Four categories of clean cooking stove determinants

attempt to reach the perfect solution directly (Sobrinho, 2001 pp. 235-7). This does not necessarily mean that the perfect solution has no analytical value; it simply has less analytical value when it comes to the shorter-term goal of improving the fuel/stove and its impacts, by designing better programmes or market instruments.

A pragmatic approach is necessary in the clean cooking sector. The perfect solution to promote a clean cooking stove may be to achieve a more equitable and stable society, so that everyone can afford such stoves; however, this is not possible without designing a specific process and defining steps to take towards the goal. As a part of the process, it is important to increase the focus on product-specific attributes so as to make a stove more desirable to the target population, consequently creating and expanding a real market.

Moreover, although there are many similarities amongst the cases, especially between Ethiopia and Tanzania, the case study approaches also show distinct differences, indicating case-specific issues. For example, ethanol ASCs are not always significant, unlike other cases and this can be explained by an Ethiopian-specific issue, as explained above, i.e., some Ethiopians do not like the ethanol stove because of previous fatal accidents caused by misused ethanol-kerosene stoves.

Policy relevant findings

By examining the trade-offs that the consumer makes between product-specific factors, one can select a stove design to fit specified market segments. This is not possible by considering socio-economic factors alone.

Moreover, as illustrated above, when the various trade-offs are understood, it becomes possible to make predictions about the market for specific products given certain conditions, for example, under different fuel price scenarios. This type of information is of particular interest to countries such as Ethiopia where policy makers are in the process of developing strategies for allocating biofuels resources (ethanol, in the case of Ethiopia) to different sectors (e.g. export, transport, household) and require firm guarantees about the existence and size of a household market for the fuel at a given price in order to allocate sufficient quantities to support the development of this sector.

Although the methodology applied in this study could be used to assess household preferences for any type of cooking stove, in each of the case studies presented here, the ethanol cooking stove was included as an alternative. In the cases of Dar es Salaam and Catembe, where ethanol stoves have not yet been field tested, the results generated are of interest to stove programme designers and policy makers looking at the potential market for this technology and fuel. In the case of Dar es Salaam, households preferred the ethanol stove over fuelwood and kerosene by a significant margin, which suggests a strong potential market for this stove. However, in order to penetrate the lower income market in Tanzania, the price of the stove must be carefully considered; the study showed that a change in stove price in dar es Salaam would affect the low income group's utility more than 10 times that of the high income group.

Results in Mozambique show that although the respondents valued the ethanol stoves' safe and clean (smoke free) attributes, the charcoal stove was still the preferred cooking option (followed by the ethanol stove and then the fuelwood stove.). However, since the research was conducted, the price of charcoal in Mozambique has increased significantly and is now less affordable for many low and middle income households. Ethanol is now a more viable option for low and middle income households in Mozambique than previously and a private company is currently pilot testing ethanol stoves in low and middle income households in Maputo. The goal is to produce an ethanol stove locally that meets the needs of the users. In the case of Catembe, the HHEA demonstrated that most important factors determining choice of cooking stove for the majority of consumers are stove price, running cost and safety. The private company is targeting the low to middle income markets in Maputo and is seeking to strike a balance between these attributes in the design and future marketing of the new stoves.(Atanassov, personal comment, 2011.03.02).

