Energy for Sustainable Development 27 (2015) 54–62

Contents lists available at ScienceDirect

Energy for Sustainable Development

Reducing energy poverty through increasing choice of fuels and stoves in Kenya: Complementing the multiple fuel model

Michael U. Treiber *, Lars Kåre Grimsby, Jens Bernt Aune

Department of International Environment and Development Studies, Noragric Norwegian University of Life Sciences, P.O. Box 5003, 1432 Ås, Norway

A R T I C L E I N F O

Article history:
Received 10 July 2014
Revised 10 April 2015
Accepted 10 April 2015
Available online xxxx

Keywords:
Energy transition
Technology adoption
Household energy

A B S T R A C T

Energy transition theory and its applications in energy policies and development interventions are dominated by the traditional theory of the energy ladder. The linear model predicts a positive relationship between socio-economic development and transition to more efficient, cleaner, and costly energy sources. This study demonstrates, however, that households do not follow the projected patterns. Instead, fuel and stove diversification is observed. Households use various energy carriers, modern and traditional, and devices to secure a continuous energy supply and counteract potential access and availability issues. Multifaceted demands of the households are an important driver of the diversification. Preference often concurs with the most efficient and best available stove and fuel for a particular task. Individual characteristics and social and cultural tradition influence the final choice. Therefore, broadening the range of available and accessible stove designs and fuels will help households to achieve energy security and greater efficiency in their consumption.

Introduction

Dependency on traditional biomass fuels such as firewood and charcoal as well as agricultural waste for various tasks such as cooking, lighting, or space heating is high in many developing countries (IEA, 2011; WHO, 2008; World Bank, 2011). Multiple links between energy consumption and the environment, human health, and poverty make it crucial to understand how people choose to adopt or reject a particular energy source (Modi et al., 2005). Insights in energy-related decision-making at household level are vital to build policy and technical interventions to effectively improve living standard, energy access and energy security in developing countries.

The dominant approach on which governmental and non-governmental activities are often based is the energy ladder model (e.g. Barnes and Floor, 1996; IEA, 2011). The linear model predicts a positive relationship between socio-economic development and adoption of and transition to more efficient, cleaner, and more costly energy sources. It implies complete transition from one fuel to another. The energy ladder model can be characterized by three stages: The lowest step is distinguished through the universal combustion of biomass in form of agricultural residues, dung and wood; the second phase is defined by the shift to so-called transitional fuels such as charcoal or kerosene; the adoption of 'clean' energy forms like LPG, natural gas, or electricity constitute the final step on the energy ladder model. The consumers are assumed to have inherent preferences for fuels types according to physical characteristics such as cleanliness, ease of use, cooking speed and efficiency as well as fuel costs (Akabah, 1990; Hosier and Kipondya, 1993; Leach, 1992; Reddy and Reddy, 1994).

Reality is more complex than what the energy ladder model predicts. Rather than a complete transition to increasingly modern fuels, households have been shown to diversify their energy consumption and utilize multiple fuels simultaneously from all levels of the energy ladder (e.g. Hiemstra-van der Horst and Hovorka, 2008; Pachauri and Spreng, 2003). The 'multiple fuel model' gives a set of factors that together explain why energy diversification may be a rational option for households (Masera et al., 2000). Different fuel or stove types are selected for a particular task due to their individual characteristics in terms of cost-effectiveness and efficiency (Evans, 1987; Martins, 2005; Tinker, 1980). Foster et al. (2000) use the multiple fuel model to develop the concept of '*different energy ladders for different types of applications*'. Energy diversification is not limited to cooking fuels. Information, communication and entertainment technology, lighting, and security are examples of end-uses that drive the demand for new energy carriers. Barnes and Floor (1996) suggest that 'broadening the range of energy technologies' could be an option for enhancing energy supply in rural developing countries. Energy use in different applications and for different end-uses is closely linked with human development (Modi et al., 2005).

According to PwC (2012) biomass energy accounts for around 70% of all energy consumed in Kenya. Overall, the average per capita energy consumption in 2008 was stated to be around 80 kg oil equivalent (UNdata, 2012). While around 95% of rural homes are reported to have access to kerosene and around 90% of whom use this fuel for

* Corresponding author at: Feldstraße 14; 65183 Wiesbaden, Germany. Tel.: +49 17631540812.
E-mail addresses: michael_treiber@web.de (M.U. Treiber), lars.grimsby@nmbu.no (L.K. Grimsby), jens.aune@nmbu.no (J.B. Aune).

http://dx.doi.org/10.1016/j.esd.2015.04.004
0973-0826/

lighting, grid electricity is available to only 13% of Kenyan homes — 45% of urban but only 3% of rural homes (HEDON, 2010). Countries such as Kenya have been subject to policies oriented towards enhancing energy access for several decades, and lessons learned suggest the importance of understanding locality, culture and existing consumption patterns and options prior to development interventions (Murphy, 2001; Sesan, 2012).

Energy development activities in Kenya include three regions where the German Gesellschaft für Internationale Zusammenarbeit (GIZ, formerly GTZ) are disseminating improved cook stoves (ICS). A range of stove options are available, both improved and traditional, which are optimized for different fuels. Technologies and energy carriers for lighting and communication are also increasingly accessible. Investigation of how people with different household characteristics choose and use energy in a semi-rural context with a range of needs and options available is pertinent. This is a context in which many of the world's energy poor find themselves.

The objective with this paper is to contribute new knowledge to contemporary theory on energy transition in developing countries by building on empirical evidence from Kenya. A survey among 320 households in rural and semi-urban areas makes the empirical basis for testing a new explanatory model for household decision-making related to overall energy use, combining technology adoption theory and the multiple fuel model.

Theoretical framework

The multiple fuel model is increasingly embraced as reflecting reality better than the linear energy ladder in countries as diverse as India (Pachauri and Spreng, 2003), Botswana (Hiemstra-van der Horst and Hovorka, 2008) and Mexico (Masera and Navia, 1997). Leach (1992) and Hosier and Kipondya (1993) indicate that in particular lower level fuels are kept for energy security reasons in the event of supply shortage or high prices of the preferred fuel. While income has an impact on the fuel choice, it is not the major factor but rather one of several motivations which together explain why many people decide to use multiple fuels (Campbell et al., 2003; Davis, 1998; Ezzati and Kammen, 2002; Soussan et al., 1990).

