



**Cooking Fuel Choice in Urban Zambia:  
Implications on Forest Cover**

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**Solomon T. Tembo, Brian P. Mulenga, and Nicholas Sitko**

**Working Paper No 94**

**March 2015**

Indaba Agricultural Policy Research Institute (IAPRI)

*Lusaka, Zambia*

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Tembo is a senior research associate at the Indaba Agricultural Policy Research Institute (IAPRI), email [solomon.tembo@iapri.org.zm](mailto:solomon.tembo@iapri.org.zm); Mulenga is research associate at Indaba Agricultural Policy Research Institute, email [brian.mulenga@iapri.org.zm](mailto:brian.mulenga@iapri.org.zm); Sitko is research fellow at the Indaba Agricultural Policy Research Institute (IAPRI), assistant professor, International Development, Department of Agricultural, Food, and Resource Economics, Michigan State University, and USAID chief of party under the Food Security Research Project, on long term assignment in Zambia, email [njsitko@gmail.com](mailto:njsitko@gmail.com)

## ACKNOWLEDGEMENTS

The Indaba Agricultural Policy Research Institute is a non-profit company limited by guarantee and collaboratively works with public and private stakeholders. IAPRI exists to carry out agricultural policy research and outreach, serving the agricultural sector in Zambia and contributing to sustainable pro-poor agricultural development.

The authors are grateful to The Central Statistical Office (CSO) for making the Living Conditions Monitoring Survey (LCMS) data of 2010 available. We also acknowledge the technical support from our colleagues, the IAPRI researchers. We further wish to thank Patricia Johannes for formatting and editorial assistance.

The authors acknowledge financial support from the United States Agency for International Development (USAID) Zambia Mission.

Any views expressed or remaining errors are solely the responsibility of the authors.

Comments and questions should be directed to:

The Executive Director  
Indaba Agricultural Policy Research Institute  
26A Middleway, Kabulonga,  
Post Net 99, 26A Middleway Road,  
Kabulonga, 10101  
Lusaka, Zambia  
Telephone: +260 211 261194  
Telefax +260 211 261199

Email: [chance.kabaghe@iapri.org.zm](mailto:chance.kabaghe@iapri.org.zm)

## **INDABA AGRICULTURAL POLICY RESEARCH INSTITUTE TEAM MEMBERS**

The Zambia-based Indaba Agricultural Policy Research Institute (IAPRI) research team is comprised of Antony Chapoto, Brian Chisanga, Jordan Chamberlain, Munguzwe Hichaambwa, Chance Kabaghe, Stephen Kabwe, Auckland Kuteya, Mary Lubungu, Rhoda Mofya-Mukuka, Brian Mulenga, Thelma Namonje, Nicholas Sitko, Solomon Tembo, and Ballard Zulu. Michigan State University-based researchers associated with IAPRI are Eric Crawford, Steven Haggblade, T.S. Jayne, Nicole Mason, Chewe Nkonde, Melinda Smale, and David Tschirley.

IAPRI carries out agricultural policy research and outreach, informs agricultural policy, serving the agricultural sector in Zambia, and thus contributes to sustainable pro-poor agricultural development.

## EXECUTIVE SUMMARY

This study examined the use of various sources of cooking energy among urban households in Zambia, and analyzed urban households' energy choice and charcoal consumption decisions using econometric models. Overall, charcoal is the most common source of main cooking energy in urban areas, followed by electricity, and lastly the other non-specific sources, such as gas, and kerosene. Of the three main sources considered in this study (i.e., electricity only, charcoal only, and a mix of charcoal and electricity) charcoal accounted for almost half (44%) of urban households, followed by a mix of charcoal and electricity representing 38%, and lastly electricity only accounting for 17% of urban households. It is therefore evident that charcoal is widely used in urban Zambia as a source of cooking, either on its own or in combination with electricity, similar to findings by others (Chidumayo et al. 2002). Further, we find that even among electrified households, charcoal was commonly used in combination with electricity, more than electricity only, an indication of pervasive *fuel stacking*, rather than *fuel switching*.

Econometric results of determinants of main cooking energy choice and quantity of charcoal consumed indicate that several other socioeconomic variables, besides income, play an important role in both processes. All else equal, the household head's education level reduces reliance on charcoal and household monthly charcoal consumption. Household size was found to positively influence quantity of charcoal consumed, and the likelihood of using charcoal only, and a combination of charcoal and electricity, as the main source of cooking energy. Further, results indicate that higher incomes increase a household's likelihood of using electricity only, and a combination of electricity and charcoal relative to using charcoal only. The high and significant influence of income on the use of a combination of charcoal and electricity implies fuel stacking behavior among urban households, contrary to the widely held theory of fuel switching as household income increases. Income was also found to have a positive effect on the quantity of charcoal consumed by a household, but only up to a certain income level before charcoal consumption begins to decline. Initially as income increases, household charcoal consumption increases, but further increases in income results in decline in charcoal consumed by a household.

An analysis of the effect of residential area on choice of main cooking energy type shows that households in high and medium cost areas were more likely to use either electricity only or a mix of electricity and charcoal as opposed to charcoal only. This buttresses the finding that high-income households are more likely to use electricity and a mix of electricity and charcoal, than charcoal only. Considering that electricity is a close substitute of charcoal in urban areas, we analyzed the effect of electricity connection on charcoal consumption. Results show that access to electricity has a negative and significant influence on charcoal consumption, and can potentially reduce household monthly charcoal consumption by 47%, all else equal. This result has implications for policies aimed at reducing charcoal consumption and slowing down forest degradation and/or deforestation, as it underscores the importance of electricity and, possibly other alternative sources, in helping to reduce charcoal demand. However, electricity connection alone is not a panacea to reducing charcoal demand and consequently deforestation and degradation, it has to be flanked by other measures such as improving the reliability of electricity supply, and making affordable electric cooking appliances, *inter-alia*. Spatially, we find that being in a particular province has significant influence on charcoal consumption, with Central, Luapula, and Northern being associated with increased charcoal consumption relative to Western Province (our reference province).

## TABLE OF CONTENTS

ACKNOWLEDGEMENTS .....	iii
INDABA AGRICULTURAL POLICY RESEARCH INSTITUTE TEAM MEMBERS .....	iv
EXECUTIVE SUMMARY .....	v
TABLE OF CONTENTS.....	vi
LIST OF TABLES.....	vii
TABLE PAGE.....	vii
LIST OF FIGURES .....	vii
FIGURE PAGE.....	vii
ACRONYMS.....	viii
1. INTRODUCTION .....	1
2. ENERGY POLICY INITIATIVES IN ZAMBIA .....	3
3. DATA SOURCES .....	4
3.1. Data Sources.....	4
3.2. Energy Data.....	4
3.3. Secondary Energy/fuel Sources .....	5
4. CONCEPTUAL FRAMEWORK AND DESCRIPTIVE STATISTICS.....	6
4.1. The Energy Ladder Model .....	6
4.2. Fuel Switching in Zambia .....	7
4.3. Multiple Fuel Choice in Zambia .....	9
5. DETERMINANTS OF HOUSEHOLD ENERGY CHOICE.....	11
5.1 Energy Choice Model Estimation Methods .....	11
5.2. Results of the Multinomial Logit Analysis .....	11
6. DETERMINANTS OF CHARCOAL CONSUMPTION .....	14
7. CHARCOAL CONSUMPTION AND FOREST DEGRADATION .....	16
7.1. Estimation of Quantities of Charcoal Consumed.....	16
7.2. Estimation of Area Equivalent in Hectares of Charcoal Consumed .....	17
8. CONCLUSIONS AND RECOMMENDATIONS .....	18
REFERENCES .....	20

