CHAPTER ONE

Introduction

1.1 Background

Energy is seen as a crucial element for development (Barnes et al., 2015). Access to clean and affordable energy allows households to meet their basic human needs, and is essential for increasing agricultural productivity, encouraging economic activity, generating employment and income opportunities, and improving the quality of life particularly of women and children (UN, 2002; UNDP, 2009). Yet, a large share of the world's population is still not able to gain from the advantages that modern forms of energy can deliver. Modern energy refers to electricity, liquid fuels such as kerosene, and gaseous fuels such as liquefied petroleum gas (LPG) and natural gas and excludes traditional biomass and coal. Biomass fuels, including wood and charcoal, are the most used sources of energy in developing countries where around 3 billion people still rely primarily on biomass fuels for cooking and heating (IEA, 2010) and approximately 1.3 billion people have no access to electricity (IEA, 2012).

Sub-Saharan Africa inhabits the highest proportion of people without access to modern fuels (see Figure 1.1). Contrary to trends throughout Asia, were the use of wood as an energy source has generally peaked, projections suggest that the use of wood in SSA will remain at current levels and may even continue to grow in both rural and urban areas (IEA, 2009, Word Bank, 2011). This increase in wood fuel consumption in sub-Saharan Africa is driven by a demographic growth rate that outpaces economic development and the related growth in access to modern fuels in this part of the world. Energy access is generally perceived a rural problem, with over 87 percent of those relying on biomass fuels residing in rural areas. In SSA, however, the urban dimension of the energy problem is substantial as well, with currently over 60 percent of the urban households lacking access to modern fuels, and are depending on charcoal as their major source of household energy (Zulu, 2013). Most of the projected increase in the world's energy consumption in the coming years will occur in cities of the developing world (EIA, 2007; IEA, 2008). This increase in energy demand is driven by the rapid urbanization witnessed in most developing countries (Dhakal, 2009; Sadorsky, 2013). Worldwide, Africa has experienced the highest urban growth during the last two decades with a 3.5 percent increase in urban population per year (African Development Bank, 2015). The share of the African urban population is expected to increase further from 36 percent in 2010 to over 60 percent by 2050 (ibid). This is expected to further increase demand for energy in urban areas and highlights the importance of a transition towards cleaner and sustainable energy sources.

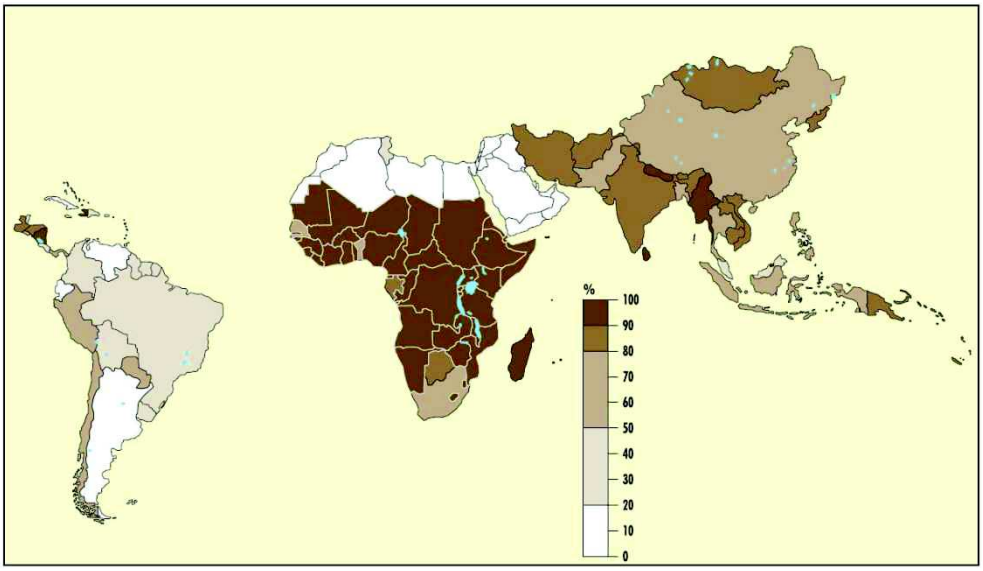

Figure 1.1 Share of traditional biomass in residential consumption by country (source: IEA, 2010)

Around 90 percent of the energy consumed by households in developing countries is used for cooking, making it the most energy intensive household activity (WEC, 1999; Murphy, 2001; IEA,2006). In SSA wood based fuels are the dominant source for domestic energy, used by some 90 percent of the households**.** Cooking with biomass is associated with a significantly higher disease burden than other forms of cooking. Household air pollution, resulting from incomplete combustion of biomass fuels is estimated to cause an annual mortality of 4.3 million (WHO, 2015), which makes it one of the most serious global health problems. In addition, the collection of biomass fuels is not only a time consuming task constraining women to engage in income generating activities, it also causes serious physical damage due to the heavy loads carried (Heltberg, 2004). Where fuels are purchased on the market the expenditures are significant due to the low efficiency of combustion severely constraining household budgets (Bensch and Peters, 2012).

