CHAPTER SIX

Conclusions and Discussion

One of the 17 sustainable development goals recently formulated by the United Nations in their 2030 agenda for sustainable development is *"Ensure access to affordable, reliable, sustainable and modern energy for all",* stressing the importance of energy for development and poverty eradication *(UN, 2015)*. Worldwide, over 3 billion people still rely on traditional biomass fuels for their daily energy needs and incur the health and environmental consequences. Projections indicate that this number will only increase further over the coming years. To stimulate the adoption of modern fuels and technologies, a better understanding of households' fuel choice behaviour and product preferences is paramount. The lack of knowledge regarding the factors that influence the fuel choices made by households limits successful implementation of programs aiming to push the energy transition towards modern fuels and technologies. Therefore, increased and improved insight in household decision-making in the developing world is essential.

This dissertation set out to provide a comprehensive analysis of household behaviour in relation to fuel and technology choices in an energy transition context. A conceptual framework was developed that incorporates both household internal and contextual or external variables for the analysis of choice behaviour. Current energy transition patterns were assessed to gain improved understanding of household fuel switching behaviour. The determinants steering fuel switching behaviour were analysed focussing on both the internal and external factors as described in the analytical framework, while household preferences and the potential demand for alternative fuel sources and cooking technologies were assessed applying discrete choice experiments. The work is based on two case studies carried out in rural, peri-urban and urban areas in Kenya and Mozambique to be able to analyze the different stages of energy use. The main results, implications and policy recommendations are summarized here, indicating where possible their general applicability across the two case studies.

6.1 Answering the research questions

The **first research question** focused on describing and explaining the current energy transition in both urban and rural areas in developing countries. Household fuel use was studied through an assessment of the energy ladder model and two cases studies on choice behavior. The energy ladder was 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 uses representing an

energy portfolio. The fuel portfolio of households represents a combination of fuels from both lower and upper levels of the energy ladder. This process of households using multiple fuels at the same time is referred to as fuel stacking. This is found to be a common strategy across both urban and rural locations as well as across income groups, and can be seen as a livelihood strategy through which households cope with irregular income flows, protect themselves from unstable markets and hold on to their cultural practices, whilst benefitting from modern fuels. Energy stacking also indicates that the ongoing process of moving towards modern fuels is still in its initial stages.

Rural households have the least diversified fuel portfolios and a majority of households rely exclusively on biomass based fuels, most importantly firewood. While firewood is generally assumed to be collected free of monetary costs, commercialization of firewood transactions is observed in all study sites. The combined use of firewood and charcoal was found to be most common across the three Kenyan study areas. With increasing income, the use of firewood declines, while the opposite trend is observed for the use of charcoal. In rural areas the switch to a combined firewood-charcoal portfolio takes place at significantly higher income levels than in the peri- urban area where income differences between firewood and firewood-charcoal users are absent. The high market dependence for firewood and the related cost of using firewood in the peri-urban area seems to have eliminated the impact of income on fuel choices in the initial steps of the energy transition process.

Charcoal is the most important fuel in the urban case and its use is relatively constant in relation to household income. As a transition fuel, the use of charcoal is anticipated to drop at higher income levels. Charcoal does not seem to have reached such a transition state yet, and still fulfills an important role across all income categories. Liquid fuels seem to function mainly as a complement rather than as a replacement of biomass fuels in view of the fact that only a relatively small group uses liquid fuels as their main cooking fuel in both case studies in Kenya and Mozambique. Electricity is projected to be the most desirable fuel for cooking, but this could not be proven in our urban case study. Fuel portfolios including LPG were more common at higher income levels than the use of electricity based portfolios.

The **second research question** tried to answer which drivers play a role in explaining and predicting household choices for modern fuels and technologies. In chapter 2 it was argued that household choices are not made in a vacuum, but instead shaped by the environment in which people operate. A conceptual

framework was developed to incorporate both household internal and external variables for the analysis of choice behavior, avoiding the overemphasis on income as the main determinant of household fuel choices as in the energy ladder. This framework, referred to as the household decision environment, represents a web of factors that influence household behavior. The conceptual framework is based upon 3 layers: (1) the household external biophysical environment, (2) the household external political and institutional-economic decision context and (3) the household internal opportunity set.