## LIST OF TABLES

<b>TABLE</b>	<b>PAGE</b>
1. Fuel Switching Status, Urban Zambia .....	8
2. Multinomial Logit Analysis of Charcoal/Electricity Combinations (Base Category: Combination of Charcoal and Electricity).....	12
3. Marginal Effects at the Sample Mean.....	13
4. Determinants of Household Monthly Charcoal Consumption.....	15
5. Quantities of Charcoal and Area Equivalent in Hectares by Residence, Urban Zambia, 2010.....	17

## LIST OF FIGURES

<b>FIGURE</b>	<b>PAGE</b>
1. The Energy Ladder (Adapted from Holdren and Smith, 2000).....	6
2. Fuel Switching Status in Urban areas of Zambia, by Expenditure Decile.....	8
3. Percent of Urban Households by Type of Cooking Energy and Residential Area.....	9
4. Electrified Urban Households by Source of Cooking Energy .....	10
5. Number of Cooking Fuels/Energy by Urban Expenditure Decile, 2010.....	10

## ACRONYMS

CSO	Central Statistical Office
ERB	Energy Regulation Board
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agriculture Organization of the United Nations
FSRP	Food Security Research Project
GRZ	Government of the Republic of Zambia
IAPRI	Indaba Agricultural Policy Research Institute
ICS	Improved Cook Stove
IEA	International Energy Agency
kg	kilogram
LCMS	Living Conditions Monitoring Survey
MNL	Multinomial Logit
OLS	Ordinary least squares
REDD	Reduced Emissions from Deforestation and Degradation
SEA	Standard Enumeration Area
SNV	SNV Netherlands Development Organization
SSA	Sub-Saharan Africa
UCS	Urban Consumption Survey
UN-REDD	United Nations, Reduced Emissions from Deforestation and Degradation
USAID	United States Agency for International Development
WHO	World Health Organization
ZESCO	Zambia Electricity Supply Corporation Limited

## 1. INTRODUCTION

Energy is critical to any country's economic growth and development. Recent consumption projections suggest that world energy needs will be more than 50% higher in 2030 than they are today (International Energy Agency [IEA] 2005). However, while energy supply has increased in an effort to meet global demand, many of the world's poor are being left behind. Approximately 1.4 billion people, over 20% of the global population, lack access to electricity and 2.7 billion people, some 40% of the global population, rely on the traditional use of biomass for cooking (IEA 2010). Projections further suggest 1.2 billion people will still lack access to electricity in 2030 (the date of the proposed goal of universal access to modern energy services), 87% of them living in rural areas. In addition, the number of people relying on the traditional use of biomass for cooking will rise to 2.8 billion in 2030, 82% of them in rural areas (IEA 2010). The proportion of the population relying on biomass is highest in Sub-Saharan Africa (SSA). In most countries in SSA, more than 90% of the rural population relies on fuelwood and charcoal to meet their energy requirements while over half of all urban households rely on fuelwood, charcoal or wood waste to meet their cooking needs (IEA 2006).

The challenge of unsustainable biomass utilization to meet household energy requirements is particularly acute in Zambia. According to the Living Conditions Monitoring Survey (LCMS) conducted by the Central Statistical Office (2012), 54% of all Zambian households use firewood as the main source of cooking energy, 29% use charcoal and only 17% use electricity. However, there is a distinct difference between the urban and rural households. In rural areas, 81% of the households used firewood for cooking, followed by charcoal with 16%; and electricity is used by only 3%. In contrast, most households in urban areas use charcoal for cooking (51%), followed by electricity (43%) while only a small proportion use firewood (6%). As a result of the high proportion of Zambian households that use biomass energy, including charcoal and firewood, the country suffers from one of the highest rates of deforestation in the world (UN-Reduced Emissions from Deforestation and Degradation [UN-REDD] 2010).

The adverse consequences of the use of traditional forms of energy for health, economic, and social development, and the environment are well documented. For example, the World Health Organization (WHO) estimates that indoor air pollution emitted by burning solid fuel indoors in poorly ventilated conditions is responsible for 2 million premature deaths per year, or 3.3% of the global burden of disease (WHO 2009.)

The use of biomass fuels can also have significant, negative social impacts, which are disproportionately borne by women and children. Women and children often bear the burden of household fuel collection and food preparation, which require substantial time allocations when the energy source is firewood or charcoal. This, in turn, diverts them from education and income generating activities. IEA (2006) reports that the average load of fuelwood in Sub-Saharan Africa was 20 kg. A survey of 30 households near Lake Malawi, for example, found that the mean distance to a fuelwood resource was 2.1 km, the average trip time was 241 minutes, and the average time spent collecting firewood per day was 63 minutes (Biran, Abbot, and Mace 2004). In Tanzania, the roundtrip distance for fuelwood collection varied from about 1 km to 10.5 km (IEA 2002). Not only is this task incredibly laborious, it represents a substantial time allocation and comes at a significant opportunity cost to other important household livelihoods activities.

Finally, the unsustainable harvest of fuelwood degrades local forests, leading to deforestation, (Hofstad, Köhlin, and Namaalwa 2009; Köhlin et al. 2011, Energy Sector Management Assistance Program [ESMAP] 2001; Heltberg 2001), damaged wildlife habitat, poor watershed functioning, and elevated carbon emissions into the atmosphere (Geist and Lambin 2001). The combination of health, socio-economic, and environmental consequences of biomass use for household energy suggest the urgent need to identify strategies to promote the more efficient use of biomass resources and the adoption of more sustainable, cleaner fuel sources (Miah et al. 2011; Lewis and Pattanayak 2012). It is important to note, however, that while wood fuels may not burn cleanly, they are among the renewable sources of energy. Most of the clean energy sources come from non-renewable sources such as oil, natural gas, coal, and nuclear energy. Zambia's electricity is almost entirely from a renewable source, hydropower.

Identifying appropriate policies to influence change in household energy utilization requires detailed analysis of the specific drivers of household energy choice. In this paper, we seek to inform discussions on fuel use through an analysis of cooking fuel choices in urban households of Zambia using a data set derived from the 2010 Living Conditions Monitoring Survey (LCMS) conducted by the Central Statistical Office (CSO 2012). We focus on cooking fuels in urban areas because biomass fuels are predominantly used for cooking and not for other purposes, while urban areas are responsible for the majority of biomass fuel consumption. Moreover, electrical connections are more widespread in urban areas, thus providing households with greater choice in energy source. However, when power outages occur, usually because of load shedding, households seek alternative sources of fuel or electricity generation for cooking, lighting, heating, or power. Energy choice is modelled empirically using the multinomial logit model framework. The analysis also aims to identify whether and to what extent other socio-demographic variables determine energy choice. Determinants of monthly charcoal consumption are modelled using the Heckman two-step model with a control function approach. Multi-fuel use for cooking is also examined. Finally, estimates of forest cover loss from urban biomass energy consumption are also calculated. Results from the analyses are important in facilitating informed policy formulation on energy in the country.

