Energy for Sustainable Development 42 (2018) 1–13

Contents lists available at ScienceDirect

Energy for Sustainable Development

Lighting and cooking fuel choices of households in Kisumu City, Kenya: A multidimensional energy poverty perspective

Tabitha Atieno Olang [a,*], Miguel Esteban [a], Alexandros Gasparatos [b]

[a] Graduate Programme on Sustainability Science–Global Leadership Initiative (GPSS-GLI), University of Tokyo, Kashiwa, Japan
[b] Integrated Research System for Sustainability Science (IR3S), University of Tokyo, Tokyo, Japan

ARTICLE INFO

Article history:
Received 30 January 2017
Revised 24 August 2017
Accepted 19 September 2017
Available online 7 November 2017

Keywords:
Multidimensional energy poverty (MEP)
Pico-solar products (PSPs)
Solar home systems (SHS)
Kenya

ABSTRACT

The present study aims to contextualize populations without access to modern energy in order to formulate effective policy considerations on modern energy adoption and continuity of usage by target groups. This objective was achieved by illustrating the linkage between fuel choice and energy poverty in low income households in an urban context. It employs a cross-sectional energy stacking model to illustrate fuel choice and the multidimensional energy poverty (MEP) index to establish the severity of energy poverty in low income households in Kisumu City, Kenya. The study also incorporates pico-solar products (PSPs) users, as this disruptive technology entered the Kenyan solar market in recent years, targeting low income households using kerosene for lighting purposes. The study identifies energy appliance type and household cooking location as key determinants of household energy choice. Moreover, the main determinants for household energy choice in households facing higher levels of energy poverty were closely associated with access concerns, whereas determinants in households facing lower levels of energy poverty were more associated with usage concerns as they already had access to modern energy. It was also noted that preferences were related to attributes of the energy source both experienced by current users and perceived by current non-users. There was a substantial persistent use of kerosene as an alternative lighting source among current PSPs users. There is a general preference and desire to use modern energy sources across most households, irrespective of the severity of energy poverty.

For meaningful improvement to be realized towards meeting the energy SDG by 2030, national and local energy policies should consider the energy technology adoption perception and behaviours of populations currently not having modern energy access. In conclusion, it is of great importance to put into context the specific characteristics of the households as well as user perspectives and how these characteristics and perspectives would affect continuity of usage of the modern energy source adopted.

Introduction

Ensuring access to affordable, reliable, sustainable and modern energy[1] for all has been identified as one of the key sustainable development goals for 2030 (SDG 7). The UN Sustainable Energy for All (SE4All) initiative defines “sustainable energy for all” to encompass three pillars, namely energy access, energy security and energy efficiency (International Energy Agency and World Bank, 2015). Energy access should be the first pillar to be addressed, as one cannot speak of ensuring the secure and efficient use of modern energy if there is not access to it in the first place. Moreover, access to modern energy services such as electricity can influence human development contributing to better healthcare (e.g. hospitals), improved literacy in schools and job creation (Eberhard et al., 2011).

Lack of access to modern energy sources, such as electricity and dependence on traditional fuels such as biomass for cooking and heating, is the main facet of energy poverty in developing countries (Sovacool et al., 2012). Energy poverty is more pronounced in Sub-Saharan Africa (SSA) than other parts of the planet, as more than two-thirds of its population has no access to modern energy (IEA, 2014). Therefore, it is imperative to address the needs and energy aspirations of this proportion of the SSA population (United Nations, 2010).

One of the objectives of the SE4All initiative, as stated in the SDG 7, is to ensure universal access to affordable, reliable and modern energy services by 2030. However, projections from the International Energy Agency (IEA) distinctly indicate that this target may not be achieved by 2030 unless more robust and aggressive interventions are put in place. In its *Africa Energy Outlook 2014*, the IEA projected that 530 million people in SSA would still have no access to electricity in 2040, and that 650 million people in the region would still be cooking with

* Corresponding author.
E-mail address: tapaulie@gmail.com (T.A. Olang).

[1] For the purpose of this paper we refer to access to modern energy as a household having reliable and affordable access to clean cooking facilities and a first electricity supply connection (Pachauri, 2011; International Energy Agency and World Bank, 2015).

https://doi.org/10.1016/j.esd.2017.09.006
0973-0826/

biomass in an inefficient and hazardous way (IEA, 2014). Furthermore, targets to achieve universal energy access must acknowledge that as development progresses, poverty reduction would lead to a substantial increase in energy demand. In this respect individuals who currently lack modern energy services will seek much more than a single light bulb (Bazilian and Pielke, 2013; Sovacool et al., 2016).

The low penetration of electricity in SSA has been attributed to various factors, including the inadequate, unreliable and costly infrastructure (Eberhard and Shkaratan, 2012) due to aging transmission lines. Vandalism can further lead to huge transmission losses averaging 25% (Eberhard et al., 2011). This has contributed to the continuous heavy reliance on traditional fuels such as biomass and firewood for meeting the household needs of 76% of SSA's population (Schlag and Zuzarte, 2008). However, overreliance on traditional energy sources has had adverse effects on the environment (Pundo and Fraser, 2006) and public health (Riojas-Rodríguez et al., 2001). Continuing the trend of relying on traditional fuels will not enable countries to achieve their sustainable development goals, as these energy sources are not able to support modern economic activities (such as heavy industries) and prevent social development by hindering the access to education and modern health services (Kaygusuz, 2012).

Eradicating poverty in all its forms and dimensions is imperative for achieving sustainable development (General Assembly, United Nations, 2015). Since energy is a central element of almost all of the SDGs, addressing energy poverty can be a potent strategy for achieving sustainable development. Towards this end it is important to increase the availability of modern energy services to groups that currently have no or limited access to them, such as poor households, rural households and households with no connections to the grid (Edenhofer et al., 2012).

Kenya is a SSA country currently facing acute energy poverty (Nussbaumer et al., 2012). In 2012, only 23% of the population had access to electricity (World Bank, 2015), while 84% of its population relies on traditional biomass for cooking purposes (REN21, 2016). According to the Kenya Power and Lighting Company (KPLC) which owns and operates most of the electricity transmission and distribution systems in the country, the national connectivity rate as at June 2016 stood at 55%. This was coupled with a power generation capacity increase of 33% from geothermal sources injected into the grid (KPLC, 2017). However, most of the population in rural areas or close to transmission lines cannot afford grid connectivity fees and are still without electricity (Abdullah and Markandya, 2012). Solar technologies have in recent years served as a modern and clean lighting alternative to kerosene-based appliances, especially to the poorer segments of society (Hansen et al., 2015).

Energy poverty is a multidimensional phenomenon irreducible to just the types of energy services or technology used (Sovacool et al., 2012). There is therefore need to expand the types of tools/metrics used to assess energy poverty, and to be more sensitive to those that suffer from it. A multidimensional energy poverty index was developed by (Nussbaumer et al., 2012, 2013) to assess energy poverty in various developing countries in SSA, Asia and Latin America, including Kenya, by estimating national energy poverty incidence and intensity. One key finding was that the degree of energy poverty can vary significantly between different developing countries, ranging from acute energy poverty (MEP index > 0.7, e.g. Niger and Bangladesh), to countries with low energy poverty (MEP index < 0.3, e.g. Colombia and Morocco). Kenya has a national MEP index of 0.73, indicating that it experiences acute energy poverty at the national level.

The MEP index was employed by (Ogwumike and Ozughalu, 2016) to establish determinants of energy poverty at the national level in Nigeria which they found to include household size, educational level, gender and age of household head, general poverty, region of residence, and proportion of working members in the household. A modification of the MEP Index was employed by (Sher et al., 2014) to establish which dimensions of energy poverty were most severe (or least deprived) by comparing four provinces in Pakistan. A study by (Edoumiekumo et al., 2013) assessed multidimensional energy poverty at the local level in Nigeria, and recommend that energy poverty reduction efforts should include inclusive education/enlightenment programs, involving all key stakeholders. The present study aims to contextualize populations without access to modern energy in order to formulate effective policies regarding modern energy adoption and continuity of usage by target groups. This objective will be achieved by illustrating the linkage between fuel choice and energy poverty in low income households in an urban context. This linkage will be illustrated through examining household energy choice and its drivers at different levels of energy poverty. The present study adopts the MEP index proposed by (Nussbaumer et al., 2012) to establish the severity of energy poverty among households. The study also investigates the extent to which the MEP index can be applied to assess very high levels of energy poverty, in a context where some households benefit from modern light options but access to modern cooking fuels is predominantly low.

The present work is structured as follows: the Methodology section outlines the methodology employed in the study. The Results section presents the key findings. The Discussion section provides a discussion of the main findings, the implications for promoting solar energy in Kenya (The contribution of PSPs to addressing energy poverty section) and the limitations of the MEP index (Application of the MEP Index in a local context section).

Methodology

Study area

Kisumu is a port city situated in the western region of Kenya on the shore of Lake Victoria as shown in Fig. 1, with a population of 409,928 according to the Kenya 2009 Census data. It is the third largest city in the country and is characterized by a large urban population, low access to modern energy services and high incidence of poverty. Despite 52% of Kisumu's population being urban, the poverty rate stands at 47.8%, with only 18% of households having access to electricity, which is lower than the national average of 23% (Commission on Revenue Allocation, 2011). Moreover, there is a heavy reliance on kerosene for lighting (Fig. 2), which exposes household members to acute respiratory diseases (Sikoliya et al., 2002). Firewood is the main cooking fuel, as 56% of households rely on open stone-hinged fireplaces for cooking (Government of Kenya, 2015). Considering the high urbanization rate, low adoption of modern energy and widespread poverty in Kenya, Kisumu is an ideal study site.

