IVM Institute for Environmental Studies

The energy ladder: Theoretical myth or emperical truth?

Results from a meta-analysis

Bianca van der Kroon, Roy Brouwer, Pieter van Beukering

06 October 2011

IVM
Institute for Environmental Studies
VU University Amsterdam
De Boelelaan 1087
1081 HV AMSTERDAM
The Netherlands
T +31-20-598 9555
F +31-20-598 9553
E info@ivm.vu.nl

Contents

Summary

Modern fuels are an important enabler of social and economic development. Still, over 2 billion people rely on traditional biomass for their daily energy needs. To overcome the negative effects of traditional energy on human health and the environment and to enhance the livelihood conditions of the poor, a transition towards cleaner and more efficient forms of energy is needed. Understanding household fuel choice and fuel switching is of vital importance in search for policies to support such a transition process.

This paper adds to the existing energy transition literature in two ways. First, we provide a novel conceptual framework to analyze the decision environment underlying energy and fuel choices. Secondly, we apply this framework in a meta-analysis of existing choice models investigating energy switching and stacking behaviour in urban and rural areas in developing countries. The meta-analysis shows that socio-economic household characteristics appear to receive most attention so far in identifying groups of fuel users, while relatively little information is available on the impact of the external decision context on household energy choices.

1 Introduction

Over 2 billion people in developing countries rely on traditional biomass fuels - wood, agricultural residues and dung - for their daily energy needs. In many countries, these resources account for over 90% of household energy consumption (IEA, 2006). The use of biomass fuels in inefficient and traditional ways can have severe implications for human health, the environment and economic development (Heltberg, 2005). The collection of biomass fuels is not only a time consuming task constraining women to engage in income generating activities, it also causes serious health problems due to the heavy loads carried and indoor air pollution. With a person's productivity being proportional to his or her health status, the use of biomass fuels restricts one's economic contribution (Rao and Reddy, 2007). Women and children are often the ones who spend most time and effort on cooking and collecting firewood and are therefore most prone to the negative impacts of the use of biomass fuels (Heltberg, 2005). Environmental concerns of biomass use focus on deforestation, land degradation and air pollution (IEA, 2006).

To overcome these negative effects and enhance the livelihood situation of the poor, a transition towards cleaner and more efficient forms of energy is needed. Understanding household fuel choice and fuel switching is of vital importance in search for policies to support this transition process. A common model to describe household fuel choices in developing countries is the "energy ladder" which assigns differences in energy-use patterns between households to variations in economic status (Hosier & Dowd, 1987; Leach, 1992; Barnes & Floor, 1996). Existing research (e.g. Masera, 2000; Campbell et al., 2003; Gallagher, 2004; Heltberg, 2004; Farsi et al., 2007; Hiemstra-van der Horst and Hovorka, 2008;Mekonnen and Kohlin, 2008; Schlag and Zuzarte, 2008) has focused on describing household behaviour in light of energy transitions and tried to identify determinants driving household energy choices beyond income.

This paper contributes to the existing literature in two ways. First, we provide a more comprehensive framework based on farm household market participation decision-making in transition and developing economies to analyze the decision environment underlying fuel choices. Secondly, we apply the framework in a meta-analysis of existing econometric choice models investigating energy switching and stacking behaviour in urban and rural areas in 12 different developing countries in Africa, Asia and Latin America. The main objective of the paper is to identify the key factors explaining energy transition processes based on the developed framework underlying household energy choices. The assessment of energy transition models is accompanied by a critical review of existing knowledge and information gaps.

The remainder of this paper is organized as follows. Section 2 introduces the energy ladder model and discusses the empirical reality of the ladder. Section 3 introduces the general framework underlying the household decision-making environment related to energy choices. In Section 4 the drivers of the energy transition are reviewed in a qualitative meta-analysis. The paper concludes with a discussion of unresolved issues and essential focal points for future research in Section 5.

2 The energy ladder

The energy ladder model assumes households to mimic the behaviour of a utility maximising neoclassical consumer, which implies that they will move to more sophisticated energy carriers as their income increases, maximizing their utility (Hosier & Dowd, 1987). Fuel switching is a central concept in the energy transition process, referring to the displacement of one fuel by another. A move up to a new fuel is simultaneously a move away from the fuel used before (Heltberg, 2005). The fuels on the energy ladder are ordered according to the household's preferences based on physical characteristics, including cleanliness, ease of use, cooking speed, and efficiency (Hiemstra-van der Horst & Hovorka, 2008).

The process of climbing the energy ladder is described by a linear movement with three distinct phases (see the left hand side in Figure 2.1). As families gain socio-economic status they abandon technologies that are inefficient, less costly and more polluting and move from universal reliance on biomass fuels to transition fuels such as kerosene, coal and charcoal belonging to the second phase. In the last phase, households switch to fuels such as LPG and electricity (Heltberg, 2004). Higher ranked fuels are usually more efficient and costly, but require less input of labour and produce less pollution per unit of fuel (Masera et al., 2000). *The energy ladder also assumes that more expensive technologies are locally and internationally perceived to signify higher status. Families desire to move up the energy ladder not just to achieve greater fuel efficiency or less direct pollution exposure, but to demonstrate an increase in socioeconomic status* (Masera et al., 2000: 2084).