The remaining part of the paper is structured as follows. Section 2 gives a brief analysis of current government policy initiatives. Section 3 describes the data sources, while section 4 gives a brief review of the conceptual model based on the 'energy ladder' and related descriptive results. Sections 5 and 6 focus respectively on analysis of the determinants of energy choice, and determinants of charcoal consumption and its implications or forest cover depletion in Zambia. Section 7 is devoted to conclusions and the main policy implications of the results.

## 2. ENERGY POLICY INITIATIVES IN ZAMBIA

Government policies can play an important role in the transition to cleaner, more efficient energy sources. Using household survey data from 12 countries, Barnes, Krutilla, and Hyde (2005) found that government implementation of pricing policies, quantity rationing, or import controls can influence the pace of the transition away from biomass energy sources, such as charcoal, in urban areas. However, government interventions in the energy sector must be appropriately targeted in order to have an impact on biomass fuel usage. For instance, government subsidies on fuels often do not target the poor, who are the primary users of biomass fuels, and end up benefiting middle income and even wealthy households (ESMAP 2000).

The Zambian government gives priority to increased access to modern energy and increased utilization of renewable energy through the implementation of its National Energy Policy (Ministry of Energy and Water Development 2008). In particular, the policy seeks to ensure environmentally sustainable exploitation of the biomass resource by promoting and expanding the generation and transmission of hydroelectric power and enhancing access to electricity by poor households. In line with the 2008 National Energy Policy, the Zambian government has spearheaded several programs and initiatives. In December 2010, the government and the World Bank signed a Connection Subsidies Framework Agreement. This financing agreement of US\$10 million, which was part of the Increased Access to Electricity Services (IAES) Project of US\$75.5 million which the Zambian government signed with a consortium of donors (led by World Bank), would be used to subsidize connection fees for approximately 30,000 new households by December 2013 (ERB 2010). Electricity access for the poor is supported through connection subsidies in low cost urban areas of the country. In 2009, the Energy Regulation Board (ERB) embarked upon a program to promote the domestic household use of liquefied petroleum gas to enable as many people as possible have access to energy and to encourage energy and environmental conservation. Further, the government, through its Vision 2030, seeks to increase access to electricity from the current levels of 3% to 51% in the rural areas by 2030. This effort is codified in the the Rural Electrification Act of 2003 and is spearheaded by the Rural Electrification Authority.

As in most developing countries fuel and electricity pricing in Zambia is, politically sensitive. The ERB only allowed the Zambia Electricity Supply Corporation Limited (ZESCO) to adjust electricity tariffs in July 2014, four years since the last time the tariffs were increased. ZESCO is state-owned and the largest power company producing about 80% of the electricity consumed in the country. However, despite relatively low and stable electricity prices, firewood and charcoal continue to be the main choices of cooking fuel in rural and urban areas respectively.

In recognition of this fact, various national government policies and strategies have recognized the importance of addressing biomass energy use as a means of tackling poverty, development, and environmental goals. The 2008 National Energy Policy lists as one of its objectives improving the technology of charcoal production and utilization through the development of stoves that are efficient, convenient to users and which produce minimal emissions. However, much of the implementation of this policy has been carried out by donor organizations through improved cookstove (ICS) projects. For example, the SNV Netherlands Development Organisation, in partnership with government ministries, the Samfya district council, Caritas Zambia, traditional leaders and community radio stations conducted some pilot projects to train cookstove producers, and carried out assessments of the acceptability of an improved stove. According to the SNV (2012), households that adopted the improved stove reduced their charcoal expenditure by 50%.

### 3. DATA SOURCES

#### 3.1. Data Sources

Data used in this study were primarily drawn from the nationally representative Living Conditions Monitoring Survey (LCMS) conducted every four years by the Central Statistical Office (CSO), collected from 19,397 households. We also used charcoal price and consumption data from Urban Consumption Survey (UCS) conducted by the Food Security Research Project (FSRP) in the year 2007. Descriptive analyses were carried out to generate tables and graphs showing distribution of households using the various energy types across provinces as well as the urban residential area income level classification. The local authorities in the country have classified urban residential areas into low cost, medium cost, and high cost areas. The LCMS also collected data on demographic and socio-economic characteristics of households.

The LCMS sample is based on a two-stage cluster sampling procedure, with an overall response rate of 98%. In the first stage, 1,000 standard enumeration areas (SEAs) were selected with equal probability. In the second stage, 20 households from each selected SEA were sampled using systematic sampling, after a complete household listing and mapping of the selected SEAs. In addition to the LCMS data, the study also used the UCS data collected in four urban towns: Lusaka, Kitwe, Kasama, and Mansa. About 2,400 urban households in the four towns were interviewed in two phases. The first phase of the survey was conducted in August 2007, and the second in February 2008. The LCMS was conducted in 2010; about the same time of the year the UCS second phase was conducted.

A third dataset that was used is the monthly price statistics data, compiled and published by the CSO. Price data for energy items for the month of February 2010 were used. The items of interest for the study included the cost of improved charcoal stoves (*mbaula*), charcoal (standard 50 kg bag), and electric cooker/stove. The price per kwh of electricity for 2010 was obtained from ZESCO.

#### 3.2. Energy Data

The LCMS of 2010 provides relatively good data on household energy use and consumption. However, the energy data in the LCMS have two major limitations. Firstly, the survey asked only for the main cooking fuel for each household, the main cooking device, whether the house was connected to electricity, and monthly electricity charge. Thus, identifying fuel-stacking behavior is difficult with the LCMS. Using the additional variables and making some assumptions, secondary fuel use was determined. If electricity was not the main cooking fuel/energy, but a household owned an electric stove or hot plate, then electricity became a secondary energy source for cooking. If charcoal was not the main cooking fuel/energy, but the household owned an *mbaula* (charcoal brazier) or purchased some charcoal, then charcoal became a secondary energy source. Secondly, access to potential alternative fuel could not be established because households were only asked about what fuels they currently use, and not what other fuels they might potentially have access to. Consequently, actual use must be taken as a proxy for access. This is a limitation in the sense that it makes it difficult to understand why particular households fail to make use of specific fuels and specifically, whether this is due to availability constraints or other factors such as affordability.

In terms of expenditure, the LCMS data make it possible to construct a variable for the total amount spent on charcoal, electricity, and value of other cooking fuels. This can be compared to total real household expenditures in order to judge the importance of energy in household budgets. The measure of aggregate expenditures that is provided along with the survey data was used. In the asset section, energy data appear in the form of appliances owned. Households reported whether they owned a brazier (mbaula), gas stove, electric stove, fridge, freezer, washing machine, dishwasher, air conditioner, and electric iron.

### **3.3. Secondary Energy/fuel Sources**

Since usage of multiple cooking fuels is widespread, and given that part of the aim of this paper is to evaluate the extent of fuel switching, other sections of the survey were used to determine secondary fuels or energy used by the household. Over 98% of households reported wood, charcoal, or electricity as their main fuel/energy for cooking.