In Kisumu, current solar energy technologies used by households for lighting purposes include PSPs and residential solar home systems (SHS). PSPs include products such as solar lanterns, LED lamps and solar chargers, with their solar panels ranging from 1 to 10 watt peak (Wp), which can be used both for lighting and charging appliances such as mobile phones in non-electrified areas (Hansen et al., 2015). Fig. 2 values are derived from Kenya Census Data 2009, which depicts a considerably lower number of households using solar technologies relative to other lighting sources. However, the major players in the PSPs market commenced their operation in Kenya after 2009. For instance, the three largest providers of PSPs (Rolffs et al., 2015) at the time of the study commenced their operation in the year indicated in the parenthesis – M-KOPA (2011), Mobisol (2010) and Azuri (2012). This is further illustrated in Table 1. Companies such as MKOPA Solar have entered the industry aggressively, marketing these systems to the poor segments of society as a cheaper and better alternative to kerosene. Such a disruptive technology has led to drastic changes in the solar industry in Kenya (REN21, 2016), and many low income households have taken up this technology, which can be easily acquired as an over-the-counter product. However, the use of PSPs does not imply that the households adopting them should be considered as electrified, as these technologies only play a niche role for specific purposes such as lighting and charging small appliances (Lysen, 2013).

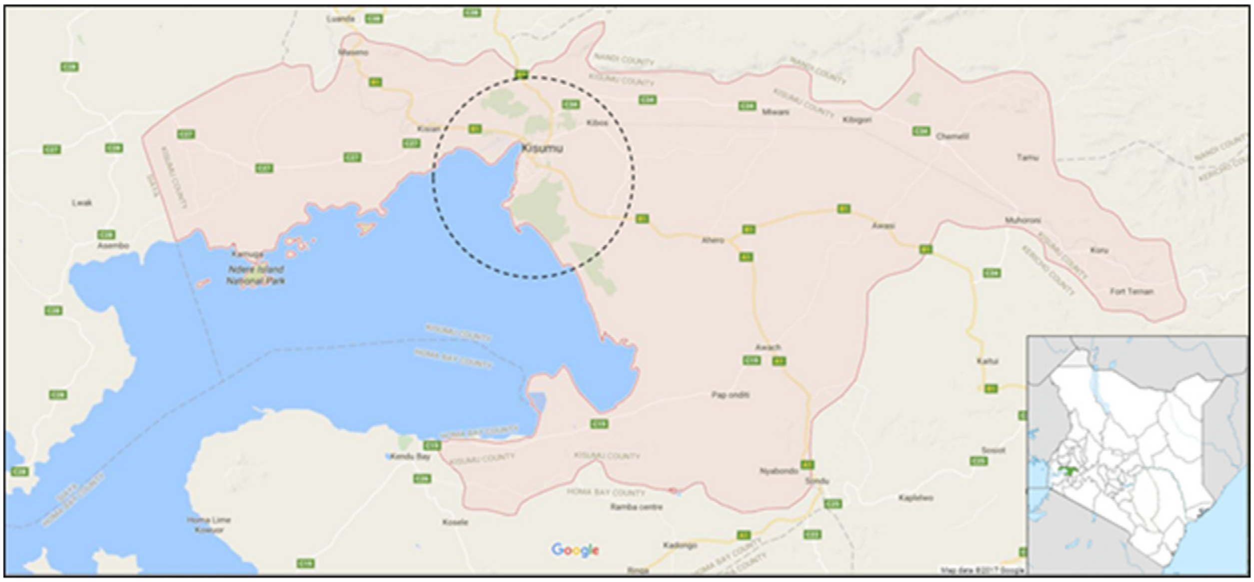

Fig. 1. Map of Kisumu County.
(Source: Google maps.)

On the other hand, residential SHS usually have an installed capacity ranging between 10 and 100 Wp, which is used to satisfy off-grid electricity demand for private homes in dispersed settlements far from existing transmission lines (Hansen et al., 2015). For the purposes of this research, SHS were excluded from the study. In the study area we encountered only 3 households with SHS, which were not included in the analysis. One possible reason for encountering only a few residential SHS is due to the snowballing sampling technique that was used in obtaining PSP users, who more often than not knew other PSP users. It is in this context of high adoption of PSPs that the study sets out to clarify the reasons behind household energy choices.

Data collection and analysis

The present study collected data from 204 households in Kisumu City through a purposive sampling technique, with the aim to capture information about the characteristics of different energy sources users in households, including current PSPs users. Current PSPs users were identified via direct observation of the small solar panels placed on rooftops, as well as through snowball sampling. The study applied the snowballing sampling technique as it was not seeking to generalize the findings of the research to the whole population, but intended to representatively capture PSPs users so as to visibly illustrate adoption and usage determinants of the technology in comparison to other lighting choices used in the study area. The study also applied the use of personal observation to reduce the level of bias that could possibly arise from the snowball sampling technique via chain referral. As a comparison we selected neighbouring households not using PSPs. In total, about 23% of the sampled households used PSPs as their main source of lighting, while 22% used it as an alternative. Households using other lighting options located in the vicinity of households with PSPs served as control groups.

The self-administered household survey included five main sections namely; household demographics, lighting choices, cooking choices, socio-economic status and issues related with the solar PV technologies used. The household demographics sections contained questions on the respondent details, place and years of residence in Kisumu city, household member details and physical characteristics of the building (ownership, number of rooms in the main house, connection to grid, building materials and information on the cooking areas). The lighting and cooking choice sections captured households' main, alternative and preferred energy sources, as well as the reasons for choosing each of them. The study asked respondents to indicate the household appliances used for lighting and cooking instead of asking for the energy source itself.

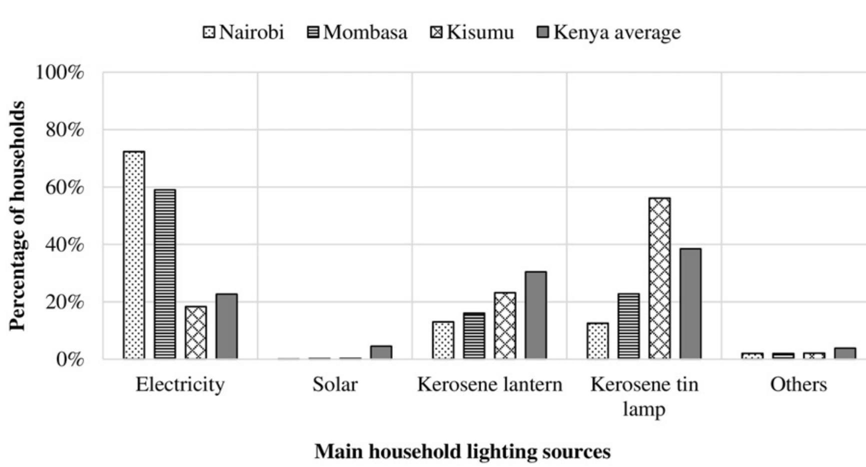

Fig. 2. Household lighting sources within major Kenyan cities (Kenya Open Data, 2015).

Table 1
Key PSP market players in Kenya.
Sources: M-KOPA Solar company website http://www.m-kopa.com, Mobisol company website http://www.plugintheworld.com, Azuri Technologies company website http://www.azuri-technologies.com.

Company	Year of entry	Payment method	Payment structure	Customer base	PSP capacity	Sales approach	Countries of operation
M-KOPA	2011	MPESA (Kenya's mobile money system)	Deposit fee and flexible repayment plan over maximum of 365 days	500,000 customers as at May 2017	8 Watt solar panels	1500 aggressive sales force	Kenya, Tanzania, Uganda
Mobisol	2010	MPESA	Deposit fee and flexible repayment plan over 36 months	90,000 customers as at May 2017	30–200 Watt solar panels	Sales via local marketing agents and community presentations	Kenya, Tanzania, Rwanda
Azuri	2012	Purchase of top-ups in the form of scratch cards	Installation fee and flexible repayment plan over 18 months	100,000 customers as at March 2017	10 Watt solar panels	Azuri local dealers for installation, selling scratch cards and maintenance	Kenya, Tanzania, Uganda, Ghana, Ethiopia,

For instance, although two households might be using kerosene as a lighting source, one household may be using a tin lamp appliance while another could be using a kerosene lantern appliance (which would result in different usage experiences). The section of socio-economic status included queries on the nature of household income, household appliance ownership and respiratory health-related issues. The last section was specific to PSPs and asked about the ownership and usage of the technology, as well as reasons behind its acquisition.

For the energy poverty analysis we used the MEP index (Nussbaumer et al., 2012), which is based on the multidimensional poverty measure developed by the Oxford Poverty and Human Development Initiatives (OPHI) (Alkire and Foster, 2007, 2009; Alkire and Santos, 2010). The MEP index establishes the level of energy poverty that a household experiences in five dimensions that represent basic energy services, using six indicators (Nussbaumer et al., 2013), (Table 2). The household energy poverty score for each household was computed by identifying the indicators in which they are energy poor (a score depending on indicator weight, see Table 2) and the indicators in which they are not deprived (score = 0), and then summing the weights w_i for all indicators. Energy poverty is designated as acute when the MEP index value exceeds 0.7, moderate when it ranges between 0.3 and 0.7, and low when it is below 0.3 (Nussbaumer et al., 2013). The study then went ahead to divide the households into three energy poverty sub samples, those facing acute MEP, those facing moderate MEP and low MEP sub samples, so as to obtain insights on household fuel choices at different levels of MEP. This is further illustrated in the scenarios shown in Table 3.