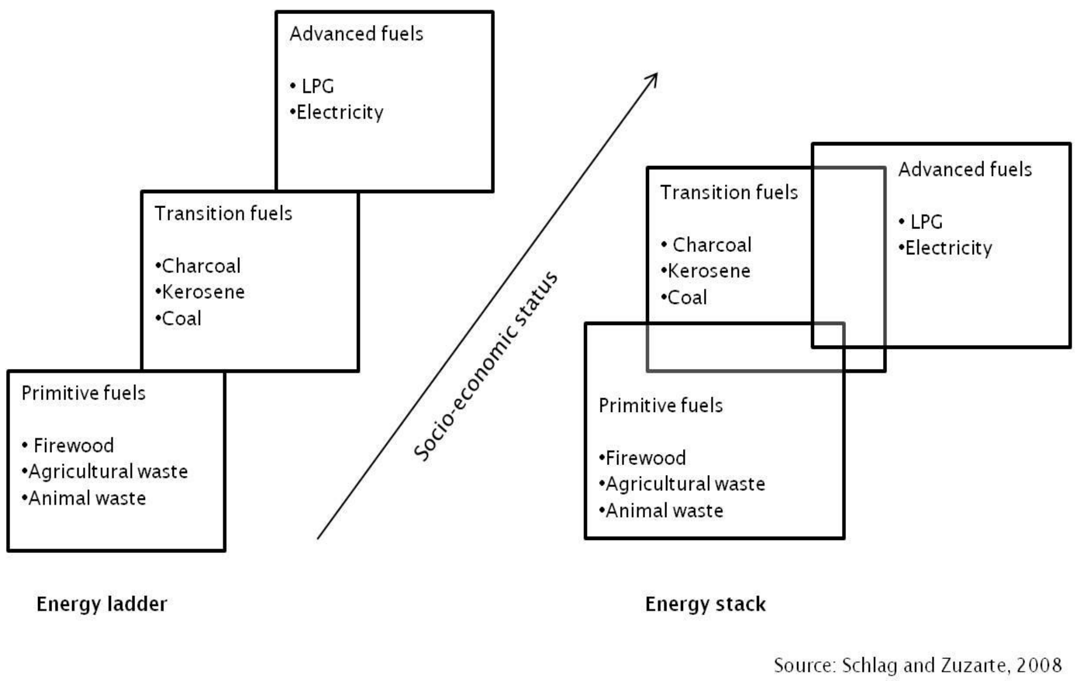

Figure 2.1 The energy transition process

The energy ladder model portrays wood as an inferior economic good, i.e. the fuel for the poor. This implies a strong correlation between income and fuel choice. Cross-country comparisons reveal a positive correlation between economic growth and modern fuel uptake, suggesting that *as a country progresses through the industrialization process, its reliance on petroleum and electricity increases and the importance of biomass decreases* (Hosier and Dowd, 1987: 347). On a micro-level, empirical studies have confirmed the relation between income and fuel choice too (see, Hosier and Dowd. 1987; Davis, 1998; Gupta and Kohlin, 2006; Farsi et al., 2007). However, empirical evidence suggests that the linkages between fuel choice and income level are rarely as strong as assumed by the energy ladder. Both Arnold et al. (2006) and Cooke et al. (2008) note that many estimated income elasticities of demand for fuel wood are insignificant, very low or even positive. Studies in developing countries have shown that fuel wood can be an important energy source for both urban and rural households at all levels of income (Hosier and Kipondya, 1993; Bhagavan and Giriapa, 1994; Brouwer and Falcon, 2004; Hiemstra-van der Horst and Hovorka, 2008; Mirza and Kemp, 2008). At the same time there are also numerous examples of low income households using advanced modern fuels such as electricity and LPG (e.g. Davis, 1998; Campbell et al., 2003; Brouwer and Falco, 2004). However, these studies were all conducted in urban locations and therefore may not be representative for rural households.

Energy use patterns of the rich and poor are certainly not identical. The per capita modern fuel consumption among high income households is far greater than that of low income households. However, the above described observations indicate that the *characterization of wood energy as the "fuel of the poor" is an oversimplification* (Hiemstra-van der Horst and Hovorka, 2008: 3336). It also suggests that a broader spectrum of influential factors besides income should be considered.

2.1 Energy stacking

A growing body of empirical studies on household energy use show that the energy transition does not occur as a series of simple, discrete steps; instead, multiple fuel use is more common (Leach, 1992; Davis, 1998; Karakezi & Majoro, 2002; Campbel et all., 2003; Brouwer & Falco, 2004; Heltberg, 2004; Martins, 2005; Arnold et al., 2006). With increasing income, households adopt new fuels and technologies that serve as partial, rather than perfect substitutes for more traditional ones (Elias & Victor, 2005). This empirical observation has lead to the development of alternative models to describe the energy transition process.

Foley (1995) argues that it is a ladder of energy demand rather than fuel preferences that determine fuel choice. Energy demand is driven by the services energy provides. At a subsistence level households rely on biomass fuels for cooking and heating, which form the main energy needs at that stage of development. With increasing income, the household can afford to purchase a variety of appliances, each of which requires a specific energy source. This leads to a more diversified energy demand including modern energy sources. For basic energy needs households will continue to use biomass fuels and add fuels to accommodate the needs for their changing lifestyle (Hiemstra-van der Horst & Hovorka, 2008).

Masera et al. (2000) go a step further and suggest that there is no such thing as fuel switching and propose a multiple fuel model. Instead of switching fuels, households choose to consume a portfolio of energy options at different points along the energy ladder. The fuel portfolio of households can represent a combination of fuels from both lower and upper levels of the ladder. The process of households using multiple fuels at the same time is termed fuel stacking (see the right hand side in Figure 2.1). Masera et al. (2000) found in their study that it is unusual for households to make a complete fuel switch from one technology to another; rather they begin to use an additional technology without abandoning the old one (ibid: 2085). For example, households in Jaracuaro in Mexico add cooking fuels such as LPG and stove types, but rarely abandon fuel wood completely.

When comparing Foley's energy demand model to Masera's multiple fuel model, they appear to be similar at first sight. An important distinction is, however, Masera's observation that for a particular purpose, such as cooking, multiple fuels are used. Hence, it is not necessarily the case that we only see multiple fuel use due to an increase in the variety of appliances available to the household.