Masera et al. (2000) investigate what influences decisions at household level on energy use in situations of uncertainty and scarcity. The resulting multiple fuel model gives a rationale for energy diversification by integrating 1) economics of fuel and stove type and access conditions to fuels, 2) technical characteristics of cook stoves and cooking practices; 3) cultural preferences; and 4) health impacts. In contrast to the multiple fuel model which focuses on uncertainty and scarcity as the contextual features set as pre-conditions for utility, the emphasis in this paper lies in how multifaceted demands of households represent drivers of the multiple fuel and stove use in a context where different fuel and stove options are available. Rather than viewing multiple fuel use primarily as an indicator of household vulnerability, it emphasizes the positive contribution that availing multiple cooking options may have.

Materials and methods

Study locations

In Western, Central, and Transmara regions of Kenya (see Fig. 1) GIZ has undertaken a variety of programs in the field of sustainable development, including dissemination of improved cooking stoves. The three regions have high population density, high rates of poverty, as well as increasing woodfuel scarcity.

The ICS disseminated by the GIZ use primarily traditional biomass fuels but exhibit much higher resource-efficiency allowing savings of up to 50% of fuelwood compared to the traditional three-stone fire (GTZ, 2007). Since 1983 the GIZ has focused on promoting a commercial approach to stove activities at all levels: production, marketing and installation. Local entrepreneurs are trained as independent stove producers. Stoves such as the Jiko Kisasa, Fireless Cooker and Rocket Stove are all made of local materials. In addition to the ICS, Improved Cooking Tips are distributed illustrating advices how to cook efficiently in order to save further energy, time, and money (Häcker and Treiber, 2012).

Transmara region is marked by high shortage of firewood. Trees are cultivated inside private compounds. The local forest consists mainly of small bushes, but of good quality wood. Women collect or buy bundles of firewood or tins of charcoal from neighbouring farms. Despite the proximity of Kakamega forest in Western region, the availability of free firewood is limited to the household's own compound due to strict laws prohibiting tree cutting within the forest reserve. Nevertheless, illegal cutting and wood collecting is an issue. Trees are scattered in compounds in Western region. In Central region, many trees are planted in the individual compounds assuring the households a stable supply of firewood. Additionally, firewood and charcoal are also bought at the nearby shopping markets.

Fieldwork was undertaken from September 2011 to March 2012. From each of the three previously described regions one 'rurban' and one rural location was selected by systematic random sampling. Rurban is here defined as a semi-urban area between an urban and rural region, featuring a certain size, distance from and degree of connectivity to a major trading centre and tarmac road. The six selected locations include Shidodo and Shiasava in Kenya's Western region, Gatuya and Kamuiru in Central region, and Boronyi and Kipsingei in Transmara region (Treiber, 2012).

Data collection and analysis

The research used a dominant-less mixed methods approach (Johnson and Onwuegbuzie, 2004), including structured household questionnaires, location profiles, in-depth semi-structured interviews with households and institutions, and direct observation. The household survey with structured questionnaires among 320 randomly selected households was stratified across the six selected locations. For analysis questionnaire data were triangulated against location profiles, in-depth semi-structured interviews (15) and direct observation.

Sample size was determined to ensure a representative sample (confidence level >95%) out of the total population in the three regions using Raosoft Inc. (Raosoft Inc., 2004). A representative sample was obtained by following the 'random-walk sampling principle' (Hoffmeyer-Zlotnik, 2003; UN, 2005).

Quantitative data were processed in SPSS statistical software for analysis 17.0 (IBM, 2014). Table 1 shows the sample distribution for the household survey. Rurban–rural distribution of total number of sampled households was 49.1% to 50.9%; 'no-response' was ~30%. Statistical methods applied to analyse the data are descriptive statistics, ANOVA and Tukey's Honest Significant Difference (HSD) *post-hoc* test.

Research design and data collection were done in collaboration with GIZ, and included use of the organization's field staff as enumerators.

Results

Energy diversification

The household energy use patterns observed among the participants in the study give a relatively consistent picture across the three regions. Table 2 illustrate the diverse use of the individual energy carriers by households for the total sample and the sub-categories rurban/rural. Batteries are common due to the ubiquity of radios, flashlights and mobile phones. The use of the basic biomass fuels is widespread: firewood for example is used by 97% of the sample. A similar picture is drawn for kerosene, a fuel mainly used for lighting purposes and only rarely for cooking, used by 96%.

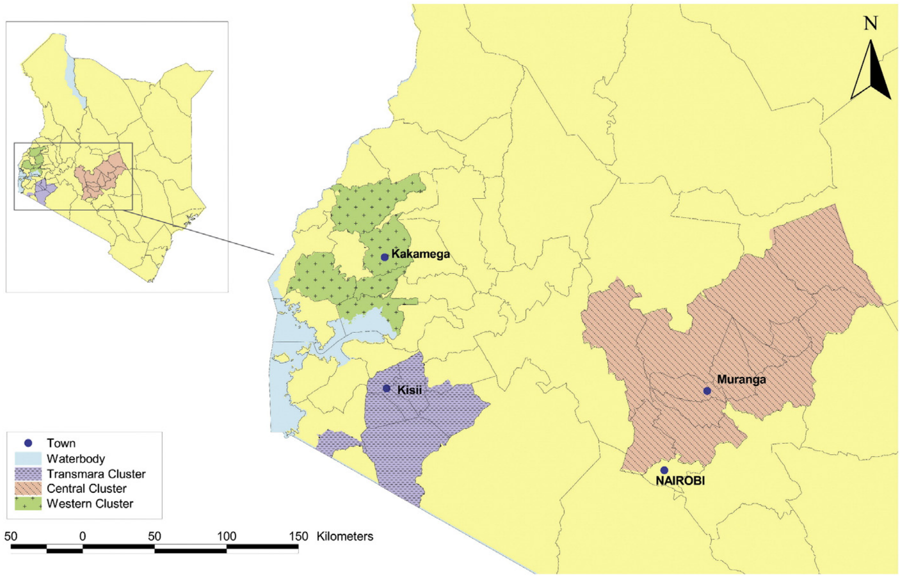

Fig. 1. Map of the GIZ clusters with ICS activities (data retrieved from GIZ & WRI).