The MEP index is a flexible methodology that can be used in different geographical contexts and spatial levels to understand the incidence of energy poverty and delineate its determinants. One key merit of the MEP index is that it focuses on the energy services that people ultimately want and need by evaluating energy deprivations directly, as opposed to other metrics which indirectly derive information through variables (such as energy consumption) that are presumably correlated (Nussbaumer et al., 2012). Moreover, the methodology allows for decomposability, as the data used as input are at micro level. The present study's makes a threefold academic contribution to the MEP framework. First, it uses energy poverty levels to group households and analyse them as sub-groups. Secondly, energy stacking[2] was observed during data collection, and hence both main and alternative energy sources were considered when obtaining W_1. For instance, in Scenario 2 (Table 3), even though the household uses kerosene as a main cooking fuel source (which is considered to be a modern cooking fuel), the household scores $W_1 = 0.2$ because they also use charcoal, which is not a modern cooking fuel. This consideration was only done for the modern cooking fuel indicator in the MEP index as its variable was type of cooking fuel which can vary. However, for the electricity access indicator, the alternative lighting source was not put into weight consideration as its variable description is only unilateral, "access to electricity". The third contribution was incorporating the determinants for using each energy source for lighting and cooking in the energy poverty analysis. Generally, the study made these strides in an attempt to bridge the gap in understanding of the factors influencing energy choice and energy poverty.

Results

Household characteristics at different levels of MEP

The study carried out further analysis to establish if the three sub-groups of households (acute, moderate and low MEP groups) had distinct characteristics warranting them to belong to separate MEP groups. Three significant household characteristics stood out across the three levels of MEP, namely housing materials, nature of income and level of education in the household (see Figs. 3–5).

The findings illustrated in Fig. 3 suggest that while the type of housing materials were similar between households considered acutely or moderately energy poor, there was a marked difference with households not considered energy poor. One plausible explanation could be that all households in the low MEP group used electricity as a main lighting source (Energy poverty and household lighting choices section, Fig. 6) and 82% of them resided in permanent[3] housing (Fig. 3), which drives most indicators in the MEP index methodology (e.g. grid electricity access, fridge ownership). This trend could be possibly due to the fact that it is more common for utility companies to connect permanent houses to the grid than temporary and semi-permanent houses, as the meters and electric wiring would be better secured. Moreover, households residing in permanent houses (with presumably higher living standards) are more likely to be able to afford grid connection fees, which are still prohibitively high in SSA (Golumbeanu and Barnes, 2013).

The nature of employment is a key determinant of household energy choices due to the different cash flow dynamics associated with each type of employment. Self-employment, which is characterized by uncertain and unstable non-periodic income flows, is more predominant in households considered acutely or moderately energy poor, as shown in Fig. 4. Unemployment, implying that a household has no assured source of income at any given point in time was not reported by any member of the low MEP group. An interesting finding is that the predominant types of employment shifts with declining levels of MEP, from self-employment to formal employment (Fig. 4), characterized by a stable periodic cash inflow in the form of monthly salaries. This is the main source of income of 76% of the low MEP group, which implies

[2] Multiple fuel use in the energy transition process of households (Van Der Kroon et al., 2013).

[3] Houses were classified as temporary if they had an earth floor, regardless of the materials of the walls and the roof. Semi-permanent houses had cement flooring, walls made of earth or corrugated iron sheets and roofing made of corrugated iron sheets. Houses were classified as permanent if they had cement or tile floors, brick or stone walls, and roofs made of either corrugated iron sheets or tiles.

Table 2
Dimensions, indicators, weights and deprivation cut-offs for the MEP index.
Source: Adapted from (Nussbaumer et al., 2012, 2013).

Dimension	Indicator	Weight	Variables	Deprivation cut-off (energy poor if)
Cooking	Modern cooking fuel	0.2	Type of cooking fuel	Any fuel besides electricity, LPG, kerosene, natural gas or biogas
	Indoor pollution	0.2	Food cooked on stove or open fire (no chimney), indoor, if using any fuel beside electricity, LPG, natural gas or biogas	True
Lighting	Electricity access	0.2	Access to electricity	False
Services provided by means of household appliances	Household appliance ownership	0.13	Fridge ownership	False
Entertainment/education	Entertainment or education appliance ownership	0.13	Radio OR television ownership	False
Communication	Telecommunication means	0.13	Phone land line OR mobile phone ownership	False

a relatively more homogenous make-up of the low MEP group compared to the other groups. This stable cash flow clearly enables households whose main source of income is formal employment to use grid electricity, as they are able to pay for monthly electricity bills as and when they fall due. In the case of the moderate MEP group, >75% of households had electricity, and 50% were self-employed, though only 25% were formally employed. In recent years the Kenya Power and Lighting Company (KPLC), the main state-owned electricity distributor in Kenya, has rolled out prepaid electric meters where consumers can purchase electricity tokens via various means.[4] Prepaid meters allow for electrified households who are either informally, occasionally or self-employed to purchase electricity tokens as and when they obtain cash to pay for it.

Fig. 5 suggests that while the patterns of higher education attainment were similar between households considered acutely or moderately energy poor, there was a marked difference with households not considered poor. These findings imply homogeneity in acute and moderate MEP groups in comparison to households not considered energy poor. We therefore went ahead to verify if this trend persisted when looking at household energy determinants at each sub-sample. If this homogeneity persisted even in the determinants of lighting and cooking sources, we would have deduced that the MEP ranges used by (Nussbaumer et al., 2012, 2013) did not apply in this context, and hence there would have been a need to readjust the ranges for this particular context. On the other hand, if the homogeneity between these two groups did not persist in the next level of analysis we would deem them to be two distinct sub groups.

Energy poverty and household lighting choices

Decomposing the MEP index allowed for an in-depth analysis of lighting energy choices at different levels of MEP. The present study attempted to establish the reasons behind household using the various lighting energy sources, how they utilized alternative sources of lighting (if they used any) and what would be the drivers for preferring a specific lighting option to use in the household. As shown in Fig. 6, the main lighting options for households that face acute MEP are kerosene (51%) and PSPs (48%), with only 1% having access to grid electricity. In households with moderate MEP there is extensive use of grid electricity (77%), with other minor lighting sources including kerosene (13%) and PSPs (10%). All households with low levels of MEP use grid electricity as their main lighting source. Affordability is the most important reason influencing the choice of an energy source for lighting for households, with higher levels of MEP using kerosene and PSPs (Fig. 6). On the other hand "convenience in usage" and availability are the most important drivers in households in the moderate and low MEP groups. Among households considered to have acute energy poverty, kerosene is the most used modern energy option, followed by PSPs. During the household survey, the respondents were asked to select only one determinant for the energy source they mainly used and were given the opportunity to elaborate why they selected that choice.

The study also set out to establish how households were making use of alternative lighting sources, if they employed any. Respondents were asked to indicate only one alternative lighting source (the one that they most frequently used). It was observed that alternative lighting sources were mostly used as substitutes rather than complements to the main lighting source. Households with no alternative lighting sources were mostly those that were using kerosene or PSPs as a main lighting source, as shown in Fig. 7. In the acute MEP group 45% of households had no alternative lighting source and for those who had an alternative lighting source, kerosene was the most predominant alternative among households. Households using kerosene both as a main lighting source and an alternative lighting source indicated that this was either because they were using alternative lighting appliances for different rooms (e.g. using one kerosene lantern in the main house while at the same time using another kerosene lantern in the outdoor kitchen) or that they were using different types of kerosene appliances (kerosene lamp with a glass chimney, tin lamp with no chimney but with a wick dipped in a tin with kerosene) either as substitutes or as complements. Fig. 7 shows that households using kerosene both as a main lighting source and as an alternative use the alternatives mostly as complements. In the moderate MEP group two things were notable; a smaller number of households indicated no alternative lighting sources (compared to the acute MEP group), and those using electricity as a main lighting source mostly used kerosene as an alternative followed by candles then PSPs. In the low MEP group, all households used electricity as a main lighting source and they all had an alternative lighting source, which was mainly used as a substitute when the main lighting source was not available.

To establish the preferred lighting sources for use in households, respondents were asked to state the energy source they would like to use for lighting purposes in their households, if all other factors are constant. After making their selection, they were asked to give a reason for their selection. As illustrated in Fig. 8, some respondents stated lighting sources similar to their main lighting source, while other selected lighting sources different from their main lighting sources. Among respondents who stated a preference for a source similar to their main lighting choice, some stated that they were content with their current lighting sources - implying that the determinant of preference was similar to that of main lighting source - while others gave reasons to emphasize their preference, which was obviously referring the source they were currently making use of. Looking at the varying preferences enabled the study to discern which determinants were related to households already using a certain lighting source, and which determinants were related to households that would like to use a lighting source different from what they were currently using.

[4] (Including mobile money, banks and retail outlets such as supermarkets, from prices as low as USD 0.98, or100 Kenya shillings). The various means available to pay electricity bills can be found in http://kplc.co.ke/content/item/30/Paying-your-Electricity-Bill.

Table 3
Illustration of MEP calculations.