Although agriculture is usually seen as the main driver of deforestation in developing countries (Geist and Lambin, 2002; Arnold, 2006), in Africa firewood harvesting and charcoal production are seen as an important cause of deforestation (Kaimovits and Angelsen, 1998; Geist and Lambin, 2000). In particular the increasing demand for charcoal from urban centers poses a real threat to the remaining forested lands (Edwards and Langpap, 2005). This conflicts with rural bioenergy requirements and erodes rural livelihoods. The incomplete combustion that emits unhealthy particles also generates compounds that contribute to global

warming such as methane and black carbon. Residential biomass burning is responsible for an estimated 18 percent of global black carbon emissions (Bond and Sun, 2005).

To overcome the negative effects of the inefficient traditional use of biomass, a transition towards cleaner and more efficient fuels and technologies is needed. Switching from traditional biomass to modern fuels, such as LPG, biogas and ethanol is generally considered paramount as these fuels are expected to bring about the largest improvements (Schlag and Zuzarte, 2008). However, the transition away from biomass to modern fuels is slow. Especially in Africa's rural areas, little activity is recorded with regards to household fuel switching (Barnes et al., 1994; Heltberg, 2004; Mirza and Kemp, 2009). Improved cookstoves[1] could serve as a low cost "bridging alternative" for those households that cannot make the switch to modern fuels (Foell et al., 2011; Bensch and Peters, 2012). Despite the numerous improved cookstove programs that have been established over the years the uptake of such stoves have not reached scale (Jan et al., 2012; Hanna et al. 2012; Mobarak et al., 2012).

The transition away from biomass to modern fuels has been described in the literature primarily based on the so-called "energy ladder" (Leach, 1992). The model underlying the energy ladder assigns differences in energy use patterns between households to variations in economic status (Hosier and Dowd, 1987; Leach, 1992; Barnes and Floor, 1996). The process of climbing the ladder is described by a linear movement with three distinct phases from universal reliance on firewood to transition fuels such as kerosene and charcoal, and finally to modern fuels such as LPG and electricity (Heltberg, 2004). The model assumes that households, whilst climbing the ladder, displace one fuel by another, referred to as fuel switching. A growing body of empirical literature on household energy use shows, however, that the energy transition does not occur as a series of simple, discrete steps. Instead, multiple fuel use is more common and is referred to as fuel stacking (Leach, 1992; Davis, 1998; Karekezi and Majoro, 2002; Campbell et al., 2003; Brouwer and Falcao, 2004; Heltberg, 2004; Martins, 2005; Arnold et al., 2006).

[1] The term improved cookstove refers to a wide variety of replacements for traditional cooking methods with a correspondingly large variation in performance (Grieshop, 2011). The main technical principals are always the same: improved combustion and improved heat transfer to the pot minimizing the release of harmful emissions and reducing fuel requirements (Bryden et al., 2006; Lewis and Pattanayak, 2012; Ruiz-Mercad et al., 2011; Smith et al., 2011).

Both the energy ladder and the stacking model fail to fully explain the role of consumer choices in fuel and stove selection (Hiemstra-van der Horst and Hovorka, 2008; Takama et al., 2012). Little is still known about how to induce the behavioral change that effectively delivers long-term benefits in the domain of household cooking (Jeuland et al., 2013). In order to promote the adoption of new fuels and technologies, an understanding of households' needs and preferences is required (Jeuland et al., 2013). The lack of knowledge regarding the factors that influence the energy choices made by households contributes to failing policies and programs aiming to push the transition process. Therefore, increased insights in household decision-making is essential.

This dissertation aims to fill this knowledge gap by undertaking a comprehensive analysis of household behaviour in relation to fuel and technology choice in an energy transition context. A new conceptual framework is developed that incorporates both household internal and contextual external variables for the analysis of choice behavior, avoiding the overemphasis in the energy ladder model on income as the main determinant of household fuel choices. This framework, referred to as the household decision environment, represents a web of factors that influence household behavior and provides the backbone of this dissertation and the empirical studies carried out in SSA addressing household fuel choice behavior.

1.2 Main objective and research questions

Given the limited information available about household decision-making in an energy transition context in developing countries in general and SSA in particular, this study aims to improve the understanding of the behavioural drivers of decision-making related to available improved cookstoves and associated fuel sources, which are crucial for explaining and predicting the energy choices made by households.

Following this main objective, the following main research questions are addressed:

i) How is the current energy transition in both urban and rural areas of developing countries best described in general?
ii) Which behavioural drivers play an important role in explaining and predicting household energy transitions?
iii) How do external local conditions influence the energy transition process?
iv) What role can improved cookstoves play in the energy transition process?

1.3 Research methods

For the first research question a literature study will be performed analyzing existing case studies that describe energy transitions in a developing country context. These findings will be compared with the results of two case studies which investigate fuel use and transition patterns in rural, peri-urban and urban areas in sub-Saharan Africa.