## 4. CONCEPTUAL FRAMEWORK AND DESCRIPTIVE STATISTICS

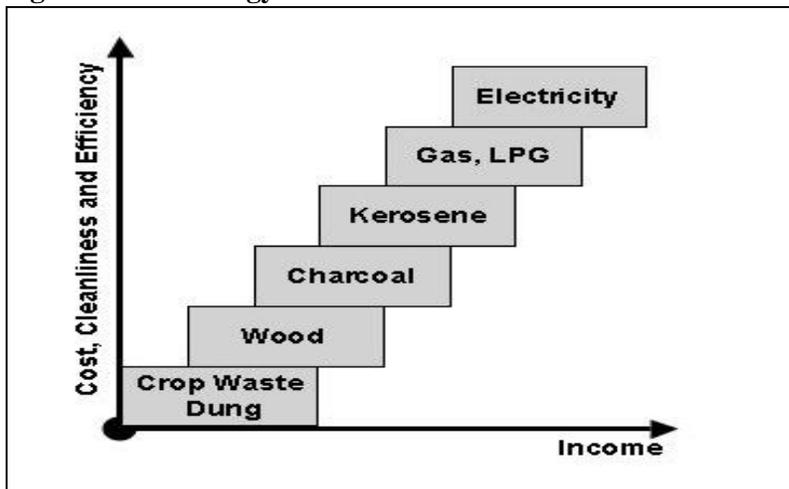
### 4.1. The Energy Ladder Model

Analyses of the interface between a household's socio-economic status and its choice of energy supply have identified an "energy ladder", where changes in household income status, and therefore the opportunity costs of household labor, drive changes in energy consumption. In its more common interpretations, the energy ladder posits that an improvement in household socioeconomic status increases the opportunity costs of utilizing lower rung fuel sources, such as dung, fuel wood, and charcoal, which tend to be cheaper yet more labor intensive to collect and use (Smith 1987; Holdren and Smith 2000; Barnes and Floor 1996). An increase in available income allows households to leave these fuels behind, and purchase technologies (stoves and fuels) higher on the ladder. These improved technologies are usually more efficient and costly, but require less input of labor and fuel, and produce less pollution. The process of moving up the ladder is commonly termed fuel switching or *interfuel substitution* (Barnes and Qian 1992; Hosier and Kipondya 1993; Leach et al. 1992).

The energy ladder model (Figure 1) captures the strong dependence of fuel choices on income. The energy ladder envisions that households are exposed to a number of fuel choices that could be arranged in an order of increasing technological sophistication and efficiency. Biomass fuels occupy the bottom of the ladder while electricity lies at the top. It is assumed that energy transition occurs linearly from the bottom to the top with increasing socioeconomic status of households either through a rise in income or a fall in price (Hosier and Dowd 1987).

Based on the Zambian Living Conditions Monitoring Survey the major sources of energy consumed at the household level in Zambia are firewood, charcoal, and electricity. Over half (54.3%) of all households in Zambia use firewood as their main fuel for cooking, 28.7% use charcoal and 16.8% use electricity. In the energy ladder theory, firewood occupies the bottom rung of the ladder while electricity is at the top. It would therefore be assumed that low levels of electricity consumption reflect broader issues related to low levels of disposable income and/or high electricity costs. Therefore, improvements in economic status of households, household energy consumption would shift towards using electricity.

Figure 1. The Energy Ladder



Source: Adapted from Holdren and Smith 2000.

However, evidence from a growing number of studies shows that multiple, concurrent fuel use is common in the developing countries. This is the situation where instead of smoothly switching from traditional energy source to modern, households only partially adopt improved and efficient energy source while continually relying on traditional fuels for performing specific tasks. Masera, Saatkamp, and Kammen (2000) in a paper in examines the energy ladder model using data from Mexico, argue that the energy ladder is limited and restrictive in its view because it does not adequately show the dynamics in household fuel choice. Another study in urban Ethiopia found use of multiple fuels, or fuel stacking behavior among households (Alem et al. 2013). Indeed, while changes in socio economic status create incentives for changes in household fuel type, other factors, including fuel type availability, its cost, cultural preferences, and intra-household decision-making dynamics all play a role in fuel use choices.

An important implication of fuel stacking is that the introduction of a new fuel may not displace other fuels, but rather add to whatever fuel is mainly used. Further, if uptake of a new fuel coincides with an expansion of household energy consumption it may not even reduce the consumption of other fuels. The misunderstanding between fuel switching and fuel uptake can affect energy policy, as it may result in excessive optimism regarding the potential for electricity to displace charcoal or wood.

#### **4.2. Fuel Switching in Zambia**

In this section, we assess the extent to which urban Zambians conform to the standard energy ladder model on fuel choice. The energy ladder is predicated on the notion of fuel switching, which refers to the displacement of one fuel by another. Yet, this is not a straightforward empirical question because households use cooking fuels in complex combinations. In urban Zambia, less than 1% of households use gas, kerosene, and other fuels. Because of this, and to avoid the confusion of dealing with a large number of categories of fuel combinations, a simplification is imposed. Fuel switching is here defined in the simplest possible manner, as the choice between charcoal (solid fuel) and electricity (modern non-solid energy) or a combination. All households belong in one of three exclusive fuel-switching categories:

1. No switching—households use charcoal only;
2. Partial switching—households use a combination of charcoal and electricity; and
3. Complete switching—households use only electricity for cooking.

The distinction between these three fuel-switching categories is made in order to isolate the problem of what determines fuel switching to a simple, tractable issue that can be studied with the data at hand. This definition of exclusive fuel switching categories can help us analyze the extent to which adoption of electricity (modern nonsolid fuel) displaces charcoal (solid fuel) in response to changes in economic status. Displacement of charcoal to a significant extent is required if electricity is to have an impact on combating problems associated with the use of traditional fuels.

The share of households in each fuel switching category is shown in Table 1. The table shows that fuel switching has not progressed much in urban areas of Zambia.

**Table 1. Fuel Switching Status, Urban Zambia**

Switching Status	Share Households
No switching – Charcoal only	0.470
Partial switching – Charcoal and electricity	0.336
Complete switching - Electricity only	0.142

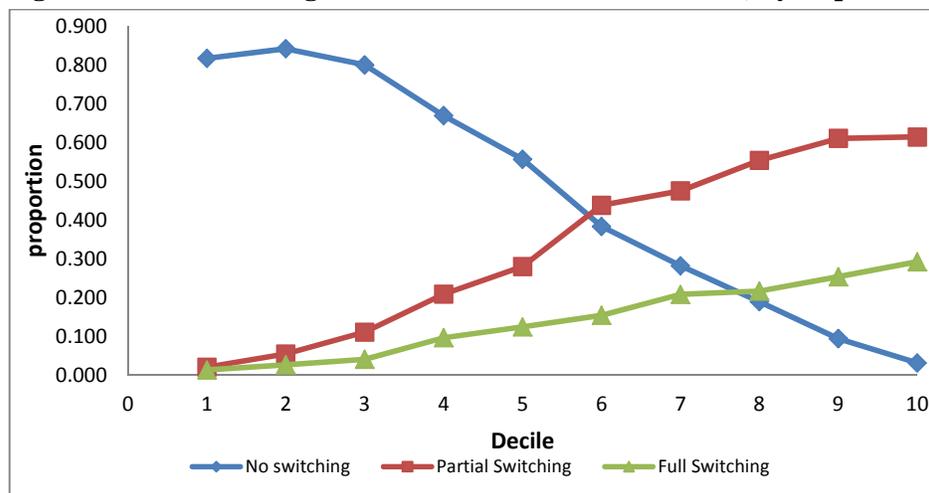
Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

Note: The shares do not sum to one since they include households reporting their fuel as 'wood' or 'other.' 0.336 is equivalent to 3.6% households.

Figure 2 shows the share of households in each expenditure decile in urban areas that belong in the three exclusive fuel-switching categories. The figure shows that there is very little fuel switching in urban Zambia—only the upper deciles exhibit fuel switching behaviors. Solid fuel is predominant in the lower deciles, until partial switching displaces it in the sixth decile. Complete switching becomes more common than solid fuel only after the eighth decile.