The multiple fuel model is gaining increasing support in the literature (e.g. Heltberg, 2004 & 2005; Hiemstra-van der Horst & Hovorka, 2008; Mekonnen & Kohlin, 2008; Mirza & Kemp, 2009). Several complementary explanations have been given to explain fuel stacking behaviour by households in both urban and rural areas. First, Davis (1998) argues that fuel stacking is inherent to the poor's livelihood strategies. Irregular and variable income flows of households (derived from agricultural work or informal selling of goods) prohibit the regular consumption of modern energy. Therefore, specific budget strategies are applied in order to maximize fuel security. Second, fuel stacking behaviour is observed due to fuel supply problems (Soussan et al., 1990; Hosier and Kipyonda, 1993; Masera et al., 2000). The supply of modern fuels is erratic and the reliability of supply channels low. Therefore, households must have one or two fuels which can be used as backups in the event that their primary fuels are temporarily unavailable (Hosier and Kipyonda, 1993). Third, fluctuations of commercial energy prices might make the preferred fuel temporarily unaffordable (Hosier and Kipyonda, 1993). Finally, culture and traditions also play a role in constraining a complete transition to modern fuels. Traditional methods of cooking are often rooted in local cultures preventing the use of modern fuels (Masera et al., 2000; Murphy, 2001). Thus, *multiple fuel use patterns in households are the result of complex interactions between economic, social and cultural factors* (Masera et al., 2000: 2004).

Heltberg's (2005) finding in Guatemala provides food for thought. The inverted U shape found for the number of fuels used for cooking in urban areas implies that during the development process the uptake of modern fuels shows a fuel stacking pattern but at the top end several traditional fuels are displaced indicating fuel switching. This may be an indication that fuel stacking is a transient phenomenon rather than a linear and continuous process. Studies in rural areas have not found such results and report only partial switching behaviour along income segments (Mekonnen and Kohlin, 2008; Mirza and Kemp, 2009). Fuel wood remains a very important energy source irrespective of household income.

3 Towards a comprehensive framework for modelling household energy choices

The literature has shown that one needs to look beyond income to explain household energy choices. A myriad of factors shape the environment in which households make their decisions. Such an environment can be referred to as the 'household decision environment', representing a complex and interactive web of factors that influence behaviour.

Here we make use of the framework developed by Bruntrup and Heidhues (2002) to structure and describe the decision environment (see Figure 3.1). They describe a decision environment for market participation by farm households in developing and transition economies. Their framework focuses on the choice between subsistence and market orientation, i.e. the degree of market integration, where subsistence orientation refers to a farmer who predominantly produces for his own family's consumption. In a developing country context, the choice between self-sufficiency and market dependence plays an important role in the choice for energy carriers as well. As the energy ladder shows, households at the bottom of the ladder depend on biomass resources which are, especially in rural areas, collected by the households themselves. Commercial fuels are ranked higher on the ladder and need to be purchased in the market. A move up the energy ladder hence involves to some degree a similar process from self-sufficiency towards market dependence. A clear distinction between market dependence for agricultural produce and energy carriers is the fact that households predominantly depend on markets as consumers for energy carriers, while many farm households are both consumers and producers on agricultural good markets.

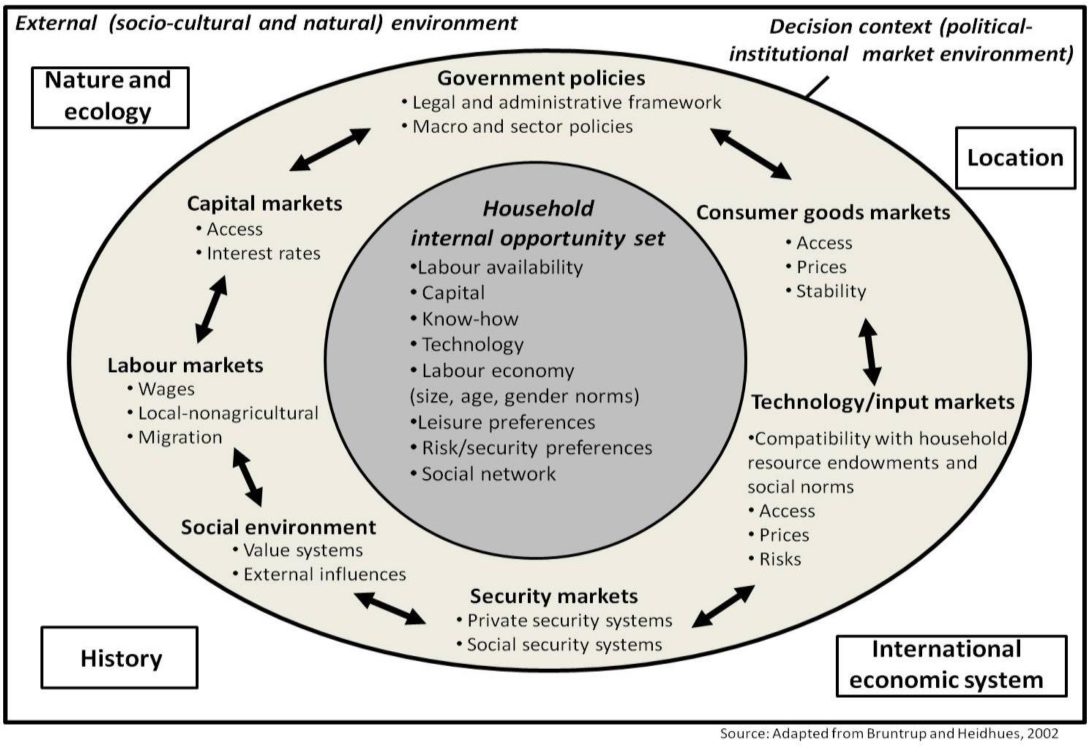

Figure 3.1 General conceptual framework for explaining household energy choices

The framework distinguishes between three categories of influencing factors: (i) the country external environment shaping the boundaries within which a society has to function (such as nature, location and history); (ii) the decision context reflecting household external and country internal factors based on the institutional, political and market situation of a specified location (factors include capital market, government policies, consumer markets etc.); and (iii) the household opportunity set representing a group of household internal factors based upon the characteristics and factor endowment of the household. The interaction between factors across categories determines the decision environment, which is unique for each individual household.

The key factors shaping the energy decision environment identified in the literature will be discussed next following the structure of Bruntrup and Heidhues' (2002) framework.