As shown in Table 2 prevalence of energy carriers used in rural and rurban households does not differ much, and an ANOVA test shows on average no significant difference across the two groups ($p > 0.05$). However, as expected LPG is more prevalent in rurban households than in rural ($p = 0.013$). There is also a higher charcoal ($p < 0.001$), sawdust ($p = 0.004$), and candle use ($p < 0.001$) in rurban relative to rural areas.

Change in energy use with changing wealth is shown in Table 3. While the use of crop residues, firewood, and twigs is nearly universal and independent of income, there is an indication of prosperity dependency for sawdust. Nearly 45% of the highest income group use sawdust as an energy source while its consumption in the lower and middle classes is 20% and 22% respectively. A Tukey *post-hoc* test of sawdust use against income category reveals a significant difference ($p < 0.002$) from lower and middle to higher wealth. A similar trend is observed in the case of charcoal ($p < 0.001$), candles and LPG ($p < 0.002$), that increase in prevalence from poor to the rich. Kerosene and batteries on the contrary do not follow this pattern, with nearly 100% of low and medium class households using kerosene. Although connection to grid electricity was only observed once or twice among the 320 sampled households, charging of batteries (mobile phones, car batteries for e.g. TV) is done at charging stations. Use of electricity is significantly higher among high- and medium income groups than in the poorer households ($p < 0.001$).

Fig. 2 illustrates the households' diversification in their individual energy consumption in the rurban and rural regions. With a minimum of two and a maximum of ten energy sources (mean 7.5), every household in the sample applies a mix of energy carriers to meet their varied energy needs. Fig. 3 shows how number of cooking fuels are skewed with income group, and a one-way ANOVA confirms this with $p < 0.001$ significant difference between groups. This is further supported by a Tukey *post-hoc* test revealing that mean number of fuels increases from the low (mean 7.0, S.D. ± 1.2) to middle income class (mean 7.6, S.D. ± 1.2 min, $p < 0.01$), and highest income (mean 8.2, S.D. ± 1.2 min, $p < 0.01$).

Table 1
Sample distribution throughout the three cluster and locations (n = 320).

Cluster	Location	Rurban/rural	Sub-location	Count	Percentage
Western	Khayega	Rurban	Shidodo	52	16.3%
	Shibuye	Rural	Shiasava	50	15.6%
	Total			101	31.6%
Central	Gatuya	Rurban	Gatuya	53	16.6%
	Maragua Ridge	Rural	Kamuiru	54	16.9%
	Total			107	33.4%
Transmara	Kiogoro	Rurban	Boronyi	52	16.3%
	Ndanai	Rural	Kipsingei	59	18.4%
	Total			112	35%
Total				320	100%

Multifaceted energy use

Over 50% of the households using more than one stove mentioned the advantage of being able to cook simultaneously as summarized in Table 4. Of the total sample 58% are using more than one fuel due to the fuel characteristics. In general, final fuel choice depends on the food type and quantity being prepared, but also on the stove being used. Additionally, the context of the task such as cooking simultaneously influences final fuel choice.

Surprisingly, relatively few respondents reported that price of fuel is driving diversification of stove use (23%) and fuel use (15%). Fuel availability on the contrary is the commonest (95%) reason for having more than one fuel in stock. Seasonal fuel availability due to changing weather and availability of agricultural residues were frequently quoted as reasons for energy diversification. Correspondingly fuel availability due to seasonal changes was a major driver for multiple stove use (43%). Charcoal and crop residues are often used as a substitute for firewood especially in the rainy seasons where dry wood is scarce. Versatility of stoves determines how well they function with various fuels, and therefore their capacity for contributing to household energy security.

All major energy carriers are relatively versatile in the sense that they are applied to different tasks. Nearly all households were using more than one fuel per cooking task as indicated in Fig. 4. In the case of lighting or communication and entertainment, the range of potential option is rather limited which is reflected in the greater portion of households using only one energy source. Differences between rural and rurban areas are marginal. A statistically significant difference ($p < 0.05$) between rural and rurban could only be established for the number of cooking fuels and warming-up fuels. Firewood is the main fuel for boiling water, cooking and warming up food, while kerosene is the main lighting source in most households. Use of electricity for lighting purposes is significantly higher in rurban areas compared to rural areas ($p < 0.01$). Besides the quoted tasks households utilized their fuels for a variety of other tasks, such as roasting maize which

Table 2
Energy use patterns across the total sample and in rural and rurban areas.

	Total (n = 320)		Rural (n = 163)		Rurban (n = 157)	
	Count	Percentage	Count	Percentage	Count	Percentage
Crop residues & dung	298	93%	156	96%	142	90%
Sawdust/briquettes	81	25%	30	18%	51	32%
Twigs	297	93%	153	94%	144	92%
Firewood	311	97%	156	96%	155	99%
Charcoal	193	60%	80	49%	113	72%
Paraffin/kerosene	308	96%	158	97%	150	96%
LPG	23	7%	6	4%	17	11%
Electricity	285	89%	140	86%	145	92%
Batteries	277	87%	138	85%	139	89%
Candles	92	29%	29	18%	63	40%
Other	4	1%	1	1%	3	2%

was a common commercial activity. In 80% of the situations where space heating was performed, charcoal was used.

Based on the assumption that households made an elaborated choice concerning their main task fuel they were asked about their reasoning, summarized in Table 5. Fuel affordability and availability are major issues in terms of fuel choice. Over 37% stated that both features are substantial while some additional 36% mentioned only fuel availability to be significant. Availability encompasses market supply and accessibility in the household's environment. Some households emphasize portability of the energy option and its versatility. In contrast, for their main lighting energy source households are more concerned about its efficiency and cost-effectiveness.