In summary, the role of electricity remains low in urban areas, even among relative more wealthy households. Moreover, these results suggest that once households start using electricity, it often complements and rarely displaces charcoal. This draws into question reductive theories of fuel use, such as the energy ladder, and suggests that household fuel decisions are conditioned by numerous factors beyond just income status.

**Figure 2. Fuel Switching Status in Urban areas of Zambia, by Expenditure Decile**



Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

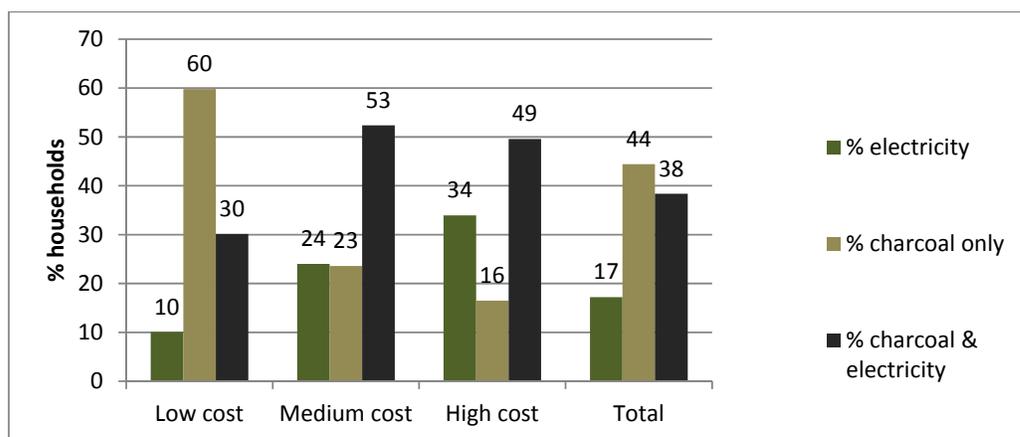
### 4.3. Multiple Fuel Choice in Zambia

In the section we show that an alternate *multiple fuel* model based on the observed pattern of household choice of energy options, rather than the simple linear progression depicted in the traditional energy ladder scenario, more accurately depicts cooking fuel use patterns among the urban households in Zambia.

Figure 3 below shows the percentage of urban households using various energy types for cooking, across residential areas and as a total.<sup>1</sup> This gives a different perspective to energy choice and household incomes. In general, use of charcoal as the main type of cooking energy, relative to other sources, accounting for 44% of the total urban households. Following charcoal is a mix of electricity and charcoal representing 38% of the total urban households, with electricity only in a distant third place (17%). When analyzed across residential areas, results indicate a possible correlation between income and relative cost of residential area. Charcoal only is the most prevalent cooking energy source in low cost areas, with close to two thirds of the households relying on this source. Electricity accounted for only one tenth of the total households in the low cost areas. Among the medium and high cost households, charcoal only was the least, with less than a quarter of households in the medium costs relying on it as the main source, and less than a fifth (16%) in the high cost areas.

A similar distribution of relatively more households in low cost areas using charcoal, followed by medium cost, and lastly high cost areas was observed by Chidumayo et al. (2002), although their analysis was based on Lusaka city only. One of the factors contributing to high charcoal dependence in low cost areas was erratic electricity supply caused by recurrent load shedding. In addition, factors such as access to electricity and electric stoves and household size also influence charcoal consumption (Chidumayo et al. 2002). Further, the graph indicates that even in the medium and high cost areas, a combination of electricity and charcoal is more common, indicating fuel stacking behavior rather than fuel switching. Thus, charcoal is an important and common source of cooking energy across all the three residential categories.

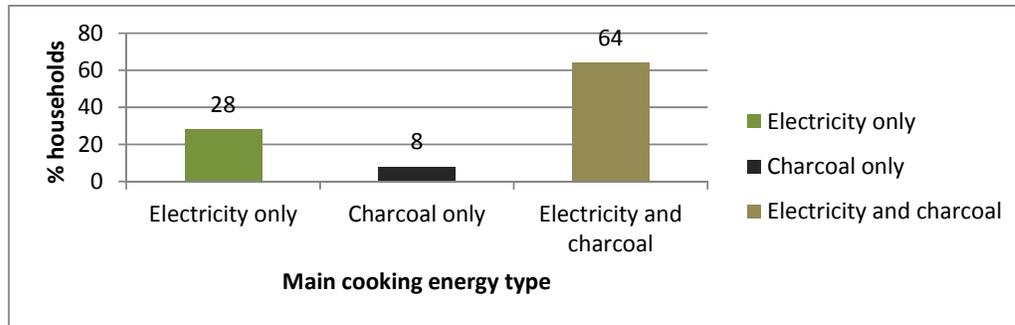
**Figure 3. Percent of Urban Households by Type of Cooking Energy and Residential Area**



Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

<sup>1</sup> At the sample selection stage of the LCMS, the urban SEAs were classified as low cost, medium cost, and high cost areas according to local authority classification of residential areas.

**Figure 4. Electrified Urban Households by Source of Cooking Energy**



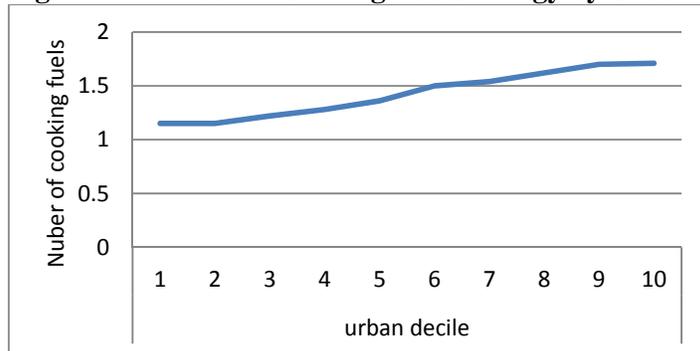
Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

We further analyzed the use of the three main types of cooking energy among electrified urban households as a way of accounting for electricity connection (Figure 4). Results reveal the most common source of cooking energy is not using electricity alone even among electrified households. Rather a combination of electricity and charcoal stands out, with two thirds of the households using both electricity and charcoal as sources of cooking energy. This reinforces the finding that fuel choice in urban Zambia is not simply a matter of economic status, nor is it simply a matter of connecting households to the electricity grid, though these both do appear to play important roles. The predominance of fuel stacking behaviors among the wealthy and those with electricity connections suggest that other factors influence households' tendency to utilizing multiple fuels concurrently. Estimating the relative magnitude of these other factors is important for devising policies to encourage the adoption of improved fuel sources.

Figure 5 shows the average number of different fuels that households used by total expenditure decile. Results show that a substantial number of households that in principle could afford modern, cleaner, and convenient electricity continued to rely fully or partly on charcoal. This does not fit easily with the traditional energy ladder model. Households consume a portfolio of energy sources spanning different points of the energy ladder.

From other studies (Chidumayo et al. 2002; WHO 2014), a number of reasons are put forward to account for this, including a preference for cooking with charcoal because certain traditional cooking techniques that give good taste or texture to the food can be employed, availability, cost, and use of charcoal as backup fuel in case of electricity power failure.