The household *opportunity set* is the building block of a household's livelihood strategy. It determines the capacity a household has and restricts or broadens their window of opportunity. Important for the opportunity set is the household endowment. Human capital is considered to be essential in the energy decision process (Gupta and Kohlin, 2006; Farsi et al, 2007). Not only does this include education and knowledge, but also household composition characteristics such as labour availability, household size, age and gender. Gender findings have mainly focused on the labour situation of women. Women's income turned out to be an important determinant of modern fuel choice in a number of studies (Sathaye and Tyler, 1991; Israel, 2002; Gupta and Kohlin, 2006). Not only opportunity costs of time, but also shifts in the gender power balance underlie this effect. Furthermore, household preferences based on traditions and cultural beliefs are found to influence fuel choice (Masera et al., 2000; Murphy, 2001; Israel, 2002; Gupta and Kohlin, 2006).

The market environment is an important feature of the *decision context* in the original framework. Access to, prices and stability of consumer markets are factors that are discussed in the energy literature as well. The fuel market structure plays an important role in the physical access to a fuel. Reliability of supply, the structure of the distribution network and the number of distributors were found to impact fuel choice (Farsi et al, 2007; Mirza and Kemp, 2009). Furthermore, transaction costs involved in purchasing a fuel, e.g. effort required from households for transportation, collection and buying time and distance to markets, influence a household's access and are found to impact their choice (Mirza and Kemp, 2009).

The effect of fuel prices on fuel choice is not well understood. Some scholars suggest that prices are the main factor restricting a household to move to modern fuels, while others find fuel prices rarely affecting fuel selection (Hiemstra-van der Horst and Hovorka, 2008). An interesting finding of Sathaye and Tyler (1991) is that when considering relative fuel prices, poor households actually appear to pay more for their fuels on an energy content basis than do higher income households. Leach (1992) suggests that energy prices more often promote shifts between fuels amongst households already using several fuels. Households who own the necessary equipment can move forth and back on the ladder when facing price chances or supply failure. This suggests that it is not the fuel price per se hindering transition, but the acquisition of modern fuel equipment, also referred to as the 'stove barrier' (Sathaye and Tyler, 1991; Leach, 1992; Masera et al., 2000; Campbell, 2003). Technology markets selling the appropriate equipment at affordable prices thus play an important role. Another constraint related to fuel prices is the problem that electricity and bottled gas must be paid for in large lump sums, while fuel wood and kerosene can be purchased in small amounts on a daily basis. Avoiding lumpy payments is an important household strategy for the poor even though they might end up paying much more for their energy supplies (Leach, 1992).

Energy access is closely related to location factors embedded in the *country external environment*. The geographical location determines type and quantity of biomass resources available. Abundant availability of fuel wood that can be collected free of monetary costs may limit the need for households to switch to alternative and more costly fuels (Heltberg, 2004). Furthermore, urbanization itself is assumed to drive inter-fuel substitution (Leach, 1992). As urban areas expand, various changes occur in access to fuels, infrastructure, market diversity, housing choices, and household behaviour and activities influencing fuel choices (Sathaye and Tyler, 1991). Rural areas on the contrary face a less dynamic situation and are confronted with slower movements or even a status quo situation.

4 Drivers of the energy transition

The previous section described the household decision environment for energy choices. This section elaborates on the specific factors influencing fuel switching behaviour distinguishing between the household opportunity set, the household decision context, and the country external environment.

The method used for this evaluation is a qualitative meta-analysis based on seven revealed preference studies (Freeman, 2003) that have analyzed the energy transition process using econometric tools. Meta-analysis is the evaluation of the findings of empirical studies, helping to extract information from data in order to quantify a more comprehensive assessment (Glass et al. 1981). It is a method of synthesizing the results of multiple studies that examine the same phenomenon through the identification of a common effect. It enables researchers to explain differences in outcomes found in single studies on the basis of differences in underlying assumptions, standards of design and/or measurement (Wolf 1986). Since the beginning of the 1990s, meta-analysis has been playing an increasingly important role in environmental economics research (Nelson and Kennedy 2009).

The multinomial logit model (MNL) has been used as the selection criterion for the studies. MNL is a standard regression technique for assessing how different variables affect fuel choices (Heltberg, 2004). It therefore enables the systematic analysis of household switching behaviour between different types of fuels. The seven studies listed in Table 4.1 are those found in the revealed preference literature on energy transitions and fuel switching using MNL.

Table 4.4.1 Overview of the studies reviewed in the meta-analysis

	Author	Country	Response variable: fuel choice	Rural/Urban	Data Source
1	Heltberg (2004)	Brazil, Ghana, Vietnam Guatamala, India, Nepal, Nicaragua, South Africa,	No switching/partial switching/full switching	Rural and urban	Living standard measurement survey 1996-2000
2	Heltberg (2005)	Guatamala	Firewood/ firewood and LPG/ LPG / Charcoal and LPG	Rural and urban	ENCOVI National Survey of Living Conditions 2000
3	Ouedraogo (2006)	Burkina Faso	Firewood, Charcoal, Kerosene, LPG, other solid fuels	Urban	1996 household expenditure survey. 1008 households
4	Rao and Reddy (2007)	India	Firewood, LPG, Kerosene and other	Rural and urban	1999-2000 National Sample Survey 118,000 households
5	Pundo and Fraser (2006)	Kenia	Firewood, Charcoal, Kerosene	Rural	Kisumu household survey 2001, 410 households
6	Mekonnen and Köhlin (2009)	Ethiopia	Solid (fuel wood and charcoal), non solid (Kerosene and electricity) or a combination of both	Urban	Household panel data 2000-2004, 1500 households in each survey
7	Hosier and Dowd (1989)	Zimbabwe	Gathered fuel wood, purchased fuel wood, transition fuels, kerosene, electricity	Rural and urban	1984 household energy survey

All studies describe and analyze actual switching behaviour of households for cooking fuels, but differ in the set of cooking fuels analyzed. Categorization of fuels is used in 2 of the studies where solid/non-solid and no switching/ full switching is used to describe the transition process. The categorization “solid” and “no switching” both refer to the use of biomass fuels only and “non-solid” and “full switching” refer to the use of modern forms of energy. The in-between stage indicates fuel stacking behaviour. The studies of Hosier and Dowd (1989) and Hetlberg (2005) have included fuel combinations in their analysis and therefore allow for partial switching as well.