Starting with the latter internal household decision-making environment, household income and wealth-related factors seem to be the main determinants explaining the transition towards more advanced fuel portfolios in the urban case study in Mozambique presented in chapter 5. With increasing income households are more likely to switch away from biomass based fuel portfolios towards more advanced portfolios which include LPG or electricity. Wealth indicators that were found to positively influence fuel switching behavior as well include house ownership, the number of rooms in the house and the availability of separate indoor cooking facilities. These findings confirm the importance of income and wealth as determining factors for fuel switching behavior. In chapter 4, however, non-income factors were found to play a more important role in rural areas in Kenya alongside income and wealth factors.

Marketing strategies for cooking fuels and cookstoves are primarily oriented towards female household members. Although traditional gender relations in SSA declare the kitchen a woman's domain, men are often the primary decision-makers regarding the allocation of the household's financial budget. Men are found to value the fuel-stove products higher than women, which we ascribe to discrepancies in the disposable budget between men and women. Once women become the head of the household and therefore in control of the financial means, they show a higher demand for the presented stoves as well. This also shows that we cannot assume a single set of preferences within the household and should take this into account when studying household choice behavior and developing marketing plans.

Focusing on the **technology characteristics** discussed in chapters 4 and 5, several factors showed a clear impact on choice behavior. First of all, a reduction of the smoke level and the implied positive health effect appeared a strong driver for consumer choice in both Kenya and Mozambique. This could be used as a key selling point for improved cookstove programs which struggle to reach sufficient scale. Considering the limited knowledge of the health implications and

complications related to traditional cooking practices, much is still to be gained from improving public awareness on this topic. Especially women who spend most time in the kitchen, turned out to know little about the often severe health risks they face on a daily basis due to the particles inhaled while cooking over open fires or using traditional charcoal stoves.

The cost of degrading the environment is often assumed not to enter the resource users' decision-making due to a poverty-related short term planning horizon (Hiemstra-van der Horst and Hovorka, 2008). We showed in chapter 4, however, that people are aware of the increasing pressure on their natural environment and are willing to pay extra for improved cookstoves to reduce the impact of their energy needs on the environment. The interest in nature conservation raised by NGOs and the local government may have positively influenced this behaviour. Quite a number of NGOs were at the time active in the area working on the protection of the Mau forest in Kenya. In chapter 5, a reduction on the environmental impact was positively valued as well by the urban sample in the Mozambican case study even though environmental protection is not such an articulated topic there.

Both the cost attributes, stove costs and fuel cost, were as expected identified as important behavioural drivers. Increasing prices generally curtail demand. Focusing on the price sensitivity of respondents for the varying fuel-stove alternatives proved an additional behavioural layer. In chapter 4, the Kenyan sample was found to be significantly more sensitive to rising price levels of firewood stoves than charcoal and ethanol stoves, while a higher price sensitivity was found related to the usage costs of charcoal and ethanol than firewood. However, no significant difference was found between the charcoal and ethanol stove and fuel cost coefficients, probably due to the substitutability of the two fuel products. Based on fuel stacking behaviour, ethanol and charcoal can be seen as complementary products to firewood rather than full substitutes. In the case of charcoal and ethanol, households can fully or partly switch back to firewood when fuel prices are increasing. In the case of firewood such a cost-free back-up alternative does not exist. This explains the lower responsiveness to changes in firewood prices, which are commonly found to be price-inelastic in developing countries. The improved firewood stove directly competes with a cost-free 3-stone alternative, which is already commonly owned by households. Ethanol and charcoal stoves provide the household not only with a new appliance, but also with an extension of their energy portfolio. Once households own the necessary

appliances they can move forth and back on the ladder when facing price changes or supply failure (Leach, 1992).