Nearly 60% of the households use a three-stone fireplace as their primary cooking solution. Households often emphasized its flexibility as its greatest advantage. It is adjustable to any pot and may be extended by making more fires. Due to the different food types and quantities cooked, the open fireplace has a relative advantage over others. Another benefit often mentioned is the stove's ability to be utilized with a great variety of fuels. A substantial share of rurban households reported a switch from the three-stone fire to charcoal-fired stoves. Kerosene- and LPG-fuelled stoves are often used for warming up food and boiling water. Households stated that in these situations LPG or kerosene is preferred due to its greater thermal efficiency and speed than the three-stone fire.

Reasons for choosing a particular main stove for a task are elaborated in Table 6. The stove's efficiency and its cost-effectiveness were for 38% the major reason to choose a particular stove. Fuel affordability was another concern, 24% of the sample stated that fuel prices are a major issue. Although many households had kerosene and LPG stoves, a recent price increase for energy made people avoid them for being uneconomical. 7% of the respondents mentioned that their stove use is based on tradition or familiarity. Only 6% declared cost of stove to be a restriction in their choice.

Table 7 gives an overview of the stove and fuel preference for the most common food types. Only cases where more than 25% of households use a particular stove for a certain food type are presented in the table. Firewood is commonly used for heavy foods such as ugali and githeri. While ICS such as the Jiko Kisasa which uses firewood as main fuel are often preferred for general cooking, they were reported to break under the weight of heavy pots. There is a clear dominance of charcoal stoves (KCJ and All-metal) for roasting meat and maize as well as cooking rice and bananas or making chapattis. Households stated that these food types need a controllable constant and durable heat. Kerosene and LPG stoves are favoured for light foods that do not need long cooking time such as tea, porridge or eggs. These fuels were preferred due to their efficiency and cost-effectiveness. Such clear fuel and stove preferences associated with a special food were also observed in all four interviewed restaurants.

Discussion

All households in this survey use a diverse range of energy sources for end-uses ranging from telecommunication to portable lighting, and the majority multiple stoves for preparing their food and heating. The extent of cooking fuel and stove diversification relates positively to household income, and is higher in rurban than in rural areas. Energy diversification was previously considered a typical indicator of insecure energy supply (Brouwer et al., 1997), which also inspired development of the multiple fuel model (Masera et al., 2000). Contrary to what may be the general view on energy transition, as projected with the energy ladder model, our study shows that people's ability to afford and access increases energy diversity. This demonstrates that income not necessarily influences quality of energy consumed, and therefore has consequences for interventions aiming at improving energy security in developing countries. In the following sections we discuss how the findings relate and contribute to the multiple fuel model. Our study is

Table 3
Households using a particular fuel as energy source sorted by income category.

	Poor (n = 105)		Medium (n = 159)		Better off (n = 56)	
	Count	Percentage	Count	Percentage	Count	Percentage
Crop residues & dung	98	93%	149	94%	51	91%
Sawdust/briquettes	21	20%	35	22%	25	45%
Twigs	101	96%	145	91%	51	91%
Firewood	102	97%	154	97%	55	98%
Charcoal	40	38%	102	64%	51	91%
Paraffin/kerosene	103	98%	157	99%	48	86%
LPG	–	–	4	3%	19	34%
Electricity	76	72%	153	96%	56	100%
Batteries	90	86%	146	92%	41	73%
Candles	18	17%	50	31%	24	43%
Other	–	–	3	2%	1	2%

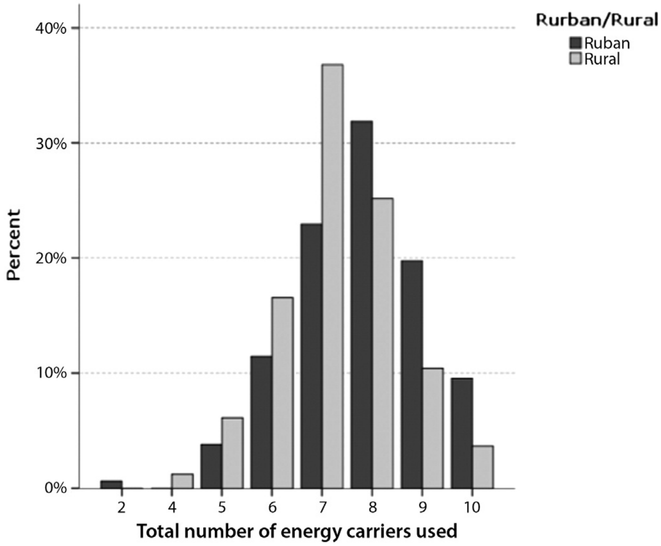

Fig. 2. Diversification of energy in rurban and rural areas.

not limited to energy carriers used for cooking. A model is presented to help explain decision-making related to household energy use in a context where multiple options are accessible.

Multiple fuels and stoves

Decision-making related to energy use in the household may appear like an easy task with limited possibilities particularly in a context with constrained economy and low demand for energy. Our study shows that households do in fact have a range of choices, not least where a variety of energy conversion technologies have recently been made available. Energy efficiency, cost-effectiveness, income level, accessibility, availability, individual preferences, culture and the specific task to be performed, all influence the decision.

Energy economization is an important reason for energy diversification, also among the well-off households in this study. Many households summarized their energy consumption as utilizing every flammable resource that is available. Freely available fuels found on the household compound such as crop residues, twigs and firewood are used as substitutes or main fuels in almost every case. Free energy sources such as what is found as by-products in local industry and agriculture are utilized until they are exhausted. However, their erratic supply makes them unsuitable as the main energy source for specific end-uses. Brouwer et al. (1997) sees use of such fuels as an indicator of severe fuelwood deficiency. Our study supports Masera et al.'s (2000) observation that multiple fuel use, irrespective of quality, is connected with economisation on fuel and household assets.

Table 4
Stated reasons for the multiple stove/fuel approach.

