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SOCIO-PHYSICAL ASPECTS OF ENERGY POVERTY IN ETHIOPIA: A CASE STUDY OF ADDIS ABABA CITY

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Abstract

This paper analyzes the socio-physical or Energy inconvenience aspects of energy poverty in Addis Ababa city. The socio-physical aspect of energy poverty index is used to estimate the energy poverty in the city, using cross sectional data from 466 households in 2012/13. The result indicates that 40% of the city households have energy inconvenience, 33% have energy inconvenience excess, 42.2 % of the households have energy shortfall and 37.6% of the households are energy poor from socio-physical aspect of energy poverty. It means that, households spend more their time and efforts for buying or accessing different energy sources (fire wood, charcoal, kerosene and LPG) and have energy shortfall .i.e. households do not use sufficient amount of energy to meet their energy needs. The study also identified that households with high education level, who own electric meter and have higher income are less likely to have energy short fall. Thus, improving access to different energy sources especially the modern ones are essential to reduce energy poverty in terms of energy short fall.

Keywords: Energy poverty, Energy Inconvenience, Energy shortfall, Socio-physical

INTRODUCTION

Energy is one of the basic elements of economic and social development. It contributes to health and education service delivery, and helps to meet the basic human needs such as food and shelter (IEA, 2006). There are traditional and modern energy sources. Traditional energy sources are firewood, charcoal, crop residues and animal waste. They are also referred as biomass energy and are obtained from natural environment. The modern energy sources are kerosene, LPG and electricity. These energy sources are collectively termed as modern or commercial energy sources (Leach, 1987). Modern energy services have important role in improving production and productivity. They relieve millions of women and children from daily burden of water fetching and firewood collection. They can help to extend the working time, increase individual income, invest children's time in schooling and deliver health services to the community (World Bank, 2000).

The number of people who depends on traditional energy sources in the world is estimated to be 2.7 billion of the global population in 2009. Among these, 2.6 billion people are from developing countries, 653 million people of which are from Sub-Saharan Africa. In case of Ethiopia, more than 67 million people are dependent on biomass energy to meet their cooking, heating, lighting and hygiene needs (UNDP, 2009; IEA, 2010; DGEP, 2011; and CSA, 2012). This dependency on traditional energy sources in developing countries in general and sub-Saharan Africa countries in particular is creates the energy poverty. Energy poverty refers to the households that spend more than 10% of their income on fuel to maintain an adequate level of energy (Masera, et.al, 2000). The term also refers to the absence of sufficient choices in accessing, affordable, reliable, high quality, safe and environmentally benign energy services to support economic and human development (Reddy, 2004).

For example: 61% of the Indian, 84% of the Cambodian , 73% of the Kenyan, 84% of the Tanzanian and 90 % of the Ethiopian population are energy poor. In these countries, many people have no access to efficient and clean energy sources for domestic energy use (Nussbaumer, et.al, 2011 and ESCAP, 2012).

Regarding access to electricity, 1.32 billion people in the world lacks access to electricity. From this, 1.3 billion people are from developing countries, of which 586 million people are from Sub-Saharan Africa. In Ethiopia, more than 46 million people live without access to electricity. Generally, 51% of the population of developing countries, 78 % of Sub-Saharan African population and 93% of Ethiopian population use biomass energy for their domestic use. Moreover, 25% of developing countries population, 69% of Sub-Saharan African countries population and 63 % of Ethiopian population have no access to electricity (UNDP, 2009; IEA, 2010; DGEP, 2011; and EPA, 2012). However, such heavy dependency on biomass energy sources creates deforestation, land degradation, soil erosion, climate change and energy poverty in those countries (World Bank, 2000; Alemu, et. al, 2008; and Yonas, et. al., 2013).

LITERATURE REVIEW

Energy poverty is defined as inability to cover basic energy cost to keep homes adequately warm, cook food and have light. It can be also defined as the absence of sufficient choices for affordable, reliable, high quality, safe and environmental benign energy services to support economic and human development (Reddy, 2004). Although many researchers have similar ideas in the definition of energy poverty, they fail to agree on what exactly is the minimum level of energy poverty line and below which a household can be classified as energy poor (Pachauri, et.al, 2004; Dhanuska, 2008; and Betchani, et, al., 2013).