In the Mozambican case study for both the weekly fuel usage cost and the stove cost no significant difference between the alternative specific estimates are found. This suggests that the type of cooking stove and fuel type do not influence the households' price sensitivity. All three fuels under consideration are market-based products and deliver the same service to the household. In an urban context households are bound to market-based fuels and do not have easy access to a free-of-costs alternative such as firewood which they can fetch themselves. This seems to be the most plausible explanation for the similar responsiveness towards the fuel costs. Looking at the stoves, the ethanol and LPG stoves provide the household not only with a new appliance, but also with an extension of their energy portfolio, the improved charcoal stove rather replaces an older model. It was therefore anticipated that households would be more sensitive to the price of the charcoal stoves as households already own a backup alternative. This study shows a similar responsiveness among the three products with respect to the stove prices. Potentially an improved charcoal stove is not seen as a replacement of the traditional all-metal stove and rather functions as an additional cooking option. Another option is that the all-metal stove is a market-based product as well, the costs of which are not very different from the improved charcoal stove. Households are therefore used to incur costs for their cooking technology.

In the study in Kenya current fuel use was included to control for its impact on fuel-stove choices in the choice experiment. The use of charcoal has a significant positive effect on the choice for the fuel-stove alternatives, while a significant negative effect is found for respondents who already have liquid fuels in their energy portfolio. Comparing these results to the prior expectations based on the energy ladder shows that respondents who have progressed to transition fuels value the improved stoves significantly higher. Households who have progressed another step further to modern fuels have less interest in the improved stoves. The inclusion of modern fuels such as LPG potentially lowers the importance of the biomass fuels in the energy portfolio explaining the lower interest in the presented fuel-stove alternatives. With a modern alternative available in their portfolio, LPG-biomass users will be less inclined to adopt any of the new technologies available despite the fact that biomass, mainly charcoal, still plays an important role in their cooking habits.

In the study in Mozambique a more rigorous approach was adopted by including household fuel portfolios instead of single fuel uses in the analysis as a determining

factor for choice behavior. As households are more likely to use a portfolio of fuels, including these portfolios will provide a more complete and hence improved insight in the impact of current behavior on future choices. Here, two important findings stand out. First, LPG-biomass users were less inclined to adopt an improved charcoal or ethanol stove despite the fact that charcoal still plays an important role in their cooking habits. Second, households who use a combination of firewood and charcoal have a significant higher preference for the improved charcoal stove than charcoal only users. This suggests that charcoal only users prefer to extend their fuel portfolio with modern fuels rather than investing in improving their current charcoal use.

The **third research question** examines the impact of external local conditions on household choice behaviour. For the analysis of the household external environment I zoomed in on the following two main dimensions: natural resource endowment and biomass pressure measured through two distinct rural areas, and market access measured through the comparison of two resource abundant and resource scarce rural areas with a peri-urban location. A significant effect for resource scarcity on current fuel switching behavior was not found. This implies that in the current stage of the energy transition process no differences can be detected that relate to the natural resource endowment of the rural locations. The major difference found in the fuel strategy between the two rural locations does not involve the fuel portfolio self, which is fairly similar between the two locations. More important is the household strategy to acquire the biomass fuels they need. Although the ecology of the biomass-scarce location is less favorable for firewood collection compared to the forested locations, a higher share of households were fetching firewood in the resource-scarce location. Households seem to have adapted to the relative scarcity of firewood by exploiting their farmland resources as a strategy to fulfill their energy needs. In the biomass-rich location, markets provide half of the households with firewood for cooking, and it seems that the proximity to the forest has enhanced the emergence of consumer markets for biomass fuels. In the choice experiments the external decision environment was found to play a significant role on choice behaviour. The external decision environment hence seems mainly driven by the market context of the different locations, and less by biomass scarcity or abundancy. The model results show that the fuel-stove alternatives are valued highest in the peri-urban location. Comparing the 2 rural locations, higher values for the energy-efficient cookstove alternatives were found in the resource abundant location. While both areas are similar in terms of employment opportunities, household income and wealth levels, the main difference in valuation could be ascribed to the household dependency on

fuel markets for their daily energy needs. Once household incur costs for their fuel needs, investing in alternative solutions becomes a feasible strategy.