Respondent	Scenario$_1$	Scenario$_2$	Scenario$_3$
Modern cooking fuel	Firewood_main Charcoal_alternative $W_1 = 0.2$	Kerosene_main Charcoal_alternative $W_1 = 0.2$	LPG_main Electricity_alternative $W_1 = 0$
Indoor air pollution	Open space/outdoors $W_2 = 0.2$	Main house – no chimney $W_2 = 0.2$	Kitchen – chimney $W_2 = 0$
Has electricity access	False $W_3 = 0.2$	True $W_3 = 0$	True $W_3 = 0$
Owns a Fridge	False $W_4 = 0.13$	False $W_4 = 0.13$	False $W_4 = 0.13$
Owns a Radio/TV	False $W_5 = 0.13$	True $W_5 = 0$	True $W_5 = 0$
Owns a mobile phone	True $W_6 = 0$	True $W_6 = 0$	True $W_6 = 0$
$(W_1 + \ldots + W_6)$	0.86	0.53	0.13
Level of MEP	Acute: $(W_1 + \ldots + W_6 > 0.7$	Moderate: $0.3 \le (W_1 + \ldots + W_6) \le 0.7$	Low: $(W_1 + \ldots + W_6) < 0.3$

As illustrated in Fig. 8 three things were observed in the acute MEP group, and those who stated a preference similar to their main lighting source were mostly content with their current energy choice. Those who used kerosene as a main lighting source preferred other lighting sources (PSP, Electricity) due to safety reasons, and those who were currently using PSP as a main lighting source preferred grid electricity, as it could run many household appliances at once. Two things stood out in the moderate MEP group; safety was a key determinant for all households that preferred electricity, and those who preferred PSPs (but were currently using grid electricity as the main lighting source) indicated that PSPs were cheaper once the devices were purchased. In the low MEP group those who used grid electricity as their main lighting source indicated safety considerations, being content with their current lighting option and that electricity could run many appliances at once, as their key determinants. However, those who preferred PSPs but were currently using electricity as a main lighting source indicated that this was mostly because PSPs were cheaper once purchased, which is similar to what was indicated by those in the moderate MEP group.

The study also had a particular interest in the adoption and use of PSPs in households. The study went ahead to ask respondents if they had changed their main lighting source over the last 5 years, as shown in Fig. 9, with 60% indicating that they had not done so. Among households in the moderate and low MEP groups there were incidences of leapfrogging from kerosene to adopting grid electricity, without having to use PSPs in the transition process. However, in the acute MEP group (and to a lesser extent in the moderate MEP group), a substantial number of households who previously used kerosene currently use PSP.

Energy poverty and household cooking fuel choice

The present study also set out to establish the reasons behind households using the various cooking fuels, how they utilized alternative cooking fuels (if they had any) and what would be the driver for preferring a specific cooking fuel to use in the household. In terms of the main cooking fuels (Fig. 10) two things were notable in the acute MEP group; >60% of households in this group used firewood as a main cooking fuel due to its widespread availability, and charcoal was the second most used cooking fuel, with determinants of its usage being mainly affordability and availability. In the moderate MEP group, charcoal was the most used cooking fuel, with its determinants being similar to those of charcoal users in the acute MEP group. LPG is the most used cooking fuel in the low MEP group, mainly due to affordability and convenience. It is interesting to note the variation in determinants among households facing low MEP (safety, convenience, affordability) compared to those facing higher levels of energy poverty (availability, affordability). Households facing acute and moderate MEP rely heavily on biomass in the form of firewood and charcoal. The extensive use of biomass for cooking is associated with high work burdens for women and girls to fetch firewood (Oparaocha and Dutta, 2011), indoor air pollution that can lead to significant health problems (Ezzati et al., 2000; Fullerton

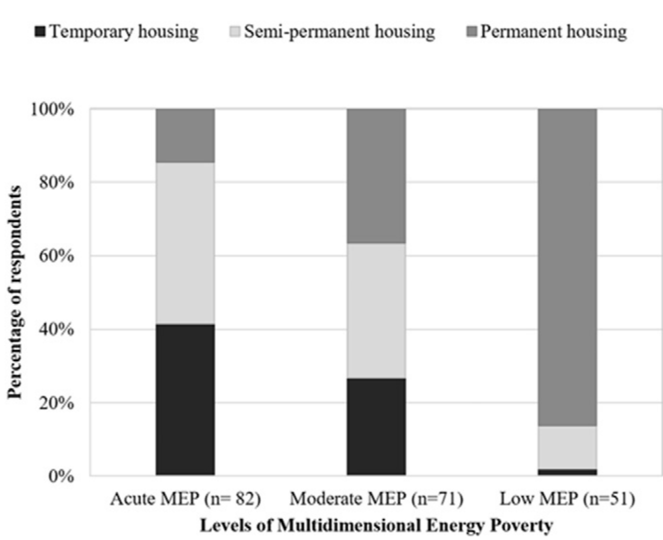

Fig. 3. Type of housing material across different MEP levels.

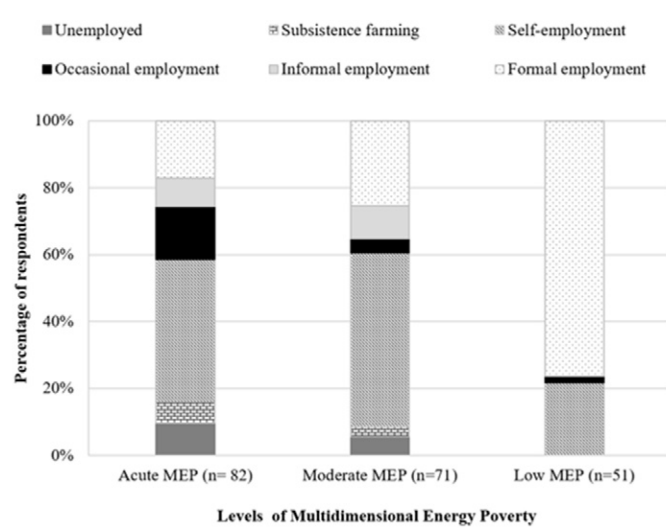

Fig. 4. Household income sources across different MEP levels.

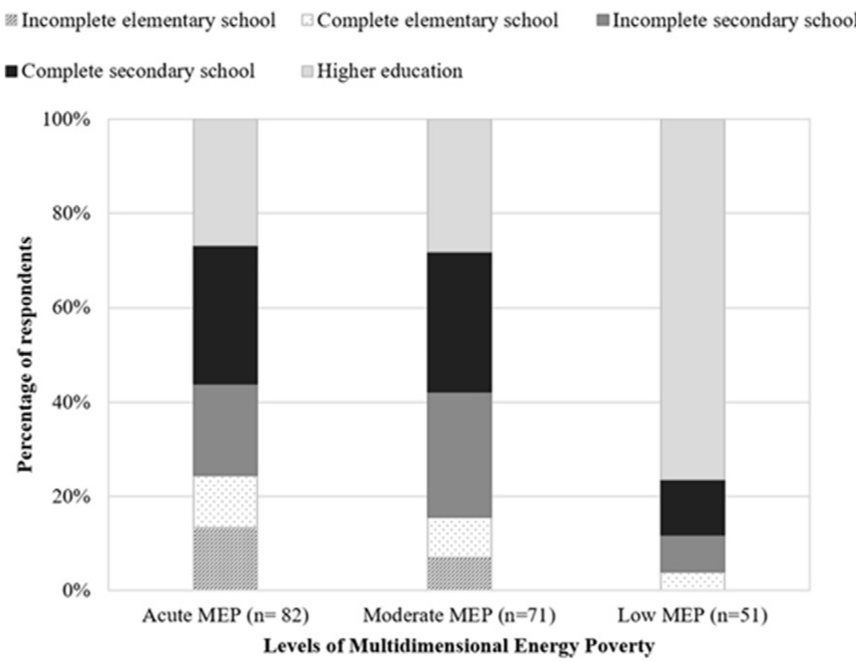

Fig. 5. Highest education attainment across different MEP levels.

et al., 2008), and environmental degradation (Pundo and Fraser, 2006). In contrast, only 14% of households with low MEP use biomass for cooking. Most households in this group (57%) use liquefied petroleum gas (LPG), which is available to customers in 6 kg, 13 kg and 35 kg cylinders at various service stations, as well as from authorized dealers.

The study also set out to establish how households were making use of alternative cooking fuels, if they used any. Respondents were asked to indicate only one alternative cooking fuel (the one that they most frequently used). There were at least 20% of households in each MEP group who did not use an alternative cooking fuel – an observation that contrasts to the findings in the Energy poverty and household lighting choices section, where all households in the low MEP group had an alternative lighting source. As shown in Fig. 11, households with no alternative cooking fuels in the acute MEP group mostly used firewood or charcoal as a main cooking fuel. Moreover, this MEP group mainly comprised of households using firewood as a main cooking fuel and charcoal as an alternative cooking fuel (>40%), with charcoal being used as a substitute or complement to firewood and

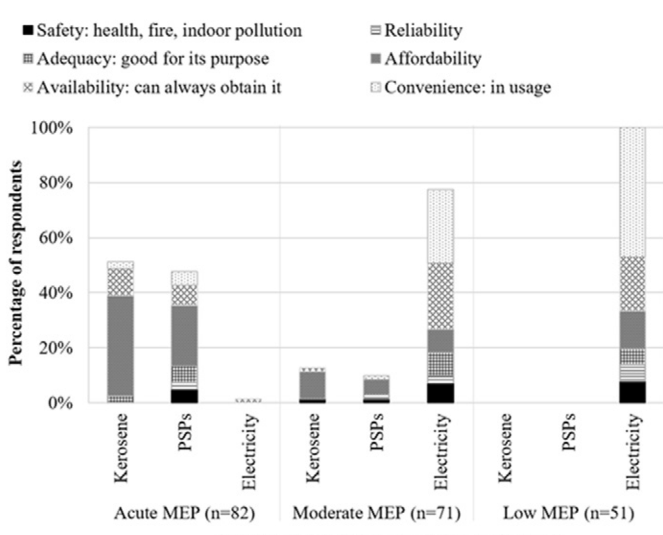

Fig. 6. Determinants of main household lighting options.

also to cook specific delicacies. Households using firewood both as a main cooking source and an alternative lighting source indicated that this was because they were using two different types of firewood cooking appliances (that is, using a traditional three stone open fire for cooking, as well as an improved traditional open fire which is insulated either by mud or cow dung) as complements, as shown in Fig. 11.