In the Ethiopian case, the results of the HHEA were particularly pertinent from a policy perspective given the ongoing ethanol stove programme and the government's efforts to develop a strategy for future biofuels development and market allocation. The Addis Ababa study clearly confirms that ethanol is the preferred option for cooking; this result validates the findings of the Gaia Association pilot ethanol cooking stove project. The most interesting, policy relevant results are related to the impact of increasing stove cost and stove running cost on various socio-economic strata. The study showed that in terms of trading off between product-specific attributes, the lower income households were more sensitive to the upfront cost of the stove than to the usage cost as compared with middle and upper income households. Moreover, the fact that an increase in stove price will affect the low income group's utility more than five times that of the high income group would seem to suggest that, unless a cheaper stove can be produced, particular financing mechanisms, e.g. subsidies or micro finance will be needed in order for the current stove model to be accessible for poorer households. For middle income households in Addis Ababa, the stove running cost (fuel cost) is a more significant factor affecting decision than the capital cost of the stove. This is a significant result given that the Ethiopian Government is interested in initially promoting ethanol cooking stoves for use in middle income condominium developments around Addis Ababa. It would suggest that although these households will likely be able to afford to pay for the stove, in order for this programme to be successful, careful consideration must be given to ensure that the price of ethanol does not exceed that of kerosene and charcoal. For further policy outcomes in Tanzania and Mozambique, as well as outreach and follow on activities in each case country, please refer to Appendix 2.

9 CONCLUSIONS AND RECOMMENDATIONS

A switch from traditional biomass fuel stoves to modern, clean, safe and efficient stoves is expected to enhance the welfare of the 2.5 billion people worldwide who lack energy access and to help to reduce negative environmental impacts associated with traditional biomass use. This research empirically investigated the application of a cutting-edged economic model that was based on a stated preference survey and discrete choice analysis, for evaluating clean cooking and energy demand assessments at a household level in Ethiopia, Tanzania, and Mozambique. This paper first explained the methodological contexts and the theoretical dimensions of attributes determining stove choice at the household level. The study found that as compared to the low-income group, the high-income group was willing to pay ten times as much for a unit reduction in indoor smoke, two times more for increased efficiency, and ten times more for increased safety, in some cases. The study also revealed the structure of household preferences for less smoky, less risky, and less costly cooking options, indicating the relative importance among such attributes and the trade-offs amongst these attributes. One of the most significant findings in this research was distinguishing between socio-economic and product-specific attributes as the determinants of cooking stove and fuel choice, with the former responsible for variation in choice between individuals or groups, and the latter for variation within individuals or groups.

This research introduces a methodology (discrete choice analysis) used extensively in transportation and marketing studies. The application includes simulation of household cooking stove/fuel choices and preference assessment. The simulation model used in this study can help to improve household cooking programme designs and to identify policy alternatives with potentially greater impacts at local and national levels. Additional research is needed to adapt the choice experiment methodology for stoves and fuel choice analyses. The issues regarding the survey design–such as the refinement of the smoke labels and levels, the inclusion of more product-specific attributes, additional alternatives, and different survey techniques–could give interesting insights into the determinants of choice and improve the choice experiment design.

If the switch from traditional biomass stoves to modern, clean cooking stoves is to be accelerated, future research should strike a balance between socio-economic and product-specific attributes and place a greater emphasis on product-specific attributes to compensate for what has been lacking in past research. When a clean cooking stove project is implemented in the field, these findings must be considered seriously, as some level of pragmatism is necessary in this sector in order to make progress towards the goal of improving energy services and reducing the social and environmental impacts of traditional biomass use.

APPENDIX 1: CHOICE EXPERIMENT AND ANALYSIS

This section briefly explains the mechanics of the choice analysis and demonstrates how this can be used for the demand assessment of clean cooking stoves.

Choice is life

Everyone is constantly making choices. Almost everything one does is the result of a choice made.—Every action taken, from reading this report to reading the local newspaper is a choice (even "not to read anything" is a choice). The set of these choice options is called alternatives. There are a number of reasons why one may continue reading this report, e.g., the length of this article, timing of your business hour, colour of the paper, etc. Regardless of what the reasons are, the factors influencing your decision are called attributes.

"Attribute" and "alternative" can be viewed as "input" and "output" of a choice process and the "behavioural rules" explain the logic from input to output (Figure 20). Choice modelling is a quantitative / statistical approach to understand the behavioural rules based on microeconomic theories with empirical data about attributes and alternatives.