**Figure 5. Number of Cooking Fuels/Energy by Urban Expenditure Decile, 2010**



Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

## 5. DETERMINANTS OF HOUSEHOLD ENERGY CHOICE

Our descriptive results suggest that while urban households in Zambia display some tendency toward fuel switching in response to changes in socio-economic status, this response is not straightforward. Indeed, with a considerable share of wealthy households, including those with electricity connections, utilizing multiple fuel sources concurrently, we believe the standard energy ladder theory requires some modification.

Given the complexity of fuel choices in Zambia, including considerable fuel stacking among wealthy and electrified households, we will use a multinomial logit model to identify the determinants of a household's fuel choice.

### 5.1 Energy Choice Model Estimation Methods

The analysis of what determines the most important combinations of cooking fuels was carried out using multinomial logit (MNL) model for urban households. MNL is a regression technique used to assess factors associated with households' choice among mutually exclusive options (or fuel types in this case). For this analysis, we focus on the most important options: electricity-only, charcoal-only, and a combination of charcoal–electricity. Ninety-five per cent of households belong in one of these energy choices. The combination of charcoal-electricity group is used as base category. The MNL model is expressed as shown below:

$$P_{ij} = P(y_i=j) = \frac{\exp(\omega_i \gamma_j)}{\sum_{k=1}^m \exp(\omega_i \gamma_k)} \quad (1)$$

where  $\omega_i$  is a vector of explanatory variables postulated to influence a household's choice of fuel type,  $\gamma$  is the set of regression coefficients associated with outcome  $(j,k)$ .

The marginal effects are computed by differentiating (1), as expressed in (2) below:

$$\frac{\partial p_{ij}}{\partial \omega_i} = p_{ij} (\gamma_j - \gamma_1) \quad (2)$$

The regressors include core variables such as household monthly expenditure, retail price of charcoal, and household size, which are usually part of any demand equation on *a priori* theoretical basis. Other variables include a dummy for whether head of household is male; dummies for whether the age of head of household is 25-44, 45-64 years, or 65 or older (with 24 or younger, the omitted category); dummy of whether the maximum level of education of head is post-secondary; and a regional dummy for each of the nine provinces in the country.

### 5.2. Results of the Multinomial Logit Analysis

Estimated parameters are presented as coefficients. Positive coefficients are associated with a higher likelihood of the outcome compared to the base case, all else equal (*ceteris paribus*). Negative coefficients indicate that the variable causes the outcome to have a lower likelihood than the base category. For example, a significant negative coefficient for charcoal-only suggests that higher values of that variable reduce the likelihood of using charcoal-only compared to using a combination of electricity and charcoal.

Table 2 presents the results of the multinomial logit. Results show that household expenditure, a proxy for household income does not influence the likelihood of using electricity as the only energy source (relative to the base case, a combination of electricity and charcoal), contrary to the traditional energy ladder theory. Higher charcoal price reduces the likelihood of using charcoal-only, compared to a combination of electricity and charcoal. This is important as it suggests that interventions that increase the cost of charcoal can prompt households to move towards using electricity and reduce reliance on charcoal. Results also indicate that type of residential area is the strongest determinant of fuel switching. Being in a higher income residential area increases the likelihood of using electricity-only, and at the same time reduces the likelihood of using charcoal-only.

Education is also a significant determinant of fuel switching. Households whose heads have an education level above secondary school have a larger likelihood of using only electricity and the likelihood of using charcoal only is less.

**Table 2. Multinomial Logit Analysis of Charcoal/Electricity Combinations (Base Category: Combination of Charcoal and Electricity)**

Variable Name	(Multinomial Logit/MLE)					
	Electricity Only			Charcoal only		
	Coefficient	Sig	p-value	Coefficient	Sig	p-value
Monthly expenditure in 100s kwacha	0.000		0.976	0.011	***	0.000
log expenditure in 100s kwacha	-0.081		0.405	-1.916	***	0.000
Retail price 50 kg charcoal 000s ZMW	0.053	**	0.037	0.066	***	0.002
log of retail price 50 kg charcoal 000s ZMW	-2.101	**	0.010	-1.537	**	0.016
household size	-0.141	***	0.000	-0.039	**	0.049
=1 if household poor	0.058		0.824	1.081	***	0.000
<i>Residence (Low cost is base)</i>						
Medium Cost Area	0.564	***	0.000	-0.727	***	0.000
High Cost Area	0.881	***	0.000	-0.906	***	0.000
=1 if owner occupied house	0.018		0.859	0.113		0.217
<i>Age of HH head (24 years (yrs) or younger is base):</i>						
=1 if age (25-44 yrs)	-0.637	***	0.006	-0.596	***	0.004
=1 if age (45-64 yrs)	-0.818	***	0.001	-0.609	***	0.007
=1 if age (65 yrs or older)	-1.185	***	0.000	-0.259		0.361
= 1 if HH head is male	0.228	**	0.031	-0.077		0.430
= 1 if education level of HH head (> grade 12)	0.402	***	0.000	-1.254	***	0.000
<i>Province (Central Province is base):</i>						
=1 if Copperbelt Province	0.486	*	0.052	-0.533	***	0.007
=1 if Eastern Province	0.131		0.544	0.075		0.692
=1 if Luapula Province	-1.199	***	0.001	0.638	***	0.003
=1 if Lusaka Province	0.287		0.457	-2.126	***	0.000
=1 if Northern Province	-1.115	***	0.000	0.687	***	0.000
=1 if Northwestern Province	-1.080	***	0.000	0.639	***	0.001
=1 if Southern Province	0.719	***	0.001	-0.077		0.678
=1 if Western Province	0.378		0.130	1.285	***	0.000
Constant						
Observations	10,297					
F stat: Joint significance of all regressors	40.99	***	0.000			

Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

Note: \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.10.

To better understand the nature of the substitution patterns between the three main cooking fuel categories among the households, we calculated the marginal effects of the significant variables at sample means. These are presented in Table 3. The numbers in this table show the effect of a unit change in a given explanatory variable (or a switch in the case of dummy variables) on the probability of choosing each one of the three fuel categories.

As the monthly expenditure variable is in logarithms, the corresponding marginal effects can be interpreted as the effect of a relative change, and thus can be used for a direct comparison of the magnitude of different effects. Among the two continuous explanatory variables, household expenditure and household size, expenditure has the most important effects and, among the dummy variables, those associated with the household's residence and head's education have the greatest effects.

These results indicate that a 10% increase in monthly household expenditure will raise the share of electricity-only users by 1.1% and that of electricity and charcoal by 36.3%, while decreasing the share of charcoal by only 4.7%. This reaffirms the fact that uptake of electricity does not necessarily result in replacement of charcoal. In addition, the household head having post-secondary education increases the probability of choosing electricity-only, and electricity and charcoal as a cooking fuel, whereas those households where the head has a lower level of education are more likely to use charcoal only. For instance, households with heads who have post-secondary education are on average about 31% less likely to use charcoal than those with lower than secondary school education.

Being in medium cost or high cost residence increases the probability of choosing electricity only and, to a lesser extent, a combination of charcoal and electricity as a cooking fuel than those living in low cost residences (base category). For instance, households in high cost and medium cost residences are on average 27% and 21%, respectively, less likely to choose charcoal only as a cooking fuel than those in low cost residences (base category).

The size of the household and the sex of the head being female have a negative effect on the probability of choosing cleaner fuels, and so does the age of the head.