For example, Bravo, et, al. (1979) measured energy poverty in terms of physical energy amount and identified 27.4 kilograms of oil equivalent (kgoe) per household per month as the minimum amount. Goldemberg, (1990) defined 32.1 kgoe per household per month as the minimum amount, while Modi, et.al. (2005) computed 50 kgoe per household per month for cooking and lighting as energy poverty line. Foster, et, al. (2000) estimated a minimum level of energy for rural and urban households. They estimated the minimum amount for rural households to comprise two bulbs, five hours service for radio use while for urban areas with additional appliances such as television and refrigerator use, the minimum energy level is estimated to be 50kgoe. All these works used the minimum amount of energy for estimation of energy poverty line in terms of physical amount without considering economic aspects.

ESMAP,(2002), Pachauri, et.al.(2004), DGEP,(2011), Patil (2011), ESCAP (2012) and Betchani, et.al. (2013) estimated energy poverty in terms of economic aspect. Economic energy poverty is at a level when households' energy expenditure is more than 10% of the disposable income, excluding transportation costs (WEO, 2004). These researches considered economic or expenditure aspect of energy poverty, but they did not consider other factors like accessibility, affordability and classification of energy for domestic activities.

DGEP,(2011), Patil (2011), ESCAP (2012 examined Access to energy usually includes three forms of energy: less polluting energy for cooking and heating, electricity for powering appliances and light in households and public facilities and mechanical power from either electricity or other energy sources to improve productivity of labor . It is also measured by the households' access to more efficient energy sources and related issues to improve the people well-being. Having energy access means that modern energy services should be physically accessible and available to the people; should be acceptable in quality, reliability and preference; should be affordable both in terms of capital and operating cost and in the context of income levels.

Masud, et.al. (2007), World Bank (2011a), DGEP (2011) and ESCAP (2012) examined the use of energy to energy poverty as: First, Traditional energy use with household's expenditure: the poor especially pay more for their daily energy needs in the form of inefficient and potentially harmful fuels. The next link is traditional energy use with health impact: Traditional biomass fuels have negative health impact when used indoors for cooking purposes. Traditional energy use can also lead to unsustainable biomass harvesting for energy production denudes rural landscapes of available foliage cover, accelerates deforestation. This in turn reduces agricultural productivity and income because of low yields and more frequent crop failures.

Mirza et. al. (2010) in their energy poverty study applied new method for estimation of energy poverty in terms of access to different energy sources such as firewood, charcoal, kerosene and LPG at household level. This energy poverty model is a bit complex to estimate for each energy source inconvenience index using energy inconvenience excess and energy short fall at household level. The model gives more emphasizes on how to access different energy sources in different forms: Energy inconvenience index, energy inconvenience excess and energy shortfall.

Nussbaumer, et. al. (2011) developed the multi-dimensional energy poverty index (MEPI) and estimated energy poverty for African countries in terms of incidence and intensity of energy poverty, and reported that the energy poverty line is at 0.30. According to their finding, 65% of Zambian, 70% of Cameron and 90% of Ethiopian are energy poor multi-dimensionally. Similarly, ESCAP,(2012) estimated multi-dimensional energy poverty index for South and East Asian countries and Edoumiekumo, et, al.(2013) also used the Nussbaumer, et.al.(2011) model to estimate multi-dimensional energy poverty index for Nigeria. MEPI focuses on measuring modern cooking fuels, indoor air pollution from burning of firewood and charcoal, access to electricity, services provided using own energy appliances for domestic energy activities.

From the forgoing discussion, it is clear that the empirical works on estimation of energy poverty are limited in scope and coverage. Some works by Bravo, et. al. (1979), Goldemberg (1990), Modi, et.al (2005) and Foster, et.al (2000) estimated energy poverty in terms of physical quantity, while other researchers such as ESMAP (2002), Pachauri, et.al.(2004), Masud, et.al. (2007),Mirza et.al. (2010), DGEP (2011), Patil (2011), ESCAP (2012) and Betchani, et,al (2013) estimated energy poverty on the basis of economic or access to energy aspect. Thus, this study estimated energy poverty by adapting the Socio-physical or Energy Inconvenience Index approach.

METHODOLOGY

The study area

Addis Ababa is the largest city in Ethiopia with the total area of 54,000 hectares or 540 km^2 (CGAA-BPACSP, 2010). Addis Ababa has a Subtropical highland climate zone, with temperature up to 10 °C differences, depending on elevation and prevailing wind patterns (NMA, 2011). According to 2007 Ethiopian census, Addis Ababa city population was estimated to be 2,739,551, of whom 1,305,387 were men and 1,434,164 were women. In the city, 662,728 households were living in 628,984 housing units, with average family size of 4.1 persons. The 2012 estimate of population of the city was 3,033,284 living within 739,829 households. The population density of the city was 5,617 persons per kilo meter square (CSA, 2008 and CGAA, 2013).