In terms of cooking stoves, there are a number of alternatives in any given market such as a "cheap" and "dirty" firewood stove, "clean" and "expensive" ethanol stove. Cheapness and cleanliness are attributes, which influence us when purchasing a certain type of stove. So, if we understand behavioural rules, which use attributes to make a choice within a set of alternatives, we can understand why one stove is selected over another. Also, if we know attributes describing the characteristics of stove buyers, we can also understand "Why a certain stove is chosen more by a particular type of buyer".

Since choice is a fundamental human behaviour and elements of many human activities, an analyst may find many interesting social phenomena by scaling up the results of findings. For example, an analysis can demonstrate the market share of an ethanol

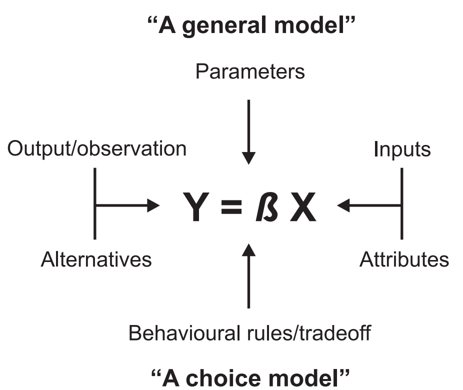

Figure 20: Relationship between attributes and alternatives

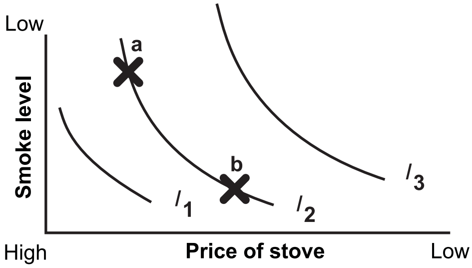

Figure 21: Indifference curves of cooking stove choice.

An indifference curve is a set of stove characteristics (in this example, with two attributes), such that the consumer does not have any special preference between them. Therefore, Stove A and Stove B on the I2 curve give the equal satisfaction. Moreover, any stove on the I3 is better than any stove on I2 for the consumer because those stoves have less smoke AND lower price.

stove and the sensitivity of demand changes in its stove price (i.e. price elasticity of demand). Estimating these macro level phenomena is usually the interest of an analyst and her/his clients such as policy makers and stove developers. It is important to note that this approach requires a high degree of knowledge of attributes; therefore, it is important to work with local stakeholders to identify them.

Choice with multi-attributes

This section explains how a choice analysis uses attributes as the sources of preference, by looking at what happens when we go to a market to buy a cooking stove. To make the demonstration simple, only two alternatives, namely a firewood stove and ethanol stove, and two attributes, such as the price of stoves and smoke levels are used.[13]

If your choice between the firewood stove and the ethanol stove is determined by their prices only, your shopping is very easy, i.e. you will buy the cheapest alternative. However, if you also consider smoke levels and your objective is to buy a cheaper and cleaner stove you will sometimes need to compromise one attribute over another, i.e. if an ethanol stove is very clean, you may give up the cheapness of the stove and vice versa. The preference between the two attributes for an ethanol stove will be like Figure 21.

At any points on the same concave-shaped line (Let's say I2), an individual has the same level of satisfaction. In other words, a consumer is indifferent among any combination of stove characteristics on the I2 curve, so that the curve is called an indifference curve. For example, a stove is relatively smoky, but cheap at the point A, and a stove is relatively expensive but not smoky at a point B on I2 curve. Although the characteristics of the two stoves are different, the overall satisfactions of the two stoves are the same as the disadvantage of one attribute is compromised by the advantage of the other attribute in theory as well as practice. An ethanol stove on the upper right

13 It is not necessary to have all alternatives in an experiment, but if an analyst has all alternatives, they simulate the market share of each alternative. If not, the focus of research is usually the valuation of trade-offs between attributes.

corner is the cheapest and cleanest stove, which means that a consumer will gain the maximum satisfaction or utility. This means that if an individual can move her/his indifference curve from I1 to I3, s/he can increase their satisfaction and they have an intention to do that, i.e. utility maximising behaviour. However, an individual has to stick with an indifference curve at some point in time due to technological or income constraints, e.g. technologically it is impossible to make the cleanest and cheapest ethanol stove in the world at the same time. Meanwhile, it is not rational to choose a combination on the I1 curve as one can choose better combinations on I2 because of utility maximising behaviour.