Reasons for	Multiple stoves		Multiple energy carrier	
	Count	Percentage	Count	Percentage
Depends on task or food type/quantity	118	57%	184	58%
Depends on fuel availability	77	37%	302	94%
Depends on fuel affordability	25	12%	74	23%
Due to seasonal fuel availability	11	5.3%	47	15%
Want to cook simultaneous	105	51%	–	–
Wanted new/better stove	57	27%	–	–
Other reason	68	33%	–	–

Access to energy may be as decisive as income in determining energy use. Table 3 shows that electricity, a high-end energy carrier, is used extensively across income levels. Access is achieved by a wide-spread system of charging stations where people can charge their devices and various batteries, but mainly mobile phones, at relatively low cost. Some stated that their electricity consumption is rather low due to long distances to the charging stations. Electricity grids were available in almost all regions. Only few villages did not have grid electricity nearby. Relatively rich households confirmed their wish and financial ability of being connected to the electricity grid, but mentioned the high upfront costs of such an investment. Furthermore, even in cases where such barrier could be overcome, access to the existing grid was reported as challenging due to organizational, bureaucratic or other obstacles. Similar to the energy available in charging kiosks, kerosene and batteries may be purchased in small, affordable quantities on a daily basis even in the most remote areas. Households often choose this option due to cash constraints. Income plays a role in energy choice, but becomes irrelevant if energy carriers and technologies are not physically available. Effective distribution systems are vital, and commonly recommended as part of a strategy for reducing energy poverty (Barnes and Floor, 1996; IEA, 2010; Modi et al., 2005; Schlag and Zuzarte, 2008).

Previous studies indicate a connection between the stove and fuel adoption and individual characteristics of the household's head such as age, education, occupation, or family size (Chambwera, 2004; Gebreegziabher et al., 2009; Heltberg, 2004). Using statistics, this study could not establish such relationships. However, Fig. 3 shows that richer households possess and use a greater number of stoves and fuels compared to relatively poor households. Rich households face less limitation of choice. A richer household may specialize fuel use and use specific fuels for a particular task only. Being able to afford a variety of fuels a richer household can afford not only the free or cheap alternatives but also those more expensive. Such fuel stocking behaviour for energy security reasons is an important part of the multiple fuel use

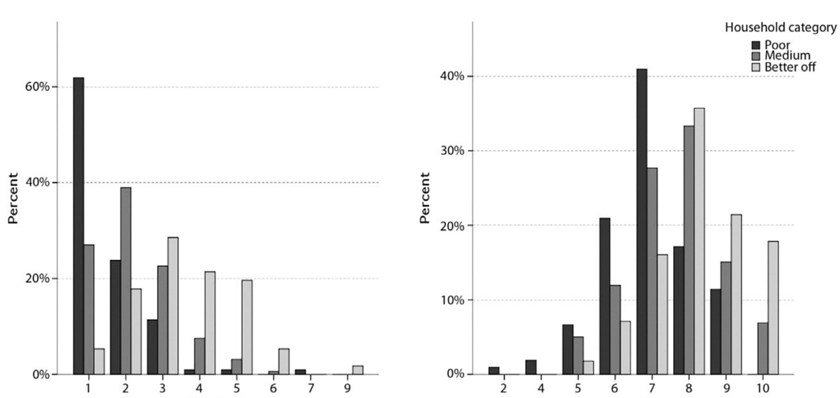

Fig. 3. Number of stoves and fuels used in households.

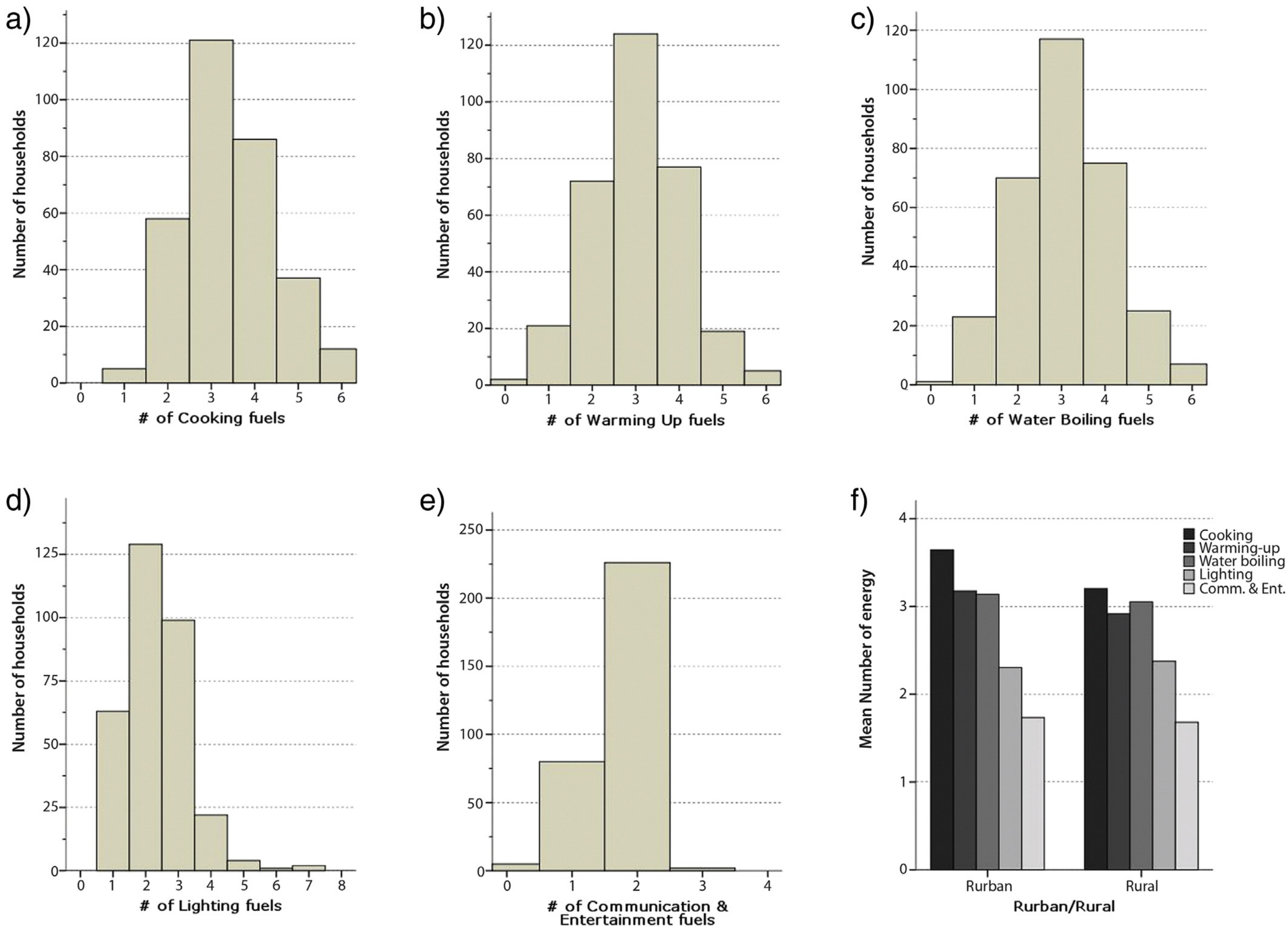

Fig. 4. Number of fuels used in households for the main tasks.

concept. Also, social capital appeared to affect access to energy. Interviews with key informants for example revealed that relatively rich households used their social networks to know when and where sawdust would be available free of cost.