Households with no alternatives in the moderate MEP group mostly used firewood or charcoal as a main cooking fuel. Among those who did have an alternative cooking fuel there were two main combinations, that is, *Firewood_main/Charcoal_alternative* and *Charcoal_main/Kerosene alternative*. Households that used charcoal as an alternative for firewood in the moderate MEP group mostly used it as a complement or substitute, which is similar to the observation in the acute MEP group. It was however interesting to note that some households using kerosene as an alternative to charcoal stated that kerosene was cheaper than charcoal (see Fig. 11). In the low MEP group, most households with alternative cooking fuels used charcoal as an alternative for LPG, the with determinant being similar to those using charcoal as an alternative for firewood in the acute MEP group.

Overall, electricity and LPG were the most preferred cooking fuels, with electricity being mostly preferred by households facing lower levels of MEP and LPG being mostly preferred by households facing acute MEP, as shown in Fig. 12. Preference for LPG is mostly associated with it being a faster cooking option, while preference for electricity is mostly due to it being perceived as a safer and cleaner cooking fuel option. In the low MEP group, >50% of these households that used LPG as a main cooking fuel would prefer to use electricity, mainly due to hygiene in the cooking environment. The respondents associated the concept of hygiene to the presence or lack thereof of soot/fumes/smoke, as well as the general cleanliness and orderliness of the cooking area. This would imply a discontent with the smell of the fumes produced by the LPG appliance while cooking.

Discussion

Household energy choice in the context of energy poverty

The present study investigated the determinants of household energy usage and preferences, with a particular interest in PSPs, which entered the Kenyan solar market as a disruptive technology targeting

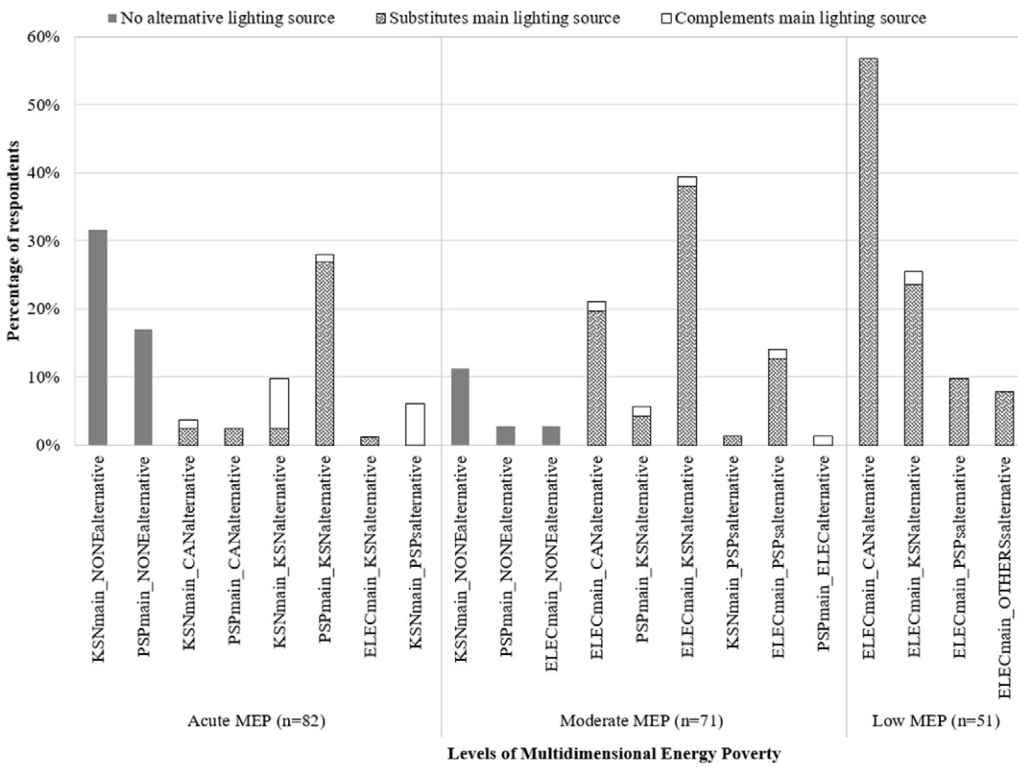

Fig. 7. Uses of alternative lighting sources with reference to current main lighting source (key: KSN – Kerosene, PSP – Pico-Solar Photovoltaic, CAN – Candles, ELEC – Electricity, NONE – No alternative).

low income households. The study applies the MEP index to a local urban context in Kenya that is characterized by high levels of poverty to better understand the various considerations made by households at different levels of energy poverty when making a choice on which energy source to use in their household for lighting and cooking purposes. The results reveal some very interesting insights on the lighting and cooking decision making considerations, adding new evidence on the relationship between fuel choice and energy poverty.

The acute and moderate MEP groups show a certain amount of homogeneity when taking into consideration specific household characteristics, such as the type of housing material, nature of household income and education level attainment (Figs. 3–5). This homogeneity

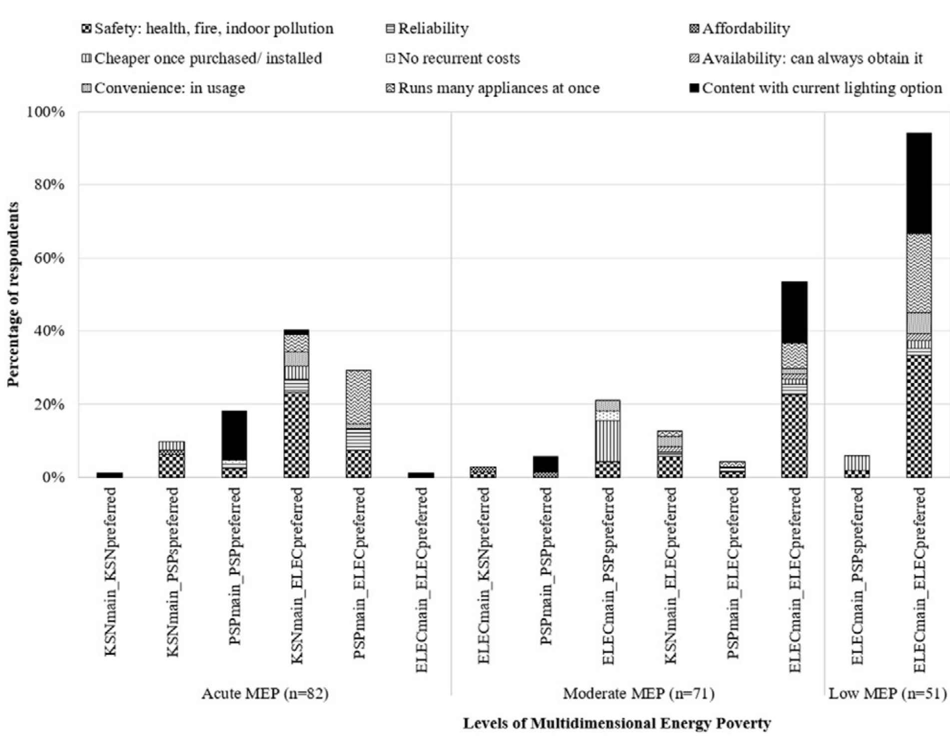

Fig. 8. Determinants of preferred lighting options with reference to current main lighting source (key: KSN – Kerosene, PSP – Pico-Solar Photovoltaic, ELEC – Electricity).

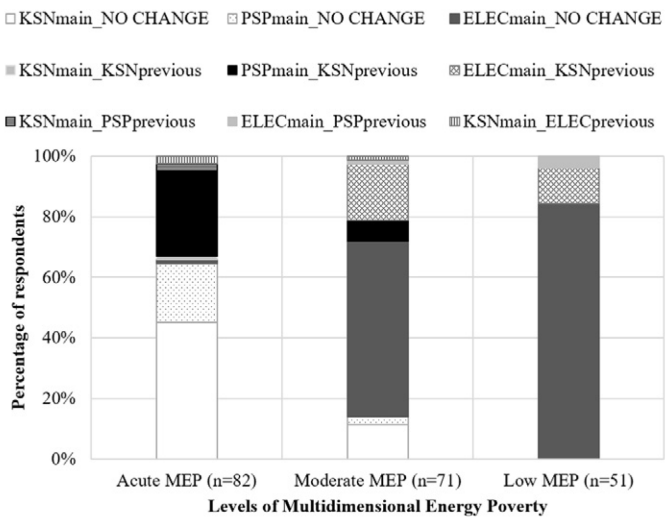

Fig. 9. Previous main lighting sources used over the last 5 years with reference to current main lighting source (key: KSN – Kerosene, PSP – Pico-Solar Photovoltaic, CAN – Candles, ELEC – Electricity).

is also visible when looking at households' main cooking fuel choice, but not their main lighting sources. This implies that the moderate MEP is a transitional phase between acute and low MEP levels, as it shares characteristics from both groups. Although the study does not take into consideration the amount of household income, there is an evidence of a cross-sectional energy ladder in which households facing higher levels of energy poverty use more traditional fuels for lighting and cooking as compared to those facing lower levels of energy poverty (Figs. 6 and 9). However, the study also observed multiple types of fuel use for lighting purposes, especially in households facing lower levels of energy poverty, where all respondents that indicated grid electricity as a main lighting source had an alternative lighting source.