In short, the preferences an individual makes are not only between alternatives, but also attributes. Moreover, in this example, what a consumer cares about is the cleanness and the cheapness of any stove, not whether the stove uses ethanol or firewood. This means that, the choice a consumer makes at the time of shopping is a tradeoff between the two attributes, but not the alternatives. In economics, this concept is called multi-attribute utility theory.

This tradeoff concept between attributes is important to operate a clean cooking stove project successfully. If an analyst asks a local consumer "what kind of stove would you like to buy?" the most likely response will be "the cheapest and cleanest stove!" However, as explained above, it is not possible to create such a cooking stove. Therefore, if a clean cooking stove project manager tries to follow the response (assuming it is actually possible to make the cheapest and cleanest stove), the cleanest stove has to be subsidised or its production cost will not be covered by its price. In either case, the clean cooking stove project will not be sustainable in the long term. A choice analysis must carefully assess the trade-off between attributes, which is observed as a choice between a set of alternatives. As an outcome, the analysis will be able to present a proper "shopping list," but not a "wish list," since the latter ignores the trade-offs between attributes.

There is an implicit assumption in this approach that consumers will always want more of a good thing (e.g. lower cost) and less of a bad thing (e.g. smoke). There may be some cases where such a relation may not be appropriate; for example, there may be a point at which further reduction in smoke will not produce any extra (perceived) utility. An economic model design based on multi-attribute assumptions can in some cases adjust the model structure so as to recognise such limitations where they may impact the results. Furthermore, by introducing a random element in the modelling approach, methods such as discrete choice analysis are more flexible in representing consumer choices (see below).

Discrete choice analysis

Practically, the choice analysis uses statistical tools and experimental survey techniques to estimate the relationship between sources of preference such as attributes and alternatives. Discrete Choice Analysis (DCA) is originated by Prof. McFadden's work in 1960's and 70's, for which he was awarded the Nobel Prize for Economics in 2000. He combined the multi-attribute utility based on consumer choice theory with

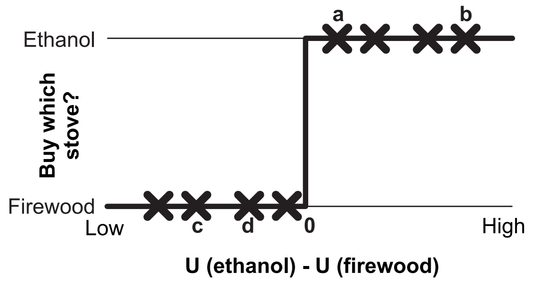

Figure 22: Deterministic choice model

statistical random utility maximization model and developed the original model of DCA namely multinomial logit (MNL) model. Conventional consumer choice theory states that if the utility of a good is greater than that of another good, a consumer will choose the former good. Thus, if buying an ethanol stove brings higher utility than buying a firewood stove, i.e. U(Ethanol) – U(Firewood) > 0, a consumer will buy an ethanol stove. The relationship of utility and the stove selection is explained as Figure 22.

Cross marks in the figure are assumed as potential observed choices and the "zigzag" shape perfectly match with all the observations, i.e. all cross marks are on the zigzag line. For example, as the utilities of buying an ethanol stove is higher than that of firewood stove at observation A and B, an ethanol stove is chosen, vice versa, i.e. it shows that at a certain point, "0", it suddenly makes sense for the consumer to choose the ethanol stove.