4.1 The household opportunity set

In all studies the socio-economic determinants in the form of household characteristics and factor endowment have received most attention. These factors lead us to identify distinct groups of households based on fuel choice behaviour. An overview of these factors is presented in the upper part of Table 4.2.

Income is a frequently used indicator to distinguish households from each other. It is also the most important influencing factor related to fuel switching according to the energy ladder theory. The relationship between income and fuel switching has therefore been commonly addressed in the studies. They confirm the relationship between income and the move towards more advanced fuels to a certain extent. Mekonnen and Kohlin (2009) find that households with higher expenditure levels are less likely to use solid fuels only, but cannot attribute the switch from non-solid fuels to a mix of solid and non-solid fuels to household expenditures only. Heltberg (2005), shows that household expenditure is insignificant for fuel switching in rural areas. Again, income appears to be not the key factor it was expected to be in the energy ladder model.

The way households earn their income characterises their economic position. On the one hand, in urban areas, Rao and Reddy (2007) found that income derived from wage/salary has a positive impact on the probability of using LPG instead of other fuels. On the other hand, farm households are less likely to use LPG only (Heltberg, 2005). The irregular and variable income flows (derived from agricultural work or informal selling of goods) could prohibit the regular consumption of modern energy (Davis, 1998) and restrict fuel switching. These results are in line with the expectation that households with a stable regular income are better able to rely on and consume commercial fuels, in this case LPG.

Capital assets are linked to a household’s wealth as well as to its living conditions. In turn, living conditions might be to a smaller or larger extent enable the use of certain cooking technologies and their respective fuels. House ownership is also one of the factors examined in the existing studies. Being the owner of a house does not imply higher purchasing power than a tenant, but it does provide freedom of space management in the house (Ouedraogo, 2006). Tenants must adhere to occupancy rules, possibly limiting their energy options (Pundo and Fraser, 2006). Ouedraogo (2006) finds household ownership to increase the probability of using firewood compared to tenants. This could be a very specific result based on the situation in Ouagadougou, where it is common for tenants to live in dwellings called ‘celibateriums’, i.e. sharing a yard with several houses with little space for wood-energy storage. However, Pundo and Fraser (2006) found a similar result showing that tenants are more likely to use kerosene or charcoal over wood. Their results are based on rural data where it is most likely not an issue of space or lack of available biomass,

Table 4.2 Driving forces underlying energy choice behaviour identified in the literature

	Hosier and Dowd (1989)	Heltberg (2004)	Heltberg (2005)	Ouedraogo (2006)	Pundo and Fraser (2006)	Rao and Reddy (2007)	Mekonnen and Kohlin (2009)
Household opportunity set							
Human capital							
Education (respondent)		$x^{-(5);+(6)}$	$x^{+(7,9);-(8)}$	$x^{-(14)}$	x^{0}	$x^{+(17,18,19)}$	$x^{-(21,22)}$
Education (spouse)					$x^{-(15)}$		
Household size	$x^{+(3)}$	$x^{-(5,6)}$	$x^{-(9)}$	$x^{-(11,12,14)}$	x^{0}	$x^{-(17,18,19)}$	$x^{+(21,22)}$
Household size squared						$x^{+(17,18,19)}$	$x^{-(21,22)}$
Share of females in the household			$x^{-(7,9)}$				x^{0}
Capital (wealth indicators)							
Inside water		$x^{-(5); +(6)}$					
Number of rooms			$x^{-(8)}$				
Ownership of dwelling				x^{0}	$x^{+(15)}$		
Type of dwelling					$x^{-(15,16)}$		
Cooking facility (external)				$x^{+(11,13)}$			
Household income	$x^{+(1,2,3,4)}$			$x^{+(11,12,13,14)}$			
Household expenditure		$x^{-(5);+(6)}$	$x^{+(7);-(8)}$			$x^{+(17,18);-(19)}$	$x^{-(21)}$
Square of per capita expenditure						$x^{-(17,18);+(19)}$	
Household characteristics							
Age				$x^{+(13)}$	x^{0}	$x^{+(17);-(18,19)}$	$x^{+(21)}$
Age of the Spouse					x^{0}		
Sex of the household head				x^{0}		$x^{-(17);+(18,19)}$	$x^{-(21,22)}$
Household category (main labour activity)			$x^{-(7,9)+(8)}$		x^{0}	x*	
Food preferences							
Frequency of cooking To				$x^{-(11)}$			
Frequency of cooking Rice				$x^{+(11,12,14)}$			
Category of food prepared					$x^{-(16)}$		
Cultural background							
Religion of the household head				$x^{-(11,12,13)}$		$x^{-(17,18,19)}$	
Social group						$x^{+(20)}$	
Indigenous			$x^{-(7);+(8)}$				
External decision context							
Access							
Electricity		$x^{-(5);+(6)}$	$x^{-(8);+(9)}$	$x^{+(11);-(14)}$			
Community median distance to firewood			x^{0}				
Difficulty of collecting firewood (perceived pressure)	$x^{-(1,3)}$						
Fuel price							
Wood price			$x^{+(7)}$				$x^{+(22)}$
Charcoal price							x^{0}
Kerosene price			$x^{-(9)}$				$x^{+(21,22)}$
Electricity price							x^{0}
LPG price			$x^{-(10)}$				
Ratio of per energy unit price of kerosene to electricity	$x^{+(4)}$						

External environment					
Location	x**	x**		x**	x**
Time					$x^{-(21,22)}$

Explanatory note:

+ significant positive effect on energy choice
- significant negative effect on energy choice
0 no significant effect on energy choice
1 Purchased wood (base gathered wood)
2 Transition fuels (base gathered wood)
3 Kerosene (base gathered wood)
4 Electricity (base gathered wood)
5 No switching rural and urban (base partial switching)
6 Full switching rural and urban (base partial switching)
7 LPG urban (base LPG and Woodfuel)
8 Wood urban (base LPG and Woodfuel)
9 LPG rural (base LPG and Woodfuel)
10 Wood rural (base LPG and Woodfuel)
11 LPG (base others)
12 Charcoal (base others)
13 Firewood (base others)
14 Kerosene (base others)
15 Charcoal (base firewood)
16 Kerosene (base firewood)
17 LPG rural and urban (base wood)
18 Kerosene rural and urban (base wood)
19 Other fuels rural and urban (base wood)
20 LPG rural (base wood)
21 Solid fuels (base non-solid)
22 Mix of solid and non-solid fuels (base non solid)
* The paper distinguishes a variety of labor activities with different statistical impacts on energy choice. For readability reasons they have not been included in the table.
** A large number of specific location dummies have been included in the studies with both negative and positive effects on energy choice. For readability reasons they have not been included in the table.

but rules and regulations of tenancy contracts. House size measured by the number of rooms has been associated with a move away from fuel wood towards exclusive LPG use (Heltberg, 2005). This is an indicator showing how wealth influences fuel switching. Similarly, having access to tap water was found to significantly reduce the probability of using solid fuels only and increase the probability of using non-solid fuels (Heltberg, 2004). Finally, households who only have external (outdoor) cooking facilities are more likely to use firewood than those with internal (indoor) facilities (Ouedraogo, 2006).

Human capital is also an important asset and refers to the quantity and quality of labor available in the household, including educational level, knowledge and skills. Education is seen as an important determinant of fuel switching behaviour. All studies except Pundo and Fraser (2006) found positive effects of education on the probability that households use modern commercial fuels such as LPG and Kerosene. This can be explained by increasing opportunity costs of collection time at higher levels of education and the positive contribution to the level of awareness of the negative effects of wood and charcoal use on health (Heltberg, 2004). The effect of education on fuel switching is the same in both rural and urban areas (Heltberg, 2004; Heltberg, 2005; Rao and Reddy, 2007).

Increasing family sizes suggest that there is abundant labour available for fuel collection, which limits the need to move to modern fuels purchased in markets. Rao and Reddy (2007) mention that larger households in developing countries are often related to lower incomes, hence explaining their limited capacity to purchase commercial fuels. Furthermore, Pundo and Fraser (2006) state that in order to feed a large family one needs a large amount of fuel. Using fuel wood is cheaper due to its lower consumption rate per unit of time compared to kerosene and charcoal, prohibiting large families to switch. Heltberg (2004) and Pundo and Fraser (2006) find no significant relationship between fuel switching and family size, contrary to Ouedraogo (2006), Rao and Reddy (2007) and Mekonnen and Kohlin (2008), who find that larger households are less likely to choose non-solid fuels over solid fuels. Heltberg (2005) confirms that smaller households are more likely to use the non-solid fuel LPG as their only fuel, but finds a switch from wood to the transition combination of wood and LPG unrelated to household size. Another contrasting finding is that of

Hosier and Dowd (1989), who found that larger households were more likely to move away from fuel wood towards kerosene. At the same time, they conclude that larger households are less likely to move to the last stage of the energy ladder choosing electricity over kerosene and fuel wood. For these findings no clear explanation was provided by others.

Within the household labour economy, women are often responsible for cooking and collecting firewood. On the one hand, a high share of females in the household increases the supply of collection and cooking labour time and reduces the need to abandon time-consuming fuel wood sources. On the other hand, women are most directly affected by the negative effects of firewood use and switching to other fuels can improve their livelihood situation considerably. A larger number of females in the household could translate into a better bargaining position inducing power over fuel choices. Heltberg (2005) finds that a high share of females in the household significantly reduces the likelihood of single fuel LPG use, while it does not affect the choice between only wood and joint wood/LPG. Mekonnen and Kohlin (2008) did not identify an effect of the share of women in the household on fuel choice. They did find, however, that female headed households are more likely to use either solid fuels or a mix as their main fuel. Rao and Reddy (2007) find an opposite trend: households headed by women are more likely to choose modern fuels over traditional fuels. This confirms the assumption that women will choose fuels that improve their collecting and cooking conditions. However, a large share of female headed households belongs to the poorest segments of society, which limits their access to modern fuels. This could explain the findings of Mekonnen and Kohlin (2008).

The age of the household head can also lead to two opposing effects. On the one hand, the age of the household head functions as an indicator for the life cycle of the household. The further a household moves up in its lifecycle, the wealthier it becomes and the more likely it has been able to accumulate financial assets, allowing them more financial freedom. On the other hand, older household heads may be more conservative, restraining them to move away from their current practices. Ouedraogo (2006) and Mekonnen and Kohlin (2009) found a positive relationship between age and the use of solid fuels as the main fuel for cooking. Mekonnen and Kohlin (2009) were unable to find an effect for age on the choice between non-solid fuels and a mix of solid and non-solid fuels. In the studies no evidence was found on a negative relationship between age and the use of solid fuels.

Traditions, habits and religion have created specific lifestyles, which are deeply rooted within societies. The social group that people belong to, based on their culture or religion serves important security and communal purposes and can play a crucial role in the behaviour of households. Indigenous ethnic groups in urban Guatemala had fuel portfolios that differed significantly from non-indigenous groups, resulting in a much higher likelihood of using fuel wood only (Heltberg, 2005). Two possible reasons explaining this finding are: (1) a traditional lifestyle and other cultural factors may lead to a preference for fuel wood among indigenous groups; (2) indigenous groups are less integrated into the formal economy and find it harder to afford or access LPG (Heltberg, 2005). The two main religions found in India, Hinduism and Islam, were included and distinguished in the study of Rao and Reddy (2007). They find that Islamic households in rural areas are less likely to use LPG than firewood. Muslims are a minority group in India, which could be a barrier to access modern forms of energy.