It is interesting to note that at least 20% of households in each MEP group did not have an alternative cooking fuel, contrasting with how all households in the low MEP group have an alternative lighting choice, as shown in Fig. 7 (though this is not true for those with acute and moderate MEP). This finding implies that lacking alternative lighting sources may not necessarily have the same implication as lacking alternatives cooking fuels. The present study looked at lighting and cooking choice

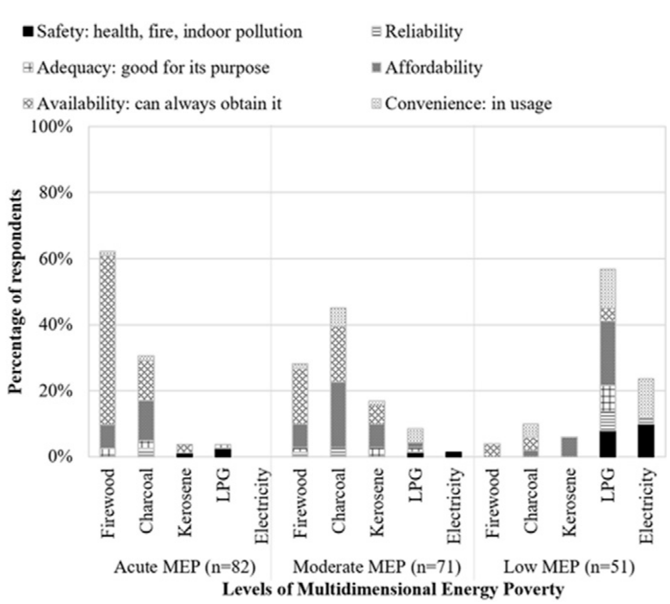

Fig. 10. Determinants of households' main cooking fuels.

behaviours independently, and hence it is not able to clearly elaborate the relationship between these two energy sources within the same household. This is a gap in our research hence further research could attempt to explain this relationship by using ranking questions to establish the level of priority for each energy use in the household. In some cases, households used the same fuel both as a main and an alternative fuel. For instance, for lighting purposes some households either used kerosene in different types of appliances or had a multiple number of the same appliance to provide light to household members in different locations at the same time. This phenomenon was only associated with kerosene, as most PSPs provide more than one bulb that can be used in different locations, in a similar way to grid electricity. A similar case was observed in the case of cooking fuels, where some households used firewood both as a main and alternative cooking fuel, using different appliances as well as charcoal. This finding highlights the role of energy appliance type as a driver for energy choice. Moreover, it is interesting that respondents perceived using an energy source in different appliances as two different choices in the case of traditional energy sources, but no respondent perceived the same for modern energy sources – for instance grid electricity for lighting sources having several bulbs to provide light in various locations at the same time. It is important to note that compared to electricity (where an electricity blackout would lead to all the bulbs not providing light in the different locations in the household), the use of kerosene in different house locations can be prioritized by the amount of kerosene put into a particular kerosene appliance at a given point in time.

The second set of key findings regards the determinants of fuel choice across the different MEP groups. In households facing higher levels of energy poverty, the main determinants for household energy choice - such as affordability and availability – are closely associated with access concerns, whereas determinants for lower levels of energy poverty are more associated with usage concerns such as convenience, safety and reliability (as users already have an assured access, for example in the form of a grid connection). Otherwise, preferences are related to the perceived attributes of a given energy source. For instance, in the choice of lighting (Fig. 12) some households using kerosene preferred grid electricity due to safety concerns, some currently using PSPs preferred grid electricity as it runs many appliances at once, and some using grid electricity preferred PSPs because they were cheaper once purchased, compared to grid electricity. However, this does not seem to imply that they would give up grid electricity to use PSPs, but rather a sentiment that the periodic electricity expense was more costly than PSPs (once they had been purchased). In terms of cooking fuels, households in the acute MEP group mainly use firewood as their cooking fuel, those in moderate MEP group mostly use charcoal (and firewood to a lesser extent), and LPG is the most used cooking fuel in the low MEP group. A further look into the data shows that 82% of households in the low MEP cook in the main house, compared to only 49% the acute MEP group with the rest cooking in the open air or in a structure separate from the main house. This finding implies that the designated cooking area also determines energy choice. Moreover, it was interesting to observe that while the low MEP used grid electricity for lighting, most of them used LPG for cooking (though almost all of them would prefer to use electricity for cooking due to the perceived hygiene in the cooking environment). Hygiene was associated with the presence or lack thereof of soot/fumes/smoke, as well as the general cleanliness and orderliness of the cooking area. This would imply a discontent with the smell of the fumes produced by the LPG appliance while cooking.

The contribution of PSPs to addressing energy poverty

As discussed in the Study area section only 3 houses in the sample had adopted SHS. The snowballing sampling technique which was used by the study to obtain PSPs users could have contributed to the few numbers of SHSs encountered. Another possible reason could be

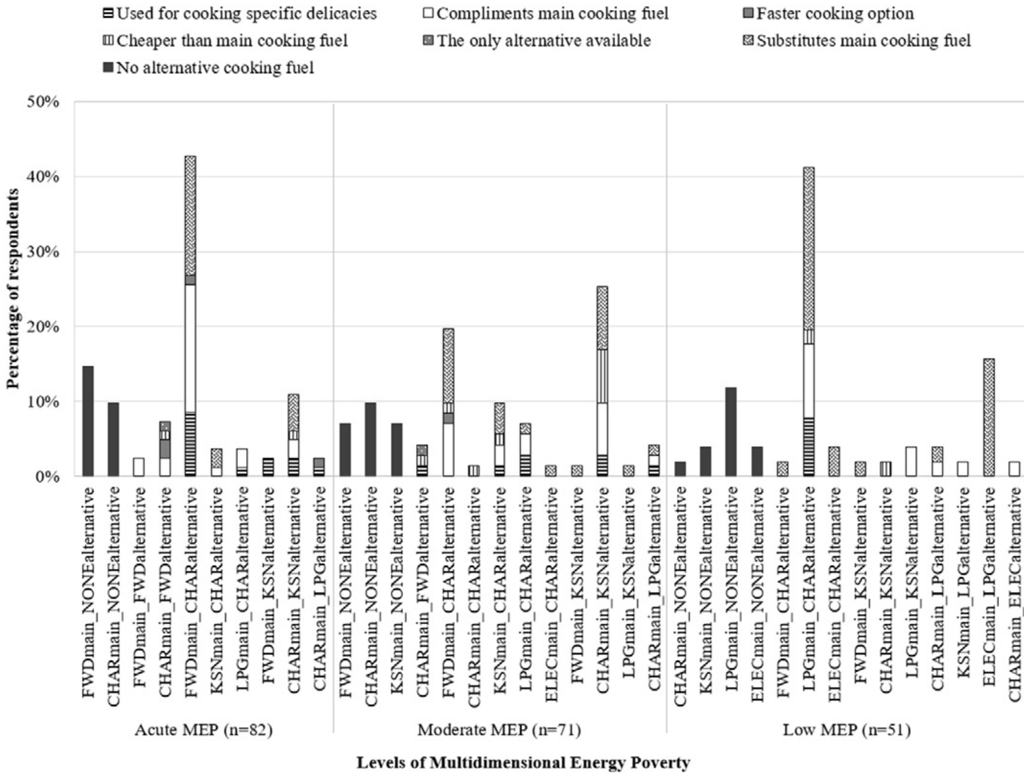

Fig. 11. Uses of alternative cooking fuels with reference to current main cooking fuel (key: FWD – Firewood, CHAR – Charcoal, KSN – Kerosene, LPG – Liquefied Petroleum Gas, ELEC – Electricity, NONE – No alternative).

that although a free market on SHS technologies has existed in Kenya since the 1970s (Ondraczek, 2013), it has been riddled with drawbacks such as poor product quality and installation (Jacobson and Kammen, 2007). Furthermore, there is a lack of local capacity, as the majority of solar PV technicians only have basic skills, with little or no formal training (Simiyu et al., 2014). Such drawbacks prompted the Energy Act of