However, in reality it is not possible to estimate the utility of stove purchase due to unobserved attributes, measurement errors, etc. Therefore, the utility model has to have an error component, i.e. random utility model. Because of the error component, an analyst may observe irrational choice such as choosing an ethanol stove when a firewood stove appears to bring greater utility. To fit a model with these observations, a choice model becomes stochastic and its "S" curve displays a probabilistic outcome as in Figure 23.

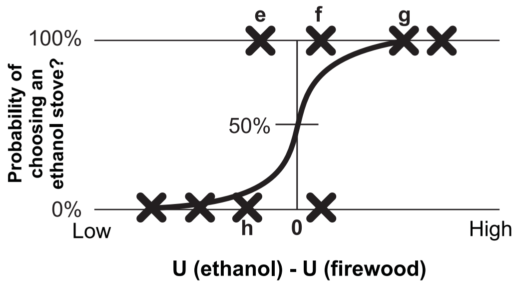

Figure 23: Stochastic choice model

For example, when the utility of choosing an ethanol stove over firewood stove is the same, i.e. U(Ethanol) – U(Firewood) = 0, the probability of buying the ethanol stove is 50 per cent as the two alternatives are indifferent in terms of satisfaction. Also, the probability is higher at observation G than F as the utility is higher at F. DCA uses a mathematical function to describe the “S” shape.

Policy makers and stove developers will be more interested in the macro level outcomes such as the market share and price elasticity of a stove than probability of buying a particular stove. The DCA will answer these questions as the probability of a stove choice is the same as the market share of the stove in *probability theory* and the slope of the “S” curve is its price elasticity.

APPENDIX 2: POLICY OUTREACH AND FOLLOW UP ACTIVITIES

This section provides an overview of the various policy outreach activities undertaken to disseminate the study results to a range of stakeholders, from the private sector to local and national government officials, stove programme implementers and the international donor community. The impact of the study at the local level is also highlighted, with particular reference to ethanol stove programmes (ongoing and recently launched) in two of the case countries.

Ethiopia

The results of the Ethiopian study were presented by SEI and Gaia Association at a special workshop hosted in Addis Ababa in March, 2009 attended by, among others, the Ministry for Mines and Energy (MME), The Ethiopian Sugar Agency and the Federal Environmental Protection Authority. The importance of displacing kerosene as a cooking fuel in the urban areas was highlighted and, from a national policy point of view, government officials were particularly interested in the potential for using the study results to predict the household market for ethanol among various income groups in Addis Ababa. A number of technical experts from within the MME expressed an interest in having more information on demand forecasting as a tool for policy formulation. In separate meetings, the study results were presented to the President of Ethiopia, and the Director General of the Federal Environmental Protection Authority. Both officials were particularly interested in the potential of the ethanol stove for reaching lower income households and were therefore keen to have specific estimates regarding the marginal willingness to pay of the various socio-economic strata.

Crucially, the results of the study were also presented to Makobu Enterprises PLC., the local ethanol stove manufacturer and key project stakeholder. Makobu is in the process of establishing local production of the ethanol stove, requiring significant investment on their part and is therefore particularly interested in the trade off between various stove attributes among consumers at different income levels. The current projected price for the locally produced stove is $20, a price which, according to the analysis in section 5 above, would be acceptable to lower income households, provided that the price of ethanol (usage cost) would be below that of kerosene and other widely used cooking fuels. Since the study was completed, the price of ethanol in Ethiopia has increased to $0.50 per liter - still lower than the price of kerosene which topped $0.80 in December 2010. Ethiopian ethanol is currently used for fuel blending in the automotive sector but the Government is supportive about expanding into the household market, particularly if ethanol can displace kerosene which constitutes a significant drain on foreign exchange.