Cultural practices could also be an explanation for the observed behaviour. Meals that are traditionally cooked on fire can steer preferences to continued use of firewood. Masera et al (2000) found that fuel stacking can among other reasons be explained by the preference and convenience of certain fuels over others for specific forms of cooking. Ouedraogo (2006) shows in his study that the frequency of cooking 'tô' increases the likelihood of using fuel wood. Tô is a meal which is rooted in the cooking culture of Ouagadougou's inhabitants. Local cereals used for preparing tô are less expensive than rice. An increase of the frequency of households cooking rice reduces the likelihood of using firewood.

4.2 The household decision context

In the reviewed studies, less attention has been paid to the household decision context which is based on the household external/ country internal environment. Factors include issues such as access to energy and price levels (see the middle part of Table 4.2). Resource scarcity induces access problems, resulting in either higher monetary costs or opportunity costs of time. Hosier and Dowd (1989) state that wood scarcity is a driving force for the likelihood of households to use another fuel than wood. It implies longer distances to collect firewood and easier switches to other fuels. A household's perception of the biomass pressure in its surroundings was found influential for fuel switching. Households that did not perceive fuel wood as difficult to collect preferred gathered wood, purchased wood, or the transition alternatives to a commercial fuel option (Hosier and Dowd, 1989). Heltberg (2005) looked at the impact of community distance to fuel wood. Longer distances imply pressure on existing biomass resources and increase the opportunity costs of collecting fuel wood. However, Heltberg (2005) did not find a relationship between distance to fuel wood and fuel switching.

Electricity access is found to be positively associated with fuel switching for cooking (Heltberg, 2004; 2005). In urban areas, it results in a significantly smaller probability of using wood only and more LPG. In rural areas it causes a significantly larger probability of consuming only LPG (Heltberg, 2005). Barnes et al. (2004) suggest two explanations for the electricity-LPG link: (i) where electricity is available, fewer barriers constrain other modern fuels as well, and (ii) availability of lighting and other appliances spurs people to a greater acceptance of modernity and modern fuels. Ouedraogo (2006) found households moving up the energy ladder when using electricity as the 'source of lighting energy'.

Beside physical access, fuel prices can influence the accessibility of fuels on the market. Prices matter to some extent for fuel switching (Hosier and Dowd, 1989; Mekonnen and Kohlin 2009). High LPG prices increase the consumption of wood in rural areas where it dominates rural cooking with LPG as an occasional complement. In urban areas where LPG dominates urban cooking and wood is a complement, high firewood prices induced an increase in the probability of using LPG only (Heltberg, 2005). This shows the local impact of prices on choice behaviour.

4.3 The country external environment

The location where the household resides is key to several influential determinants of the country external environment. Urbanisation is one of the variables that has been linked to energy transitions from the early days onwards (bottom part of Table 4.2). Hosier and Dowd (1989) identify urban locality as an important driver of energy transitions. Households in urban areas are more likely to utilize higher quality energy carriers than comparable households in rural areas (Hosier and Dowd, 1989; Heltberg, 2005). Heltberg (2004) found that in both rural and urban areas the same variables are significant, but that the magnitude of the effect often differs. This implies that similar mechanisms drive fuel switching in urban and rural areas, but in different degrees. He assumes that the lower levels observed for fuel switching observed in rural areas must be because of lower rural levels of the triggering variables. Furthermore, larger cities are assumed to provide a better enabling environment for modern fuels. Mekonnen and Kohlin (2008) find that households residing in Addis Ababa, the capital of Ethiopia, are more likely to choose non-solid fuels than households in smaller towns. They ascribe this finding to better access to electricity and kerosene, higher awareness levels, and learning from others. Mekonnen and Kohlin (2008) are the only ones that used panel data. This enabled them to include the factor time in their analysis. They conclude that over time, in casu a period of 4 years, households were more likely to have non-solid fuels as their main fuel, suggesting a shift towards non-solid fuels over time.

5 Conclusions

This paper studied energy transitions in a developing country context through an assessment of the energy ladder model and empirical studies on fuel switching behaviour. The energy ladder remains somewhat of a myth, not observed empirically. Instead of a linear pattern showing fuel displacement at higher income levels, the ongoing transition process is best described by multiple fuel use representing an energy portfolio. This energy stacking behaviour can be seen as a livelihood strategy through which households cope with unstable income flows, protect themselves from fragile markets and hold on to their cultural practices, while benefitting to some extent from modern fuels.

The decision to move from universal reliance on biomass fuels to partial or full market dependence takes place in a household decision environment. Such an environment is complex and multidimensional, stressing the need to look beyond income as the prime driving force behind fuel switching. We described a conceptual framework for the analysis of household behaviour based upon 3 layers of factors: (1) the external environment, (2) the decision context and (3) the household opportunity set. This framework provides a comprehensive tool to assess household behaviour in an energy transition context. Several factors from this framework have been identified influencing fuel switching in the selected empirical studies. Among those are human capital, the household labour economy, cultural background and customs, household characteristics such as age, labour activity, income and access to fuels.

Existing research has put most emphasis on describing behaviour by socio-economic characteristics of the household opportunity set. Relatively little attention has been devoted to the decision context and the external environment. Nevertheless, factors such as consumer markets or government policies can play an important role in the behaviour of households. Inclusion of such elements in the analysis could provide us with further insides in existing behaviour.

Furthermore, product specific preferences of households are key for the adoption of the supplied products. We therefore emphasize that research on energy transitions combine social characteristics with a better understanding of preferences for products.

So far the focus has been on conventional energy sources, disregarding the potential role of renewable energy technologies in the energy transition process. Renewable energy technologies serve as promising alternatives to conventional modern energy sources. Not only are these technologies expected to provide increased energy security, they also reduce environmental pressure, improve personal health and enhance development potential in a sustainable low carbon way. The inclusion of renewable energy technologies in energy transition studies asks researcher to no longer focus on fuels only, but to also understand the interaction between for instance fuel and stove and the impact of the decision environment on the choice for a specific combination of the two.