The **fourth and final research question** addressed the role improved cookstoves can play in the energy transition process. It is argued that improved cookstoves could serve as an intermediate strep on the energy ladder for those who cannot yet make the switch to modern fuels. As shown in chapters 3 and 5, only a minority of households have made the switch to modern fuels such as LPG. Our analysis in chapters 4 and 5 showed a clear demand and positive WTP for the presented fuel-stove combinations in both case studies, indicating that there is clear potential for improved cookstoves as well as modern fuels. Although in the Kenyan case study the charcoal and ethanol stoves are preferred over the firewood alternative, firewood nevertheless remains a product of interest and continued usage is expected. A discrete energy switching pattern as defined by the energy ladder, moving from firewood to charcoal and subsequently to ethanol, is not observed, among others because we do not detect a significant difference in preferences for the charcoal and ethanol alternatives. Given current energy stacking behaviour, charcoal and ethanol are more likely to function as additional fuels, used to extend a household's energy portfolio. In the urban case study in Mozambique, the modern conventional alternative LPG is preferred over the ethanol and charcoal alternatives. But also here the inclusion of modern alternatives in the choice mix has not eliminated the interest of households to cook with charcoal and also here continued usage is to be expected. The positive interest in the improved charcoal stove does allow for a cleaner and environmental friendlier use of charcoal for cooking.

6.2 Suggestions for further research

Based on the experiences gained in this PhD thesis, developing and applying novel household survey approaches to assess fuel switching behavior in the case studies in the developing world a number of recommendations are presented here for future research.

This thesis made use of both revealed and stated preferences methods and techniques for the analysis of fuel switching and stacking behavior. The major strength of working with revealed preference data is that it is based on actual fuel choices. However, revealed preference data are limited when aiming to analyze behavior in response to new market developments where consumers have no

experiences yet. Such hypothetical future behavior in new markets is better captured by stated preference data. The uptake and use of improved cookstoves as well as modern fuels and their respective technologies is still marginal in developing countries, especially among the poorer consumer segments. Therefore, stated preference methods were considered the best available approach for this study to assess the potential future uptake of the new technologies. Taking into account current fuel stacking behavior, assessing preferences for single fuel-stove alternatives in particular helped to better understand potential demand resulting from a change in supply on local markets as well as the drivers underlying this demand. But the understanding of future fuel portfolios instead of single fuels remains limited. Further research is therefore needed to examine how fuel stacking behavior can be better assessed using stated preferences methods.

Furthermore, stated preference methods depend on choices made in hypothetical settings. The extent to which individuals might behave inconsistently, when they do not have to back up their choices with real commitments, can cause a hypothetical bias (Hensher, 2010). Although stated preferences are the only available method for analyzing preferences for products that are new or relatively unknown to the population of interest, this hypothetical bias can typically cause the WTP measures to be overstated (List, 2003). Actual market behavior would provide the ideal and most accurate and reliable assessment of cooking technology adoption. However, current trends and developments do not suggest or predict any widespread availability of various improved cookstoves or alternative cooking technologies operating on modern fuels on a reasonable short term, especially in rural areas. Potentially, field experiments would be the most appropriate alternative revealed preference method to simulate actual market behavior by asking household to make actual purchase decisions.

While the developed analytical framework in this PhD thesis discusses a wide variety of influential internal and external factors, it somewhat ignores the element of time. The study is based on a cross-sectional analysis of household energy consumption and fuel switching behavior. This results in a comparison of differences between households at one point in time. Ideally a so-called retest would be performed over time using either stated or revealed preference methods to check the consistency of the findings in this dissertation. Generalizing from cross-sectional data and draw time-series conclusions should be done with caution to prevent misrepresentation of transition trends and relationships. Changes in energy consumption among the same households over time could add valuable information that is missed by using the cross-sectional approach. The element of

time with respect to fuel switching behaviour could be approached in two ways in further future research. First, variations of fuel use within a short time frame such as one year could be examined. As fuel stacking is common practice a more detailed registration of this process within varying seasons could enrich the understanding of the mechanisms that force households to move back and forth between fuels over time or to use them in combination. Second, fuel switching behaviour over a longer period of time, such as a number of years, is needed as it will allow for a more detailed registration of household specific developments in relation to fuel use.