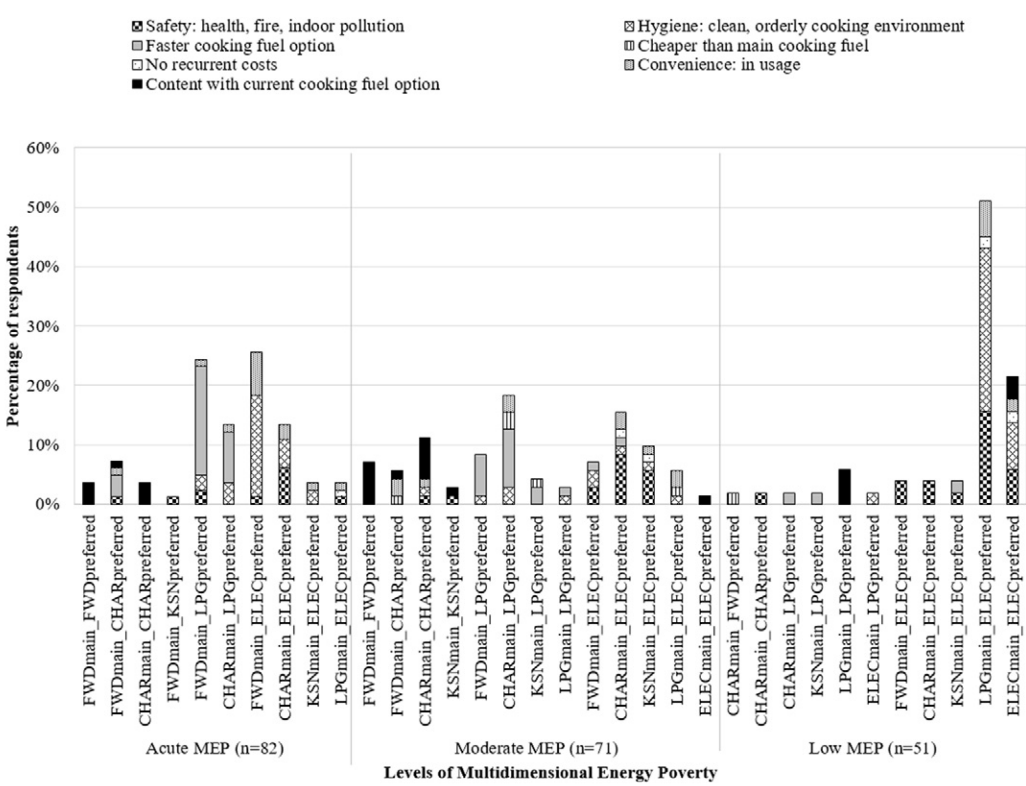

Fig. 12. Determinants of preferred cooking fuels with reference to current main cooking fuel (key: FWD – Firewood, CHAR – Charcoal, KSN – Kerosene, LPG – Liquefied Petroleum Gas, ELEC – Electricity).

2006 to be amended in 2012 so as to provide a legislative framework specific to solar PV systems and market players.

On the other hand, the PSPs, which entered the Kenyan market in the late 2000s, followed an entirely different trajectory. In 2010, the *Lighting Africa* (a joint World Bank and IFC program) produced an extensive report on all approved PSPs available in the market. Companies involved in PSPs were mostly based in the capital city, Nairobi, and had weak distribution channels leading to the products barely being sold beyond major urban areas. The *Energising Development Kenya Country Programme (*ENDEV), in collaboration with the Ministry of Energy and Petroleum, stepped in to facilitate the distribution of Lighting Africa-approved products available in the Kenyan market. Some of the mechanisms that were employed to promote the distribution of the technology included raising customer awareness, developing the capacity of PSPs companies, creating business linkages between value chain actors and facilitating access to finance for both the companies and consumers (Bensch et al., 2016). As at June 2014, the ENDEV project reported that over 400 solar entrepreneurs had benefitted from training and were able to sell nearly 57,000 PSPs, reaching over 100,000 people.[5] PSPs products were targeted at low income earners using kerosene and were therefore priced in a similar manner as a household periodically buying kerosene for lighting purposes. For instance, purchasing an 8 W PSP from MKOPA Solar requires a USD 34.28[6] (3500 Kenya shillings) deposit and flexible repayments of USD 0.49 (50 Kenya shillings) per day over a maximum of 12 months.[7] Expandable PSPs allow for households to start by buying a small kit, adding an extra kit later on, which can allow for extra lights and appliances (e.g. a small TV) to be used (Lysen, 2013).

In the present study, affordability was the key determinant for using PSPs as a main lighting source. Most households using PSPs as the main lighting source employed kerosene as a substitute the main lighting source when not available. A further look in the data showed that a substantial number of current PSPs users previously used kerosene as a main lighting source, and there is evidence to show that they continue to use it as a substitute.

To a lesser extent, some PSPs users did not have alternative lighting sources. Current PSPs users who still preferred using PSPs were content with their current lighting choice, but those who preferred grid electricity stated as a reason the wish to run many appliances at once. On the other hand, current kerosene users preferred PSPs due to safety considerations. A few electricity users preferred PSPs, as PSPs are cheaper once installed. However, this does not necessarily mean that they would give up electricity use and shift to PSPs. This finding shows the role of technology attributes and how they can influence adoption and persistence of usage or the preference of users.

Application of the MEP index in a local context

One key positive attribute of the MEP index methodology is its decomposability. This can enable the analysis of energy poverty in households across different levels. This is because the input data used – at the household level– allows for a detailed analysis focusing on the acute, moderate and low MEP sub-groups. Moreover, MEP index methodology directly focused on energy services instead of deriving information indirectly through variables that are presumed to be correlated (Nussbaumer et al., 2012). This can allow for a robust empirical analysis of energy poverty at the local level using easily collectable primary data, rather than relying on simulations based on secondary data.

One key reason the study employed the MEP index resided in its consistency with IEA and the Energy SDG in the definition of what comprises modern energy. In the MEP index methodology, electricity-related indicators drive most of the results as they can account for about 50% of the overall weight (Table 2). For instance, 82% of those in a permanent type of housing also had a connection to grid electricity, leading to most of these households ending in the low MEP group. Moreover, all households in the low MEP group relied on grid electricity as their main lighting source. Households using PSPs were generally considered energy poorer, as it was challenging for them to own appliances such as fridges or TVs, which consume significant amounts of electricity. Owning such appliances accounts for as much as a quarter of the weight in the MEP (Table 2). This finding is in line with the study's standpoint that the use of PSPs does not imply that the households adopting them should be considered as electrified, as these technologies only play a niche role for specific purposes such as lighting and charging small appliances. In terms of the main household cooking fuel, the study incorporated both main and alternative energy sources, and hence it modified the modern cooking fuel indicator. This implied that a household which had either one or two traditional cooking fuels was considered energy poor in the modern cooking fuel indicator. This modification was made in order to be in line with the local context, which involves people who experience very high levels of poverty and employ multiple fuels. Another reason for this modification was the modern cooking indicator (defined as "type of cooking fuel" in the MEP index), which is variable in nature, compared to the electricity access indicator, which is absolute in nature.

The present study also observed that the MEP index relies on occurrence indicators (e.g. do you have access to electricity? do you own a fridge?). While such indicators can be captured accurately with relative ease (Data collection and analysis section), in its current format the MEP index misses indicators of stability of access, which is an important aspect of energy poverty/security. For instance, a poor household living in rented accommodation (that is considered as permanent housing) connected to electricity will register low energy poverty, even if they barely make ends meet to pay the electricity bills or the rent. On the other hand, a rural non-electrified household that uses abundant local resources (e.g. firewood) or PSPs for lighting and cooking will most likely register a high energy poverty, even though it does not run the risk of not having the necessary fuel for its daily activity.

A potential area of further research would be to add stability of access indicators to the MEP index. For instance, such indicators can go beyond asking whether a household has electricity connection, to inquire about the number of blackouts they experience and how many times they were unable to pay their electricity bill in a given period. Moreover, the MEP index could be extended to inquire about alternative lighting and cooking fuels, so as to establish the severity of energy poverty. For instance, if two households use LPG as the main cooking fuel but use different alternatives (e.g. electricity vs. firewood), the current MEP index would consider them to be similar in terms of energy poverty, although their cooking experiences are actually different.

Conclusion

This study illustrates the linkage between fuel and lighting choices and energy poverty in low income households by using the cross-sectional energy stacking model and the MEP Index. The results provide a comprehensive understanding of varying household characteristics at different levels of energy poverty, household energy choice, determinants as well as energy source preferences. It also established evidence of a cross-sectional energy stacking, in which households facing higher levels of energy poverty use more traditional fuels for lighting and cooking as compared to those facing lower levels of energy poverty. Moreover, in some instances the type of energy appliance influences lighting and cooking behaviour among traditional energy source users – particularly kerosene use for lighting and firewood use for cooking. Households perceived using an energy source in different appliances as two different choices, in the case of traditional energy sources. However, this was not the case among current modern energy sources users. Specifically, the main determinants of energy choice for lighting (such as affordability

[5] For more information refer to https://www.giz.de/en/worldwide/21975.html.

[6] The exchange rate used is 1 Kenya shillings = 0.0098 USD (26 December 2016).

[7] For more information refer to http://www.m-kopa.com/products/.

and availability) among those facing higher levels of energy poverty were closely associated with access concerns, whereas in those in the lower levels of energy poverty were more associated with usage concerns such as convenience, safety and reliability. There was a substantial persistent use of kerosene as an alternative lighting source among current PSPs users, indicating that it is considered as a safety net. In terms of cooking behaviour, location was found to also determine energy source use in households. There is a general preference and desire to use modern energy sources for lighting (grid electricity) and cooking (grid electricity, LPG) across most households, irrespective of the severity of energy poverty.

The energy Sustainable Development Goal 7's aim to "ensure access to affordable, reliable and sustainable energy for all" is universal in nature, and hence both developed and developing countries will have to establish how to best overcome this challenge and provide sustainable solutions to meet the energy needs of society. However, it is in the developing world, and particularly SSA, where substantial decisions and the most far-reaching and dramatic developments in the energy landscape will most likely occur. According to the Report of the United Nations Secretary General on the "Progress towards the Sustainable Development Goals", the progress in every area of SDG 7 as of 2017 falls short of what is required to achieve universal energy access by 2030, especially in the SSA region (United Nations, 2017). The report recommends that for meaningful improvements to be realized, higher levels of financing and bolder policy commitments, coupled with the willingness of countries to embrace new technologies on a much wider scale, will be required.