According to Foley (1995), subsistence households only demand fuel for cooking purposes, usually in form of gathered wood. But as households' economic conditions improve they will expand their demands, including lighting, space and water heating and even brewing. Foley therefore shifts away from the sole monetary value of an income increase and focuses on the positive contributions to living standard an increase might bring along. Unfortunately, statistical tests did not reveal whether the number of tasks is related to income, household size or any other variable or how these demands are formed. However, rich households were observed to practice their task more often like cooking three instead of two times a day as poorer households might do. Further, communication and entertainment are more prevalent in households with a higher income. Number of mobile phones, TVs and other electronic devices was higher. Hence, it can be assumed that income influences task demand. The reviewed literature on demand creation focuses mostly on marketing strategies to promote certain products or services. Information about the benefits of owning and/or using a product or services is as important as the understanding of the product or services by the individuals themselves (Amelink et al., 2010; Koerner, 2008).

Taste plays a role in decision-making related to energy use for cooking. Kerosene is less used by restaurants since customers dislike the odour it leaves on the food. Households using charcoal as their main cooking fuel regularly use firewood for special dishes. The smoky flavour associated with firewood or charcoal is preferred when

Table 5
Reasons for choosing a particular energy carrier as main fuel.

Reasons for main	Cooking fuel		Lighting fuel	
	Count	Percentage	Count	Percentage
Affordability & availability	120	38%	59	18%
Availability	114	36%	52	16%
Affordability	18	6%	49	15%
Efficiency & cost-effectiveness	43	14%	102	32%
Flexibility	9	3%	20	6%
Smoke & cleanliness	5	2%	11	3%
Development	–	–	5	2%
Other	11	3%	22	7%

Table 6
Reasons for particular stove as main cooking stove.

Reasons for main	Cooking stove	
	Count	Percentage
Efficiency & cost-effectiveness	123	38%
Fuel affordability	76	24%
Stove affordability	19	6%
Tradition & familiarity	21	7%
Lack of knowledge	5	2%
Smoke & cleanliness	3	1%
Other	33	10%

Table 7
Stove preferences for specific types of food.

	Three-stone	ICS	KCJ	All-metal	Kerosene/LPG	Other
Ugali	40%	15%	15%	15%	10%	5%
Githeri	35%	18%	23%	18%	–	6%
Maize	22%	8%	45%	24%	–	1%
Bananas	18%	–	46%	18%	9%	9%
Green vegetables	13%	12%	6%	25%	31%	13%
Meat	9%	4%	48%	39%	–	–
Rice	6%	–	75%	13%	6%	–
Chapatti	5%	–	57%	34%	2%	2%
Tea	2%	7%	12%	16%	51%	12%
Porridge	–	–	25%	–	63%	12%
Egg	–	–	17%	17%	67%	–

preparing e.g. roasted meat or maize or cooking traditional green vegetable dishes. This illustrates that in general the stove adoption is always dependent on the local cuisine and cultural cooking habits of the population.

Culture and tradition influence the uptake of new energy technologies. Preparation of chapattis is on one hand associated with the use of charcoal as this fuel provides constant and controllable heat. On the other hand, tradition and culture also influence this connection since it was stated more than once that chapattis also can be made with firewood. In some regions households were stating that traditionally chapattis were a special and expensive dish only prepared for Christmas and charcoal as expensive fuel had to be used. Due to this traditional background other fuel options such as firewood are not even considered. Although within the survey only 7% of the households mentioned tradition and familiarity as reason for their particular main cooking stove choice, one person in Western region has summed up the ideas gained in other interviews as well as questionnaires: "*We cannot leave the three-stone, it makes us remembering the culture*". Bonfill-Batalla (1990) formulated the awareness of rural communities persistently using traditional stoves as a result of the "autonomous culture" to keep their culture alive against the wave of adopting western values and technologies.

Over 27% of the 320 households interviewed stated that stoves had piled up in their homes as acquired newer and better stoves. In these cases no indication was given whether the old stoves were still in use or not. Stove and fuel may be connected with social status. One household uses "*firewood for everything […] only if guests are there we cook with charcoal*". The fuel choice comprises a certain social status where the use of charcoal indicates a richer household compared to one using firewood. In general, households tend to like "*modern stoves*" made out of bricks while "*clay is for poor people*".

Access and availability influence the adoption and drive households to possess more than one fuel or stove due to energy security reasons. Fig. 4 also allows another view on the issue of fuel diversification. It indicates that almost all households use more than one fuel for a particular task. This demonstrates that for each task, some fuels are more suitable. Nevertheless, the initial assumption of clear preferences for a specific fuel for each particular task has also been confirmed. While firewood dominates in all cooking related activities, kerosene is the most preferred for lighting. Over 57% use multiple fuels as they choose a particular fuel depending on the task and its requirements.