The Gaia Association is now planning to establish small scale, community based micro distilleries to produce ethanol from various agri-wastes for household use in and around Addis Ababa. The NGO is seeking funding to pilot test one micro distillery in a low income community in Addis Ababa and has requested that SEI conduct the same economic analysis in this community if and when funding has been secured.

Tanzania

The household energy economic analysis was also well received by policy makers in Tanzania. Preliminary results were presented at the Ministry for Energy in October 2009 and there were indications that such analyses could be useful in future national level policy formulation on biofuels and household energy. In April 2010, the household energy study was highlighted during a roundtable discussion on biofuels led by Director of the Department for Environment, Climate Change and Sustainable Services of the Swedish International Development Cooperation Agency (Sida) at the Swedish Embassy in Dar es Salaam. In January 2011 SEI Participated in a consultation meeting at the Swedish Embassy in Dar es Salaam and presented the full SEED report including the HHEA results as input into their work drafting a new development cooperation strategy for Tanzania-Sweden. Sida views the household energy analysis positively and gave the impression that energy, environment, and private sector development could become focal areas for Swedish development cooperation in Tanzania as Sweden refines and focuses its cooperation with Tanzania.

In January 2011, the research carried out under the SEED programme (particularly the issue of applying a Strategic Environmental Assessment approach to assessing alternatives to household energy and the work on household energy economics) was presented to the Minister of Natural Resources and Tourism and his technical staff, following a plea from the minister to find workable solutions to make a transition from charcoal to cleaner cooking fuels.

Mozambique

In November 2009, the study was presented during a seminar hosted by the Swedish Embassy in Maputo. The audience consisted of policy-makers, high-level government officials, representatives of donor groups (SIDA, USAID, GTZ, Italian cooperation, Norad, and the French Development Agency), International organizations (World Bank) and some private sector representatives. A private company, CleanStar Ventures, is now undertaking the task of introducing Ethanol cookstoves to the market in Mozambique. The decision to launch this initiative as well as much of the initial market analysis for the venture is based on the household energy economic analysis study. CleanStar Ventures has now engaged a consultant to manage the stove pilot testing and initial market roll-out phase.

International

The study was presented during the Partnership for Clean Indoor Air (PCIA) biennial forum in Kampala, Uganda in March 2009 for more than two hundred improved cooking stove practitioners (NGOs), researchers and policy makers from around the world. The presentation generated much interest, in particular from members of the household energy NGO community interested in conducting similar studies.

In March 2010, the study was presented for Sida at the Swedish embassy in Lusaka, Zambia. Sida indicated an interest in working at the interface of technology end-users and the private sector as a possible alternative route to working through Government agencies such as the Department of Energy.

There is now a renewed international commitment to tackling the issue of household energy access. In September, 2010 US Secretary of State, Hilary Clinton announced a new initiative, the Global Alliance for Clean Cookstoves, a partnership between the US government and other nations and charitable foundations which is the first major attempt to address the issue worldwide. The project aims to introduce modern low-pollution stoves to the homes of 100 million poor people by 2020.

The Alliance is seeking to support a thriving global market made up of a range of organizations—from cottage industries to large-scale companies—that are both sustainably supplying clean, efficient, affordable, and user-desired cooking solutions (stoves and fuels) at greater scale and that are constantly innovating to improve design and performance, while lowering cost.[14] Building the capacity of such organizations will require a thorough understanding of the factors affecting household level decision making in each specific market. The methodology applied in this study could offer a very practical means of rapidly assessing the feasibility of particular approaches and policies for scaling up access to cleaner cooking options and ensuring that, from the perspective of the consumer, the most appropriate technologies are promoted.

14 http://cleancookstoves.org/

REFERENCES

Bailis, R., Ezzatti, M. and Kammen, D. (2007) Health and Greenhouse Gas Impacts of Biomass and Fossil Fuel Energy Futures in Africa. *Boiling Point* 54:3-8.