For meaningful improvement to be realized towards meeting the energy SDG by 2030, national and local energy policies should consider the energy technology adoption perception and behaviours of populations currently not having modern energy access. Moreover, it is of great importance to put into context the specific characteristics of the households as well as user perspectives and how these characteristics and perspectives would affect continuity of usage of the modern energy source adopted. In conclusion, it is important to keep in mind that the target to achieve universal modern energy access should also ensure that every individual has energy access to an amount of energy compatible with a decent standard of living.

Acknowledgments

Tabitha Olang acknowledges support from a Monbukagakusho MSc scholarship offered by the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT) and travel funding provided by the Graduate Program in Sustainability Science-Global Leadership Initiative (GPSS-GLI), at the University of Tokyo.

References

Abdullah S, Markandya A. Rural electrification programmes in Kenya: policy conclusions from a valuation study. Energy Sustain Dev 2012;16(1):103–10.

Alkire S, Foster J. Counting and multidimensional poverty. OPHI work pap [Internet], 7; 2007. p. 77–89 [Available from: www.ophi.org.uk].

Alkire S, Foster J. Counting and multidimensional poverty measurement. OPHI working papers; 2009.

Alkire S, Santos ME. Acute multidimensional poverty: a new index for developing countries [Internet]. Hum Dev 2010;179. [Available from: http://www.econstor.eu/dspace/handle/10419/48297].

Bazilian M, Pielke RJ. Making energy access meaningful. Issues Sci Technol 2013;29(4):74–8. [Internet, Available from: http://search.proquest.com/docview/1506955999?accountid=14357].

Bensch G, Jersch N, Kluve J, Stöterau J. Employment and income effects of improved cook stove and pico-solar interventions: an impact evaluation of the EnDev Kenya Programme. RWI Proj [Internet]; 2016. p. 1–87 [Available from: http://www.rwi-essen.de/media/content/pages/publikationen/rwi-projektberichte/rwi-pb_kenya_employment_evaluation_final_report.pdf].

Commission on Revenue Allocation. Kenya county fact sheets [Internet]. Nairobi. Available from: https://www.opendata.go.ke/dataset/Kenya-County-Fact-Sheets-Dec-2011/zn6m-25cf, 2011.

Eberhard A, Shkaratan M. Powering Africa: meeting the financing and reform challenges. Energy Policy 2012;42:9–18.

Eberhard A, Rosnes O, Shkaratan M, Vennemo H. Africa's power infrastructure: investment, integration, efficiency [internet]. Available from: http://www.ppiaf.org/sites/ppiaf.org/files/publication/africas-power-infrastructure-2011.pdf, 2011.

Edenhofer O, Pichs Madruga R, Sokona Y. Renewable energy sources and climate change mitigation (special report of the intergovernmental panel on climate change). Clim Pol 2012;6.

Edoumiekumo SG, Tombofa SS, Tamarauntari MK. Multidimensional energy poverty in the South-South Geopolitical Zone of Nigeria. J Econ Sustain Dev 2013;4(20):96–104. [Internet]. [Available from: http://s3.amazonaws.com/academia.edu.documents/32663755/9814-12017-1-PB.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1469449804&Signature=0yoOkalN2g2Z7E+u3C02zs7wR5E=&response-content-disposition=inline; filename=Multidimensional_Energy_Poverty_in_the_].

Ezzati M, Saleh H, Kammen DM. The contributions of emissions and spatial microenvironments to exposure to indoor air pollution from biomass combustion in Kenya. Environ Health Perspect 2000;108(9):833–9.

Fullerton DG, Bruce N, Gordon SB. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. Trans R Soc Trop Med Hyg 2008;102:843–51.

General Assembly, United Nations. Transforming our world: the 2030 agenda for sustainable development. https://sustainabledevelopment.un.org/content/documents/7891Transforming%20Our%20World.pdf, 2015.

Golumbeanu R, Barnes D. Connection charges and electricity access in sub-Saharan Africa. Policy res work pap, 6511. World Bank [Internet]; 2013, June. [Available from: http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2013/06/27/000158349_20130627091637/Rendered/PDF/WPS6511.pdf].

Government of Kenya. Kisumu County fact sheet-1. 2015; 2015. p. 1–15 [Available from: http://kisumu.go.ke/download/5].

Hansen UE, Pedersen MB, Nygaard I. Review of solar PV policies, interventions and diffusion in East Africa. Renew Sustain Energy Rev 2015;46:236–48.

IEA. Africa energy outlook: a focus on prospects in Sub-Saharan Africa. World Energy Outlook Spec Rep 2014:1–242.

International Energy Agency, World Bank. Energy for all 2015-progress toward sustainable energy. Glob track framew [Internet]; 2015. p. 332 [Available from: http://www.se4all.org/wp-content/uploads/2013/09/GTF-2105-Full-Report.pdf].

Jacobson A, Kammen DM. Engineering, institutions, and the public interest: evaluating product quality in the Kenyan solar photovoltaics industry. Energy Policy 2007;35(5):2960–8.

Kaygusuz K. Energy for sustainable development: a case of developing countries. Renew Sustain Energy Rev 2012;16(2):1116–26.

Kenya Open Data. Main lighting energy sources averaged to counties in 2009 [Internet]. Kenya Open Data Portal. cited 2016 Jan 1, Available from: https://www.opendata.go.ke/Distribution-and-Consumption/Main-Lighting-Energy-Sources-averaged-to-Counties-/g9hi-bs9n/data, 2015.

KPLC. Milestones in Kenya's electricity access [Internet]. cited 2017 Jan 19, Available from: http://www.kplc.co.ke/content/item/1040, 2017.

Lysen EH. Pico solar PV systems for remote homes: a new generation of small pv systems for lighting and communication. International Energy Agency; 2013.

Nussbaumer P, Bazilian M, Modi V. Measuring energy poverty: focusing on what matters. Renew Sustain Energy Rev 2012;16(1):231–43.

Nussbaumer P, Nerini FF, Onyeji I, Howells M. Global insights based on the multidimensional energy poverty index (MEPI). Sustainability 2013;5(5):2060–76.

Ogwumike FO, Ozughalu UM. Analysis of energy poverty and its implications for sustainable development in Nigeria. Environ Dev Econ 2016;21(3):273–90. [Internet, Available from: http://www.journals.cambridge.org/abstract_S1355770X15000236].

Ondraczek J. The sun rises in the east (of Africa): a comparison of the development and status of solar energy markets in Kenya and Tanzania. Energy Policy 2013;56:407–17.

Oparaocha S, Dutta S. Gender and energy for sustainable development. Curr Opin Environ Sustain 2011;3:265–71.

Pachauri S. Reaching an international consensus on defining modern energy access. Curr Opin Environ Sustain 2011;3:235–40.

Pundo MO, Fraser GC. Multinomial logit analysis of household cooking fuel choice in rural Kenya: the case of Kisumu district. Agrekon 2006;45(1):24–37.

REN21. Renewables 2016-global status report [Internet]. REN21 renewables. Available from: http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf, 2016.

Riojas-Rodríguez H, Romano-Riquer P, Santos-Burgoa C, Smith KR. Household firewood use and the health of children and women of Indian communities in Chiapas, Mexico. Int J Occup Environ Health 2001;7(1):44–53.

Rolffs P, Ockwell D, Byrne R. Beyond technology and finance: pay-as-you-go sustainable energy access and theories of social change. Environ Plan A 2015;47(12):2609–27.

Schlag N, Zuzarte F. Market barriers to clean cooking fuels in Sub-Saharan Africa: a review of literature. Fuel 2008(April):1–21. [Internet, Available from: http://sei-international.org/mediamanager/documents/Publications/Climate/market_barriers_clean_cooking_fuels_21april.pdf].

Sher F, Abbas A, Awan RU. An investigation of multidimensional energy poverty in Pakistan: a province level analysis. Int J Energy Econ Policy 2014;4(1):65–75. [Internet, Available from: www.econjournals.com].

Sikoliya D, Mwololo K, Cherop H, Hussein A, Juma M, Kurui J, et al. The Prevalence of acute respiratory infections and the associated risk factors: a study of children under five years of age in Kibera Lindi Village, Nairobi, Kenya. J Natl Inst Public Health 2002;51(1).

Simiyu J, Waita S, Musembi R, Ogacho A, Aduda B. Promotion of PV uptake and sector growth in Kenya through value added training in PV sizing, installation and maintenance. Energy Procedia 2014:817–25.

Sovacool BK, Cooper C, Bazilian M, Johnson K, Zoppo D, Clarke S, et al. What moves and works: broadening the consideration of energy poverty. Energy Policy 2012;42:715–9.

Sovacool BK, Bazilian M, Toman M. Paradigms and poverty in global energy policy: research needs for achieving universal energy access. Environ Res Lett 2016;11(6):64014. [Internet, Available from: http://stacks.iop.org/1748-9326/11/i=6/a=064014?key=crossref.472f71771b45d2d64383c71704e58d31.

United Nations. Energy for a sustainable future. Secr Advis Gr Energy Clim Chang [Internet]; April 2010. p. 44 [Available from: http://www.un.org/millenniumgoals/pdf/AGECCsummaryreport[1].pdf].

United Nations. Progress towards the sustainable development goals: report of the secretary general [Internet]. Available from: https://unstats.un.org/sdgs/files/report/2017/secretary-general-sdg-report-2017–EN.pdf, 2017.

Van Der Kroon B, Brouwer R, Van Beukering PJH. The energy ladder: theoretical myth or empirical truth? Results from a meta-analysis. Renew Sustain Energy Rev 2013;20:504–13.

World Bank. Access to electricity (% of population) [Internet]. Sustainable Energy for All (SE4ALL) database from World Bank, Global Electrification database. cited 2017 Jan 19, Available from: http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=KE, 2015.