Fuel and device choice has also been observed to be affected by the situation and context of the task. While some households might have particular preferences for a stove and fuel in connection to a special dish, the context of its preparation might change these. The choice not only depends on "*which food we are cooking […]* [but also] *for how many*". Over 57% of the surveyed sample has stated that these play a role in their stove choice. "*When you want to cook Ugali for a good number of people, […] you cannot cook with the Jiko Kisasa. I have to move to use the three-stone.*" Only smaller pots can be used with the Jiko Kisasa while the three-stone fire is flexible in its size and hence can hold any pot size. In addition, time is an issue when choosing fuel and stove. While firewood might generally be the dominant fuel, households use faster fuels like kerosene or gas for the same tasks "*when you are late or in a hurry*". Since firewood needs a lot of attention due to reasons of security and constant combustion, other fuels are then preferred. "*Firewood needs too much time; you need to sit beside to blow […]. If there are guests* [we] *also use gas. You don't need to stay at the stove*". Time-savings and the possibility to move from the stove and spend the time with guests were the key reasons to deviate from the main fuel firewood. In general, as reason for their main cooking stove, the majority of households quoted among other things the time-savings as a principal motive for their adoption. Especially in the case of ICS, designed not only for saving fuel but also time, this issue was of great importance. Some households stated that also other factors such as weather and hence the location of the activity influences the choice. While there is rain, the respondents preferred to use a less smoky charcoal stove indoors. The same households would utilize firewood in their outside three-stone fire when the weather permitted it. A similar observation was made in the case of lighting. Candles, although much less efficient and much more expensive than kerosene, are bought for their cultural and ritual value and used mostly only on special occasions such as birthdays or baptism. Masera et al. (2000) summarized this phenomenon as the interaction of technical characteristics and consumer's demand.

In our study we found that in a context where a variety of energy carriers are available, availability of a variety of appropriate energy conversion technologies may give people more choice. Efforts to displace traditional stoves may face an uphill battle because people are likely to continue using multiple cooking techniques, including the three stone fire, and use ICS some of the time. People have to weigh supply security against standard of living. ICS do contribute to both. Whereas only a limited range of stoves were sold in rurban areas, more diversity in design and fuel-specificity was observed in the main district cities in. Studies from South Africa and Botswana have shown interesting effects of access to grid electricity. Contradictory to expectations, access to electricity saw a continued increase in energy diversification including biomass (Davis, 1998; Hiemstra-van der Horst and Hovorka, 2008). Among the surveyed households in our study few were connected to the grid. Our observations of energy diversification and high prevalence of biomass use in ICS suggest a future with electricity and biomass also in Kenya.

Fuel choice model

A model visualising factors influencing fuel use decision is presented in Fig. 5. Out of the pool of all stoves and fuels available to a user, those chosen are selected not solely by their efficiency and cost-effectiveness as projected in the energy ladder model. The first step in Fig. 5 organises fuels and stoves according to their technical suitability for a specific task. Secondly, cultural and traditional issues lay the basis for scrutiny by the user. Individual characteristics such as age, education, and other personality traits are assumed to influence the behaviour towards a technology or the energy source and hence influence adoption. Third, availability and access and hence income restriction exclude further potential fuels and stoves.

Dynamics within this illustrative model are not static. While the first selection based on intended task is fixed, it might be argued that access and availability as well as income play greater roles than culture and the individual's characteristics. The proposed order has been set to emphasize the cultural and individual's characteristics over external decision dynamics such as access or fuel and stove prices and income. The order is interchangeable and households consider all factors rather simultaneously and not in a lengthy process.

Households in most developed countries focus on single or few stove and fuel options which meet all of their individual needs. But such specialization while households' energy needs is only possible due to stable access, affordability and availability of stoves and fuels higher on the

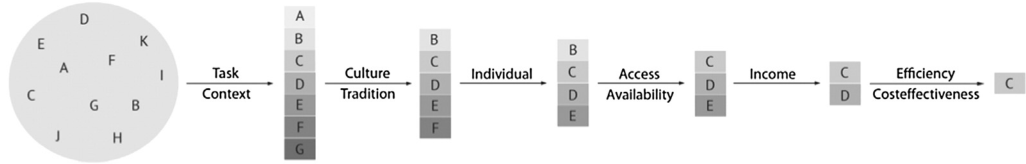

Fig. 5. Framework for stove and fuel adoption process.

energy ladder. According to Rogers (2003) a technology must have a certain compatibility with the targeted population's culture. The concept of 'appropriate technology' was developed in the early seventies to ensure that technologies are designed to satisfy rural people's needs (Schumacher, 1973). Under that definition, a technology is 'appropriate' when it responds to the users' need while respecting their culture and tradition. It acknowledges that there are no blueprint solutions.

Masera et al. (2000) showed how four factors similar to what has been presented here interchangeably influence the decision to opt for multiple fuels rather than single energy options. The study from Mexico shows how constraints necessitate local creativity in energy use. Sesan (2012) calls for more realistic expectations from dissemination of single energy technologies in the current agenda for providing energy security and poverty alleviation. Barnes and Floor (1996) suggested broadening the range of available and accessible stove designs and fuels will help households in developing countries to achieve energy security and greater efficiency in their consumption.

The fuel choice model presented in Fig. 5 contributes to the literature arguing for changing the approach to alleviating energy poverty. In portraying the complexity of household decision-making the model on one hand suggests why it has been so difficult to disseminate stove technology. On the other hand it purports an approach to energy development where a variety of choices are made available — opening for households to choose. Availability and accessibility to a variety of energy conversion technologies may be part of a more appropriate strategy for enhancing people's energy supply security.

Conclusion

The model proposed here gives guidance and a better understanding of the various influencing factors that need to be considered when implementing a development program associated with energy and technology. Energy diversification is relevant for cooking fuels as well as energy for other end-uses in the household. The study shows how particular tasks alter stove and fuel preference. Access and availability as well as individual characteristics and tradition all influence decisions related to domestic energy use. Multifaceted demands in households drive the use, and even demand, for multiple fuels and stoves. As number of energy alternatives increases, so does the dependency of the intended task's nature on the final stove and fuel choice. Broadening the range of available and accessible energy carriers and conversion technologies may contribute to alleviate energy poverty.

Acknowledgments

We would like to thank the GIZ as a whole for its collaboration and assistance during the research as well as Karen Häcker for her support during the field work.