Barnes, D.F. *et al*. *What Makes People Cook with Improved Biomass Stoves? A comparative international review of stove programs*, World Bank technical paper, No.242 Energy Series (1994)

Bond, T.C. and Sun, H. (2005) Can Reducing Black Carbon Emissions Counteract Global Warming? *Environ.Sci.Technol* 39(16):5921-5926.

Briscoe, J. (1979) *The Political Economy of Energy use in Rural Bangladesh*.

Cirillo, C., Daly, A. and Lindveld, K. (2000) *Eliminating Bias due to the Repeated Measurements Problem in SP Data*. Stated Preference Modelling Techniques: PTRC Perspectives 4.

CSA (2004) Welfare Monitoring Survey 2004-2005 (1997 E.C) [ETH-WMS-2004-v1.1], Retrieved 11/11/2009, 2009..

Davis, M. (1998) Rural Household Energy Consumption: The Effects of Access to Electricity-Evidence from South Africa. *Energy Policy* 26:207-218.

DFID (2002) *Energy for the Poor: Underpinning the Millennium Development Goals*. London: Crown.

FAO and PISCES (2009) S*mall-Scale Bioenergy Initiatives: Brief description and preliminary lessons on livelihood impacts from case studies in Asia, Latin America and Africa*. FAO.

Ghanadan, R. (2004) *Negotiating Reforms at Home: Natural Resources and the Politics of Energy Access in Urban Tanzania*. University of California Berkeley.

Goldemberg, J., Johansson, T.B., Reddy, A. K. N. and Williams, R. H. (20040 A global clean cooking fuel initiative. *Energy for Sustainable Development*, 8(3).

Gupta, G. and Köhlin, G. (2006) Preferences for Domestic Fuel: Analysis with Socio-Economic Factors and Rankings in Kolkata, India. *Ecological Economics* 57(1):107-121.

Heckett, T. and Negusu, A. (2009) *Agrofuel Development in Ethiopia: Rhetoric, Reality, Recommendations.* Forum for Environment.

Heltberg, R. (2005) Factors Determining Household Fuel Choice in Guatemala. *Environment and Development Economics* 10(03):337-361.

Heltberg, R. (2004) Fuel Switching: Evidence from Eight Developing Countries. *Energy Economics* 26(5):869-887.

Hensher, D.A., Rose, J.M. and Greene, W. H. (2005) *Applied Choice Analysis: A Primer.* Cambridge University Press.

Hosier, R.H. and Dowd J. (1987) Household Fuel Choice in Zimbabwe: An Empirical Test of the Energy Ladder Hypothesis. *Resources and Energy* 9:347-361.

Johnson, F.X. and Lambe, F. (2009) *Energy Access, Climate and Development*. Stockholm: Commission on Climate Change and Development, online available: http://www.ccdcommission.org/Filer/commissioners/Energy.pdf.

Kassa, M. (2009) *Ethanol Cooking Fuel and Stove Market Development Project Highlights*, Summary Document Prepared for Federal Environmental Protection Authority, Addis Ababa.

Kassa, M. (2007) *Business Plan for Ethanol Cooking Fuel and Domestic CleanCook Stove Market Development in Addis Ababa, Ethiopia*: Presentation to Makobu Enterprises PLC, Gaia Association, and UNDP. Addis Ababa, Ethiopia: Partners Consultancy and Information Services.

Lambe, F. (2006) *Clean Cooking Technology in Ethiopia: From Pilot Project to Sustainable Business Model*. UNDP.

Louviere, J. J., Hensher, D. A. and Swait, J. D. (2000) *Stated Choice Methods: Analysis and Applications*. Cambridge University Press.

McFadden, D. (1973) Conditional Logit Analysis of Qualitative Choice Behavior. *Frontiers in Econometrics*:105-142.

McFadden, D. (1987) Regression-Based Specification Tests for the Multinomial Logit Model, *Journal of Econometrics*, 34:63-82.