**Table 3. Marginal Effects at the Sample Mean**

<b>Variable Name</b>	<b>Electricity Only</b>	<b>Electricity and charcoal</b>	<b>Charcoal only</b>
log expenditure (ZMW)	0.110	0.363	-0.473
household size	-0.014	0.015	-0.001
=1 if household poor	-0.060	-0.198	0.258
<i>Residence (Low cost is base)</i>			
Medium Cost Area	0.120	0.092	-0.212
High Cost Area	0.194	0.079	-0.273
<i>Age of HH head (24 yrs or younger is base):</i>			
=1 if age (25-24 yrs)	-0.036	0.133	-0.097
=1 if age (45-64 yrs)	-0.056	0.145	-0.089
=1 if age ( 65 years or older)	-0.104	0.088	0.016
= 1 if HH head is male	0.029	0.004	-0.033
= 1 if education level of HH head is post sec (> grade 12)	0.132	0.181	-0.313

Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

## 6. DETERMINANTS OF CHARCOAL CONSUMPTION

Having estimated the determinants of fuel choice in the previous section, we now focus on the determinants of the quantity of household charcoal consumption. Determining factors that influence household charcoal consumption is important in informing strategies aimed at reducing charcoal consumption among charcoal users.

We used the Heckman two-step model with a control function approach to account for selection bias and suspected endogeneity of access to electricity, respectively. We log transformed the dependent variable so that we can interpret the coefficients on independent variables as percentage change in the dependent variable due to a unit change in a particular independent variable. Notice also that expenditure (income) and charcoal price were log transformed so that we can interpret the coefficients associated with these two variables as income and own price elasticities, respectively.

Table 4 presents the results of the determinants of urban household monthly charcoal consumption. The results show that age of the head and education level of the head are important determinants of charcoal consumption. The positive coefficient on age indicates that households headed by older people consume more charcoal than their counterparts headed by relatively younger heads. This could be a reflection that older people are used to cooking with charcoal since this was the most common source of energy in the past, therefore they still prepare most of their meals using charcoal. Education of the head has a negative influence on charcoal consumption, implying that having a head with one more level of education reduces charcoal consumption by one percentage point. As expected, household size has a significant and positive influence on monthly charcoal consumption, given the high-energy requirement to prepare meals for a large family. Increasing household size by one more member increases charcoal consumption by 25 percentage points.

Household income as proxied by total monthly expenditure has a positive and significant coefficient, implying that charcoal consumption by an average urban household in Zambia increases with income. This result shows that a percentage increase in income leads to 0.28 percentage points increase in the quantity of charcoal consumed. This result provides evidence that charcoal is not an inferior good, contrary to most literature and the energy ladder model, in particular. This result corresponds with Mekonnen and Köhlin (2008) who find that even at higher income levels, urban households still use traditional energy sources such as charcoal in Ethiopia, mainly because of preferences, taste, reliability of supply, and cooking and consumption habits. However, notice that the square of expenditure has a negative coefficient, indicating that although charcoal consumption increases with income, this increase is at a decreasing rate and tends to diminish as income continues to increase. Charcoal price on the other hand was not significant, but had an unexpected sign. The insignificance of price in influencing charcoal consumption is probably due to the fact that, at district level, charcoal prices are largely uniform.

**Table 4. Determinants of Household Monthly Charcoal Consumption**

<b>Dependent Variable: Log of monthly charcoal consumption (kg)</b>	<b>Heckman (OLS)</b>	<b>Sig.</b>
Constant	-10.670	***
Age of head	0.200	**
Education level of head	-0.112	
Household size	0.252	***
Charcoal price (log)	0.229	
Per capita monthly expenditure (log)	1.931	***
Square of per capita monthly expenditure	-0.070	***
Household electricity connection (=1)	-0.473	**
Central Province	0.465	***
Luapula Province	0.746	***
Northern Province	0.741	***
Generalized residuals for electricity connection	0.005	**
Inverse Mills Ratio	-2.024	***
Joint provincial test	75.53	***
Observations	9,388	
R-squared	0.2717	

Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

Note: \*\*\*, \*\*, and \* refer to significant at 1%, 5%, and 10% level respectively.

In order to assess the effect of access to electricity on charcoal consumption, we included, as one of the covariates, electricity connection equal 1 if a household is connected and 0 otherwise. Since we suspected electricity connection to be endogenous, we accounted for this possibility by employing the control function approach. The results show that access to electricity has a negative and significant influence on charcoal consumption, with the coefficient implying that being connected to electricity reduces charcoal consumption by about 47 percentage points. Therefore, on average, households that are connected to electricity consume 47% less charcoal per month than those that are not connected.

Spatially, we find that being in a particular province has significant influence on charcoal consumption, as indicated by the significant coefficient of the joint provincial dummy variable. In particular being in Central, Luapula, and Northern Provinces increases charcoal consumption relative to Western Province.

## **7. CHARCOAL CONSUMPTION AND FOREST DEGRADATION**

With approximately 67% (49,468,000 ha) of its land surface covered by forest, Zambia is one of the most forested countries in Africa (FAO 2011). However, at the global level, Zambia has been identified as one of the top 10 greenhouse gas (GHG) emitting countries as a result of deforestation and degradation (EIA 2008). Estimated rates of deforestation for Zambia vary depending on the methods of measurements used. The Food and Agriculture Organization of the United Nations (FAO 2011) estimates average annual rates of deforestation to be 167,000 ha per annum or 0.33% of total forest cover between 2000 and 2010. However, the most commonly quoted figure is 250,000-300,000 ha per annum (approx. 0.50-0.60% of total forest cover) based on 1965-2005 data (see Vinya et. al. 2012; UN-REDD 2010).

Charcoal and wood fuel production, logging for timber, expansion of small-scale agriculture and unsustainable agricultural practices have been identified as the main drivers of deforestation in Zambia (GRZ and UN-REDD 2010). Charcoal and wood fuel production (for domestic, commercial and industrial uses) is a main driver of deforestation. Therefore, the use of charcoal for cooking may not be the main cause of deforestation. That said, the predominance of charcoal use among urban households suggests that it is important. It is also critical to know, from our results that the continued economic growth in Zambia will not reduce the demand for charcoal, it will increase if other measures are not taken on board. In this section, we estimate what the implications on Zambia's woodland are.

In Zambia, few studies provide estimates of forest cover lost due to charcoal consumption. In this paper we use the methodology and conversion factors generated from the work done by Hibajene and Kalumiana (2003), in which they describe the production process and estimation of wood use through the determination of the kiln efficiency. The carbonization ratio that we calculate is comparable to what other sources give. According to FAO assumptions one ton of charcoal is derived from six cubic metres of fuelwood (which means 4.35 tons of wood for one ton of charcoal). However, this estimate is not likely to be generalized for the case of Africa where the carbonization efficiency is substantially lower. For sources other than FAO, the general Carbonization Ratio assumed is six. Area cover estimation is based on work by Chidumayo (2002).

### **7.1. Estimation of Quantities of Charcoal Consumed**

In order to estimate the quantities of charcoal consumed, data on fuel expenditures have to be converted into physical units of consumption, and to do that, data on energy prices are required. Since the LCMS did not collect price data, regional unit prices were taken from the UCS of 2007. The UCS collected data on the units, weight, and price of charcoal. The average unit, weighted by the frequency of unit purchases recorded in the main questionnaire, was used to calculate a weighted average price of charcoal per kg. Dividing expenditures by unit prices yielded an estimate of the physical quantities of consumption of charcoal, which we then converted to metric tons per year (Table 5).