References

Akabah EM. Real incomes and the consumption of woodfuels in Ghana: an analysis of recent trends. Energy Econ 1990;12(3):227–31.
Amelink C, et al. *Global scaling up sanitation project second annual progress report — Indonesia, Tanzania and the States of Himachal Pradesh and Madhya Pradesh, India*, Washington D.C., USA; 2010.
Barnes DF, Floor WM. Rural energy in developing countries: a challenge for economic development. Annu Rev Energy Environ 1996;21:497–530.
Bonfill-Batalla G. México profunda: una civilización negada. In: Masera OR, Saatkamp BD, Kammen DM, editors. (2000) From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model, 28 (12). World Development; 1990. p. 2083–103.
Brouwer ID, Hoorweg JC, Van Liere MJ. When households run out of fuel: responses of rural households to decreasing fuelwood availability, Ntcheu District, Malawi. World Dev 1997;25(2):255–66.
Campbell BM, et al. The energy transition in action: urban domestic fuel choices in changing Zimbabwe. Energy Policy 2003;31(6):553–62.
Chambwera M. Economic analysis of urban fuelwood demand — the case of Harare in Zimbabwe. Wagening, The Netherlands: Wagening University; 2004.
Davis M. Rural household energy consumption: the effects of access to electricity — evidence from South Africa. Energy Policy 1998;26(3):207–17.
Evans MI. *Stoves programmes in the framework of improved cooking practices: a changes in focus with special reference to Latin America*, Geneva, Switzerland; 1987.
Ezzati M, Kammen DM. Evaluating the health benefits of transitions in household energy technologies in Kenya. Energy Policy 2002;30(10):815–26.
Foley G. *Photovoltaic applications in rural areas of the developing world*, Washingthon D.C., USA; 1995.
Foster V, et al. Nota Preliminar sobre la Pobreza en Guatemala con Base en la ENIGRAM 1998/99. In: Martin J, editor. 2005. The impact of the use of energy sources on the quality of life of poor communities, 72(3). Social Indicators Research; 2000. p. 373–402.
Gebreegziabher Z, et al. Urban energy transition and technology adoption: the case of Tigrai. Northern Ethiopia, Addis Ababa: Ethiopian Development Research Institute (EDRI); 2009.
GTZ. Evaluation study on the performance of cook stoves to quantify air pollution. *Health impacts, energy efficiency and sustainability in Kisii*, Nairobi, Kenya; 2007.
Häcker K, Treiber MU. *Evaluation study and recommendations on ICS dissemination and the GIZ stove programme Kenya*, Nairobi, Kenya; 2012.
HEDON. Kenya: Household Energy Demand and Use. http://www.hedon.info/KenyaCountrySynthesis, 2010. [Accessed July 9, 2012].
Heltberg R. Fuel switching: evidence from eight developing countries. Energy Econ 2004;26(5):869–87.
Hiemstra-van der Horst G, Hovorka AJ. Reassessing the "energy ladder": household energy use in Maun, Botswana. Energy Policy 2008;36(9):3333–44.
Hoffmeyer-Zlotnik JHP. New sampling designs and the quality of data. Dev Appl Stat 2003;19.
Hosier RH, Kipondya W. Urban household energy use in Tanzania: prices, substitutes and poverty. Energy Policy 1993;21(5):454–73.
IBM. SPSS software — predictive analytics software and solutions. http://www-01.ibm.com/software/analytics/spss/downloads.html, 2014. [Accessed February 5, 2014].
IEA. *Energy poverty — how to make modern energy access universal?*, Paris, France; 2010.
IEA. *Energy for all — financing access for the poor*, Paris, France; 2011.
Johnson RB, Onwuegbuzie AJ. Mixed methods research: a research paradigm whose time has come. Educ Res 2004;33(7):14–26.
Koerner L. Achieving revenue goals through demand creation. Revenue Storm White Paper 2008;3(11).
Leach G. The energy transition. Energy Policy 1992;20(2):116–23.
Martins J. The impact of the use of energy sources on the quality of life of poor communities. Soc Indic Res 2005;72:373–402.
Masera OR, Navia J. Fuel switching or multiple cooking fuels? Understanding inter-fuel substitution patterns in rural Mexican households. Biomass Bioenergy 1997;12(5):347–61.
Masera OR, Saatkamp BD, Kammen DM. From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model. World Dev 2000;28(12):2083–103.
Modi, V. et al., 2005. Energy Services for the Millennium Development Goals, United Nations Development Programme, Washington D.C., and World Bank, New York.
Murphy JT. Making the energy transition in rural east Africa: is leapfrogging an alternative? Technol Forecast Soc Chang 2001;68(2):173–93.
Pachauri S, Spreng D. *Energy use and energy access in relation to poverty*, Zürich, Switzerland; 2003.
PwC. Energy industry in Kenya — overview of the sector in Kenya. http://www.pwc.com/ke/en/industries/energy.jhtml, 2012. [Accessed July 9, 2012].
Raosoft Inc.. Sample Size Calculator. *Sample Size Calculator*. http://www.raosoft.com/samplesize.html, 2004. Accessed April 27, 2012.
Reddy AKN, Reddy BS. Substitution of energy carriers for cooking in Bangalore. Energy 1994;19(5):561–71.
Rogers EM. Diffusion of innovations. New York, USA: Free Press; 2003.
Schlag N, Zuzarte F. *Market barriers to clean cooking fuels in sub-Saharan Africa: a review of literature*, Stockholm, Sweden; 2008.

Schumacher EF. Small is beautiful. London, UK: Blond & Briggs; 1973.
Sesan T. Navigating the limitations of energy poverty: lessons from the promotion of improved cooking technologies in Kenya. Energy Policy 2012;47:202–10.
Soussan J, O'Keefe P, Munslow B. Urban fuelwood challenges and dilemmas. Energy Policy 1990;18(6):572–82.
Tinker I. *Women and energy: program implications*, Washingthon D.C., USA; 1980.
Treiber MU. Fuel and stove diversification in the light of energy transition and technology adoption theory. Ås, Norway: Norwegian University of Life Sciences; 2012.
UN. *Designing household survey samples: practical guidelines*, New York; 2005.
UNdata. Kenya country data. http://data.un.org/CountryProfile.aspx?crName=kenya, 2012. [Accessed July 9, 2012].
WHO. *Evaluating household energy and health interventions — a catalogue of methods*, Geneva, Switzerland; 2008.
World Bank. *Wood-based biomass energy development for sub-Saharan Africa – issues and approaches*, Washingthon D.C., USA; 2011.