Narasimha Rao, M. and Reddy, B.S. (2007) Variations in Energy use by Indian Households: An Analysis of Micro Level Data. *Energy* 32(2):143-153.

Naumoff, Kyra (2005) *Indoor Air Pollution Measurement Options*.

Ouedraogo, B. (2006) Household Energy Preferences for Cooking in Urban Ouagadougou, Burkina Faso. *Energy Policy* 34(18):3787-3795.

Pachauri, S. and Jiang, L. (2008) The Household Energy Transition in India and China. *Energy Policy* 36(11):4022-4035.

Peirce, C.S. (1878) How to make our Ideas Clear. *Popular Science Monthly* 12:286-302.

Peirce, C.S. (1877) The Fixation of Belief. *Popular Science Monthly* 12:1-15.

Pohekar, SD, Kumar, D. and Ramachandran, M. (2005) Dissemination of Cooking Energy Alternatives in India—a Review. *Renewable and Sustainable Energy Reviews* 9(4):379-393.

Pundo, M.O. and Fraser, G.C.G. (2006) Multinomial Logit Analysis of Household Cooking Fuel Choice in Rural Kenya: The Case of Kisumu District. *Agrekon* 45(1):24-37.

Revelt, D. and Train, K. (1998) Mixed Logit with Repeated Choices: Households' Choices of Appliance Efficiency Level.*Review of Economics and Statistics* 80(4):647-657.

Sanga , G. A. (2003) *Evaluation of Impacts of Clean Technologies and Substitution of Cooking Fuels in Urban Residences in Dar Es Salaam*, Academic Master's Degree Dissertation. Campinas state university.

Schlag, N. and Zuzarte, F. (2008) *Market Barriers to Clean Cooking Fuels in Sub-Saharan Africa: A Review of Literature,* online available: http://sei-international.org/publications?pid=80.

Sobrinho, B.J. (2001) *Signs, Solidarities, and Sociology: Charles S. Peirce and the Pragmatics of Globalization*. Rowman & Littlefield Publishers.

Stokes, H. and Ebbeson, B. (2005) "Project Gaia: Commercializing a New Stove and New Fuel in Africa." *Boiling Point* 50.

UNDP (2008) UNDP Human Development Report 2007/2008.

UNDP (2005) *Energizing the Millennium Developing Goals: A Guide to Energy's Role in Reducing Poverty*. New York: UNDP. Retrieved 11/8/2009.

Varmola, M., Valkonen, S. and Tapaninen, S. (2008) *Research and Development for Sustainable Management of Semiarid Miombo Woodlands in East Africa*. 130. Retrieved 11/11/2009.

Watkins, K. (2008) *Human Development Report 2007/2008 Fighting Climate Change Human Solidarity in a Divided World*. Palgrave Macmillan.

WHO (2006) *Fuel for Life: Household Energy and Health*. Geneva: WHO.

Wooldridge, J.M. (2002) *Econometric Analysis of Cross Section and Panel Data*. MIT press.

WWF (2008) *Mozambique consultancy report on bio-fuel study.*

Yahya, S.S.(2000).*Woodfuel and Change in Urban Tanzania*. SYA Associates, Nairobi, Kenya

Switching from traditional biomass to cleaner, safer and more efficient fuels for cooking can enhance the welfare of the 2.5 billion people worldwide who currently do not have access to modern energy sources, while helping to reduce the negative health and environmental impacts associated with traditional biomass use. Despite the numerous benefits associated with cleaner alternatives, the transition to improved cooking stoves and fuels has largely stalled in Sub-Saharan Africa (SSA). Why is it that well-designed, efficient and clean stoves often fail to penetrate the market in developing countries, as expected? This report presents a study conducted by the Stockholm Environment Institute to address this knowledge gap by empirically assessing the role of socio-economic attributes and product-specific attributes as determinants of cooking stove choice at the household level.

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