Another framework to analyze the drivers of energy choice and technology adoption would be a household model reflecting choices in labor allocation and energy demand. In this study such a model has not been further developed due to limitations in data collection with respect to the household's time and labour allocation. Interviewed households did not manage to indicate a clear or consistent pattern of time and labour needed for the collection of firewood on a weekly or monthly basis. Households struggled to indicate distances travelled as well as time allocated to reach the locations where they fetch their firewood. Moreover, specifying the quantities of wood used and collected was also considered a very difficult task by the households self. To accurately assess these quantities, a household needs to be followed over a longer period of time, either making use of self-reported measurements through a logbook tracking procedure or measurements made by the researcher. The indicated data collection problems led to the conclusion that for this study the data were not reliable enough to build and estimate such a household model. The cross-section survey approach would need to be replaced by a longitudinal survey approach to overcome the mentioned barriers and yield more reliable information regarding the use of labour and the allocation of time within the household.

Finally, common practice in household surveys is typically to select one respondent from the household as a representative for preference elicitation and treat that individual's choice as a reliable proxy for the joint household choice. Here, households are assumed to be unitary, acting as a single agent with a single set of preferences (Bateman and Munro, 2005). Traditional gender relations in Sub-Sahara Africa 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. In chapter 4, the gender dimension of choice behaviour was studied by interviewing both men and women from the same household separately. The results showed that there is a significant

difference between the sexes, implying that we cannot assume a single set of preference. An important question therefore is whether the decision to purchase a cookstove or alternative fuel is entirely the decision of an individual person or that the choice is the outcome of joint deliberation by the couple, raising the question of how close individual preferences are to those underlying joint deliberation. Initially, a study on household intra-household choice behavior was set to be part of this study, but due to time limitations could not be included in this PhD dissertation. To understand how intra-household decisions come about will be essential for improving our understanding of choice behavior. Future work applying choice experiments where household members will make individual as well as joint decisions will be an important step to increase our understanding of household choices. Such experiments will most probably benefit when complemented with a more qualitative assessment of intra-household bargaining and power balances, which are considered essential for our understanding of the outcome of joint decisions.

6.3 Policy recommendations

As discussed, the values attached to the various technology characteristics of the fuel-stove combinations presented in the choice experiments provide direct policy-relevant indications and input in awareness and marketing programs to encourage the adoption and uptake of energy-efficient cookstoves in rural, peri-urban and urban areas in Kenya and Mozambique. In particular the positive health effects that are associated with the use of modern fuels and improved cookstoves are expected to be a strong driver for consumer interest and choice behavior. As awareness is still very limited there is a need for awareness raising campaigns on health and cooking. Explaining the benefits of new products and the negative effects of traditional stoves seems crucial in urging households to switch to alternative fuels and technologies. Including male household members as a target group in such promotion campaigns is considered essential as male household members typically control a household's financial means and budget.

Recent attention of governments, development organizations and donors has focused on encouraging the use of improved cooking practices, especially through the use of improved firewood stoves in rural areas and improved charcoal stoves in urban areas. This focus is primarily based on the fact that households currently use either firewood or charcoal as their main cooking fuel in the respective areas. The results presented in this PhD dissertation show that households tend to prefer and

choose complementary products instead of substituting their traditional stoves by an improved version using the same fuel type. This behavior is inherent to household fuel stacking behavior. Diversifying the fuel portfolio seems to be households' priority as a livelihood coping strategy. In the rural and peri-urban case studies, public and consumer interest in the improved charcoal and ethanol stove was significantly higher than for the improved firewood stove. A similar result was observed in the urban case study were the LPG product also received a higher interest than the traditional urban fuel charcoal. Programs aiming to stimulate the uptake of modern fuels and technologies therefore should carefully consider diversifying the products on offer to better fit public consumer preferences.

Investments in improved cookstove programs in rural locations where households' monetary fuel cost are relatively small to non-existent will most probably run into a number of problems and potentially experience low success rates. Most importantly, because households in such locations are not strongly motivated to use expensive technologies, which promises them a reduction in fuel consumption as their need to reduce fuel costs is not pressing. Even in areas which are considered resource-scarce these external conditions do not directly lead to a higher need and demand for fuel-efficient products as households develop alternative coping mechanisms to solve local and temporary shortages. Results have shown that in those locations where households depend on existing markets for their cooking fuels, the interest and willingness to pay for improved cooking technologies is significantly higher. These regions should therefore serve as target areas for the further development of cookstove markets.