References

Arnold, J.E.M., Kohlin, G. & Persson, R. (2006). Woodfuels, livelihoods and policy interventions: Changing perspectives. *World Development, 34* (3), 596-611.

Barnes, D.F., & Floor, W.M. (1996). Rural energy in developing countries: a challenge for economic development. *Annual Review of Energy Environment, 21*, 497-530.

Bhagavan, M.R. & Giriappa, S. (1994). Biomass, energy and economic and natural resource differentiation in rural southern India. *Biomass and Bioenergy, 8* (3), 181-190.

Brouwer, R. & Falcao, M.P. (2004). Wood fuel consumption in Maputo, Mozambique. *Biomass and Bioenergy*, 27, 233-245.

Brüntrup, M. & Heidhues, F. (2002). *Subsistence agriculture in development: Its role in process of structural change.* Research in Development Economics and Policy Discussion Paper 1/2002. Hohenheim, Institute of Agricultural Economics and Social Sciences in the Tropics and Subtropics.

Campbell, B.M., Vermeulen, S.J., Mangono, J.J. & Mabugu, R. (2003). The energy transition in action: urban domestic fuel choices in a changing Zimbabwe. *Energy policy, 31*, 553-562.

Cooke, P., Kohlin, G. & Hyde, W. (2008). Fuel wood, forests and community management- evidence from household studies. *Environment and Development Economics, 13*, 103-135.

Davis, M. (1998). Rural household energy consumption: The effects of access to electricity evidence from South Africa. *Energy Policy, 26*, 207-217

Elias, R.J. & Victor, D.G. (2005) *Energy transitions in developing countries a review of concepts and literature.* Working paper, Stanford University

Farsi, M., Filippini, M. & Pachauri., S. (2007). Fuel choices in urban Indian households. *Environment and Development Economics, 12*, 757-774.

Foley, G. (1995). *Photovoltaic applications in the rural areas of the developing world*. World Bank technical paper 304, Energy Series. World Bank, Washington DC.

Freeman III, A.M. (2003). The measurement of environmental and resource values: theory and methods. Resources for the Future, Washington D.C.

Gallagher, K.S. (2004). Limits to leapfrogging in energy technologies? Evidence from the Chinese automobile industry. *Energy policy, 34*, 383-394.

Glass, G.V., McGaw, B. & Smith, M.L. (1981). *Meta-analysis in social research*. Sage Publications, Beverly Hills.

Gupta, G. & Kohlin, G. (2006). Preferences for domestic fuel: Analysis with socio-economic factors and rankings in Kolkata, India. *Ecological Economics, 57*, 107-121.

Heltberg, R. (2004). Fuel switching: evidence from eight developing countries. *Energy Economics, 26,* 869-887.

Heltberg, R. (2005). Factors determining household fuel choice in Guatamala. *Environment and Development Economics, 10,* 337-361.

Hiemstra- van der Horst, G. & Hovorka, A.J. (2008). Reassessing the “energy ladder”: Household energy use in Maun, Botswana. *Energy Policy, 36,* 3333-3344.

Hosier, R.H. & Dowd, J. (1989). Household fuel choice in Zimbabwe: An empirical test of the energy ladder. *Resources and Energy, 9*, 347-361.

Hosier, R.H. & Kipondya W. (1993). Urban household energy use in Tanzania. Prices, substitutes and poverty. *Energy Policy, 21*, 454-473.

International Energy Agency (IEA)(2006). "World Energy Outlook 2006," especially chapter 15, "Energy for Cooking in Developing Countries." Organization for Economic Cooperation and Development and IEA, Paris.

Israel, D. (2002). Fuel choice in developing countries: evidence from Bolivia. *Economic Development and Cultural Change, 50*, 865-890.

Karekezi, S. & Majoro, L. (2002). Improving modern energy services for Africa's urban poor. *Energy Policy, 30*, 11–12.

Leach, G. (1992). The energy transition. *Energy Policy, 20,* 116-123.

Martins, J. (2005). The impact of the use of energy sources on the quality of life of poor communities. *Social Indicators Research, 72*, 373-402.

Masera, O.R. (2000). From linear fuel switching to multiple cooking strategies: A critique and alternative to the energy ladder model. *World Development, 28*(12) 2083-2103.

Mekonnen A. & Kohlin G. (2008). *Determinants of household fuel choice in major cities in Ethiopia*. Working papers in economics no. 399, University of Gotenburg.

Mirza, B. & Kemp, R. (2009). *Why rural rich remain energy poor*. UNU-MERIT Working Papers, ISSN 18719872.

Murphy, J. T. (2001). Making the energy transition in rural East Africa: is leapfrogging an alternative? *Technological Forecasting & Social Change, 68* (2), 173-193.

Nelson, J.P. & Kennedy, P.E. (2009). The use (and abuse) of meta-analysis in environmental and resource economics: an assessment. *Environmental and Resource Economics, 42*, 345-377.

Ouedraogo, B. (2006). Household energy preferences for cooking in urban Ouagadougou Burkina Faso*. Energy Policy, 34,* 3787-3795.

Pundo, M.O. & 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.

Rao, M.N. & Reddy, B.S. (2007). Variations in energy use by Indian households: An analysis of micro level data. *Energy, 32* (2), 143-153.

Sathaye, J. and Tyler, S. (1991). transitions on Household energy use urban China, India, the Philippines, Thailand and Hong Kong. *Annual Review of Energy Environment, 16*, 295-335.

Schlag, N. & Zuzarte, F. (2008). *Market Barriers to clean cooking fuels in Sub-Saharan Africa: A review of literature.* Working paper, Stockholm environment institute.

Soussan, J., O'Keefe, P. & Munslow, B. (1990). Urban fuel wood: Challenges and dilemmas. *Energy Policy, 18*, 572-582.

Wolf, F.M. (1986). *Meta-analysis*. Sage Publications, Beverly Hills, California, USA.