For research question two the results of the literature study will be used to develop an analytical framework that incorporates the factors influencing household choice behavior. This framework overcomes one of the main shortcomings of the current applied theoretical models which heavily rely on income as the main driver of household choice behaviour. The framework is applied in a meta-analysis of existing choice models investigating fuel switching and stacking behaviour in urban and rural areas in 12 different developing countries. For each case study we will also assess which of the previously found drivers play a role in explaining and predicting household choices for modern fuels and technologies based on revealed preference data for cooking fuels. Additional explaining factors are added based on shortcoming found in previous work. The information on the behavioural drivers found in the revealed preference data are limited when aiming to also analyze behaviour in response to new market developments where consumers have no experiences yet. To address potential demand and future fuel switching patterns a choice experiment is used to assess the impact of the household decision environment on modern fuels and new technologies. Further, a combination of both revealed and stated preference data is used to more accurately assess household preferences for improved cook stoves and modern fuels. The household energy consumption profiles elicited through the revealed preference data are used as determinants of choice behavior in the stated preference choice experiment. Existing studies use only one of the two data types and never combined the two.

For research question three both the impact of external local conditions on household choice behaviour is examined as relatively little is known about the impact of location factors on fuel switching behaviour. Although location dummies are often included in fuel switching studies, they rarely explain the underlying factors contributing to the effects on fuel switching. That is, hardly ever attention is paid to the differences between the locations included in the analysis. In this study I therefore focused on the impact of 2 specific local conditions which are deemed important for the fuel choice; local natural resource endowment and infrastructure conditions. The impact of these location factors are assessed by using both revealed and stated preference data.

The last questions focusses on the role of improved cookstoves in the energy transition process as they are assumed to offer households an intermediate step on their way to modern fuels. A choice experiment is used to analyze the preferences of consumers for new technologies that are not yet widely available. This will give new insights in the market potential of various cooking technologies in different socio-economic settings.

We target both men and women to account for possible gender effects. Existing studies on cooking fuels and cookstoves are primarily oriented towards female household members. Traditional gender relations in SSA show that the household's domestic tasks such as food preparation are indeed considered women's responsibilities, but men are often the decision-makers regarding the household's financial issues. By focusing on rural and peri-urban areas this study moreover contributes to the small body of empirical literature on energy transitions in such locations where little is known about household behavior.

The empirical data for this study have been collected in rural, peri-urban and urban locations. This geographical spread allows us to study and analyze the different stages of energy use. The peri-urban location is expected to be an intermediate stage between the urban energy profile and the rural energy profile, with the former depending more on modern forms of energy and the latter on traditional forms. The study takes part in the Sub-Saharan countries Kenya and Mozambique between which we find a distinct difference in socio-economic development as well as advancement in diffusion of renewable and efficient energy technologies.

1.4 Outline

This dissertation is organized as follows. **Chapter 2** starts with a critical review of the existing theories used to assess energy transitions in a developing country context. This leads to the development of a new conceptual framework to analyze the decision environment underlying fuel choices. This framework is applied in a meta-analysis of existing choice models investigating fuel switching and stacking behaviour in urban and rural areas in 12 different developing countries in Africa, Asia and Latin America. The main objective of this chapter is to identify the key factors explaining energy transition processes based on the developed framework underlying household energy choices.

Chapter 3 pays specific attention to the impact of external conditions on household fuel switching behavior. The case study zooms in on three rural and

peri-urban areas in Kenya with distinct local natural resource and infrastructure conditions. Fuel switching behavior of households is studied in these distinct external contexts to gain insight into the specific energy strategies applied by households and to evaluate the determinants steering their choice behavior. For the analysis of household fuel switching behavior we apply a multinomial logit model (MNL) which enables the systematic analysis of household switching behavior between different types of fuels.

Chapter 4 assesses the internal household characteristics driving choice behavior for fuels and alternative cookstove technologies in Kenya. By means of a choice experiment, the impact of the household decision environment on fuel choice and improved cookstoves is tested. The potential for a transition towards cleaner and more efficient fuels and technologies is assessed by zooming in on three fuel-stove combinations that represent different stages on the energy ladder. By specifically focusing on the relationship between product choice and the external decision environment insight are provided in the impact of contextual factors on fuel choice behaviour

Chapter 5 concentrates on energy transitions in an urban context. The study is carried out in 'Greater Maputo' where rapid urbanization and increasing demand for charcoal are a major cause for concern. The drivers of fuel switching behavior are assessed based on current urban household fuel profiles using revealed preference data. These fuel profiles form the basis for the analysis of potential demand and future fuel switching behavior for alternative fuel sources and cooking technologies. Using a choice experiment we analyze how household choices are influenced by current fuel profiles in order to improve insight in demand-side features for the development of energy products and market segments.

Chapter 6 summarizes and concludes based on the findings presented in chapters 2 to 5, provides answers to the research questions, highlights the novelty and limitations of the methods and data used, and gives recommendations for further research.