**Table 5. Quantities of Charcoal and Area Equivalent in Hectares by Residence, Urban Zambia, 2010**

		Monthly charcoal consumed for cooking in tons	Annual charcoal consumption for cooking estimates	Monthly area (ha) Cleared for charcoal	Annual area (ha) cleared for charcoal
Urban Zambia		16,518.1	198,217.2	1,939.0	23,268.0
Stratum	Low Cost	12,678.7	152,144.4	1,488.3	17,859.6
	Medium Cost	2,518.8	30,225.6	295.7	3,548.4
	High Cost	1,320.6	15,847.2	155.0	1,860.0

Source: Authors' calculations based on LCMS 2010 data, CSO 2012.

## 7.2. Estimation of Area Equivalent in Hectares of Charcoal Consumed

To convert charcoal consumption into equivalent wet wood and forest area change, we adapted the methodology and factors used by Hibajene and Kalumiana (2003) and Chidumayo (1993). Work by Hibajene and Kalumiana (2003) gives the conversion factors for charcoal produced using the traditional kiln in Zambia. It was found that 3% of the charcoal produced is left at the earth kiln site as small pieces that cannot be packaged. The tree biomass-to-charcoal conversion efficiency, with moisture content of 18%, for oven dried wood and air-dried wood was 25% and 21% respectively. The following formula is used to calculate the wet wood mass for air-dried wood.

Green wood (wet) = Air-dry weight/(1-Moisture content).

This formula, for 1 kg of charcoal, translates into:

Green wood (wet) =  $((1/0.97)*(1/0.21))/(1-0.18) = 5.9868$ .

This gives a factor of 1 kg of charcoal to about 6 kg of green wood. This factor was used to convert the quantity of charcoal (in kg) consumed into wet wood equivalent. The quantity of wood equivalent was converted into estimated area cover using the factor given by Chidumayo et al. (2002), in which it is assumed that in plateau miombo woodland, cord wood density per hectare is 51 tons. Dividing the wet wood quantity by 51 tons gave the equivalent area in hectares.

Assuming that the survey month reflected typical monthly consumption of charcoal, the annual consumption of charcoal by urban households in 2010 was 198,217 tons. This quantity of charcoal is produced from 1.187 million tons of cordwood, which equals 23,268 hectares of well-stocked plateau miombo woodland. The estimates are based on a number of assumptions: that all trees are felled primarily for charcoal production, and that all forests are of uniform density. In reality, trees may be selectively harvested for charcoal production leaving uneven forest cover. Moreover, charcoal may also be produced from forest cleared for other purposes.

Despite these potential concerns with the estimate, it is clear that the contribution of charcoal consumption to forest degradation is significant.

## 8. CONCLUSIONS AND RECOMMENDATIONS

This paper was conducted primarily to provide results regarding household fuel use and fuel switching behavior using a nationally representative database of 10,297 observations in urban Zambia. Results of estimates of a discrete choice model on fuel choices and patterns of cooking fuels in urban Zambian households was used to determine the responsiveness of fuel choices to economic, socio-demographic and geographic characteristics of households. In addition, the study carried out analysis of the determinants of monthly household charcoal consumption. Lastly, by providing estimates of the contribution charcoal makes to forest cover depletion, this study clearly shows that the environmental implication of charcoal use has serious consequences for the country now and in the foreseeable future.

The descriptive results and the econometric analysis reported in this paper suggest that there is an order in the distribution of energy shares that depends largely on the level of income of the household. In general, the observed patterns in the data are consistent with the 'energy ladder' theory. Charcoal only and electricity only are at the two extreme end of the income spectrum with the combination of the two in the middle. However, within this pattern, we observe fuel stacking behavior (combination of charcoal and electricity) as incomes increase, contrary to the widely held hypothesis of fuel switching. Higher incomes do increase the household's probability of electricity uptake. However, in the majority of cases, this does not lead to fuel switching from charcoal to electricity, but rather households stack fuel. This results in the addition of electricity to charcoal, rather than completely switching from charcoal to electricity.

The results also show that, in addition to income, there are several socio-demographic factors such as education and age of the head of the household, which are important in determining the choice of fuels in urban Zambian households. Other recent studies (Heltberg 2005; Masera, Saatkamp, and Kammen 2000; Mekonnen and Köhlin 2008) show similar results suggesting that fuel choice is not determined purely by economic factors and that a more general interpretation of the energy ladder theory is needed.

Regarding determinants of charcoal consumption, results show that higher incomes result in substantial reduction in charcoal consumption and an increase in electricity consumption by majority of households in urban Zambia. However, as with the determinants of fuel choice, households do not abandon charcoal for electricity but continue to consume both types of energy. The study also shows that other social, economic, and household factors affect charcoal consumption. Among the most influential are the size of the household, educational level of head, and whether the house is connected to electricity.

The study also presents a calculated contribution of charcoal consumption by urban households to the forest cover reduction. We provided the estimation of forest cover lost due to charcoal consumption by urban households. We used the tree biomass-to-charcoal conversion efficiency rates from work by Hibajene and Kalumiana (2003), which provides a more accurate formula for calculating the factor for converting the quantity of charcoal (in kg) consumed into wet wood equivalent. The estimated area of 23,268 hectares of forest cover lost due to charcoal consumption by urban households underscores the gravity of the situation.

The following policy recommendations based on the findings are made:

There are policy options for promoting fuel switching. Price subsidies for modern energy such as electricity are probably the most popular with the general public and therefore attractive to governments. Such subsidies can win politicians votes and bring substantial political benefits. However subsidizing electricity would bring with it high fiscal costs. Without corresponding increase in power generation, such subsidies may cause supply shortages, restricting access to the electricity it is meant to promote. In addition, subsidies on recurrent use of any good, including electricity, often create vested interests that will lobby for their continuation making them hard to reverse even when they become fiscally unsustainable. Further, unless careful targeting is in place, such subsidies may benefit many better-off households and fail to reach the poor households.

The alternative policies such as subsidizing uptake costs such as cookers and a one-off electricity connection charge should be considered a priority. The advantage of this is the better targeting, directing the subsidy to new users with lower income than the average existing users.

Physical infrastructure services can also be important catalysts to fuel switching. The most important and the most basic of these physical infrastructure services are electricity, water supply, and roads. Barnes, Krutilla, and Hyde (2002) from their comprehensive assessment of the evolution of residential fuel choice and consumption in urban areas in the developing world, report that electrification appears to spur fuel switching.

Electricity uptake interventions may also be dependent on the purchasing power, and other conditions being present for its adoption. Where adoption of electricity is unlikely, other energy improvements such as improved stoves or improved kilns should continue to be made. There is need to consider low-cost technologies in cases where target households have limited purchasing power.

Considering that charcoal will remain the most common fuel of choice in urban Zambia in the foreseeable future, programs that target the improvement of production and utilization of charcoal should be intensified. Bensch, Kluve, and Peters (2011) show that the dissemination of the Improved Cooking Stove (ICS) project in Senegal resulted in households saving around 25% of charcoal per stove utilization, on average.

The government should not neglect charcoal markets in its energy policies. Urban buyers of charcoal are among the poorest and are those who are most exposed to energy price fluctuations because they spend a large share of their income on cooking fuels. Lower and more stable charcoal prices could bring real benefits to this group, until when in the longer run they may be able to switch to electricity.

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