The residents of Addis Ababa use both modern and traditional energy sources for domestic energy activities. The sources are firewood, charcoal, animal dung, sawdust, barks, roots, leaves, kerosene, LPG and electricity (GTZ-Sun, 2010). Many factors were considered for selecting the study area. The key reasons for selecting Addis Ababa city are: steady growth of the population of the city, shortage of firewood, charcoal, kerosene and LPG, and the accompanying rise of their prices, and the sustainability challenges of energy supply. The other important energy feature of the city is that there are some peri-urban *kebeles* that have no access to electricity. In these places, there is less expansion of electricity grid, price fluctuation of different energy sources, and physical inaccessibility of kerosene and LPG.

There is also an increasing shortage of firewood in the city due to the imbalance between the supply and demand for the source due to depletion of the forest in the periphery of the city. The city is however still a good market for biomass energy supplies from its surroundings. Besides, the city is strategically located to access different kinds of energy sources like fire wood, charcoal, kerosene, LPG, electricity and even other varieties of energy sources like animal dung, leaves, barks, etc. The fact that the city is inhabited by people of different income groups makes ita marketplace for diverse kind s of energy sources.

Data sources

The study used primary data that were collected from 466 households in 2012/13. The study employed a multistage stratified random sampling technique to identify data sources. The multistage random sampling technique is used for large scale enquiry covering large geographical area such as a state, large or medium city.

Addis Ababa city is the largest city in Ethiopia and has ten sub cities and 116 urban and peri-urban *woredas* (CGAA, 2013). In the first stage of multi-stage sampling, sub-cities were selected randomly from stratified sub-cities, in the second stage *woredas* from each sub-city were selected randomly and finally households from each *woreda* were selected randomly.

For sampling purposes, the sub cities were categorized into two strata based on the following criteria: geographical location (distance from the center), boundaries with surrounding rural areas, size of geographical areas, population density and economic activities. Stratum one (outer sub cities) has six sub cities, namely, Gullele, Kolfe Keranyo, Nefas Silk, Akaki- Kality, Bole and Yeka. Those sub-cities with long distance from the center (Menilik II Square) border with rural areas in Oromia region, have large geographical areas, are sparsely to densely populated (on average 4,576.3 persons per Km^2) and the major economic activities of the people are trade, services, transport, hotel, manufacturing, urban agriculture and animal husbandry.

Stratum two (inner sub-cities) has four sub cities that include Arada, Kirkos, Lideta and Addis Ketema. These four sub cities have short distance from the center, have no border with rural areas, have small geographical areas, are located relatively at the center of the city, densely populated with average of 35,794.5 Persons/Km^2, and the major economic activities of the people are trade, services, transport, hotel and tourism.

After classifying the city into strata, three sub cities (50%) were randomly selected from the first stratum, i.e. Gullele,Yeka and Akaki-Kality sub cities and two sub-cities (50%) from second stratum - Arada and Lideta. After selecting the five sub cities, 50% of *woredas* were also selected randomly from each selected sub-city. Accordingly, 26 woredas, 466 households were randomly selected from the sub-cities for the study. The number of sample households for each *woreda* is proportional to the respective *woreda* household population.

Model specification

Socio-Physical Aspect of Energy Poverty Index (SP-EPI)

Energy poverty can be estimated by socio-physical estimation method for households. It is usually expressed in terms of energy inconvenience to households. Energy inconvenience is the degree of physical difficulties or inconvenience involved in acquiring and using a particular energy source to meet households' energy need. It can be estimated by different indicators like buying frequency of energy, distance covers by household travel to buy, means of transport use, time spent to buy, children involvement, household health status, etc. Each indicator has its own measurement index to estimate the degree of energy inconvenience. It can be estimated by:

***1) Measuring of household energy inconvenience index by**---------------------------------------(1)*

a) Measuring the inconvenience index for each inconvenience indicator

$Y_{hij} = \frac{X\mathrm{hij} - \mathrm{Xij(min)}}{Xij(\max) - Xij(\min)}$---(1.1)

Where: Y_{hij} = energy inconvenience associated with energy source j for household h,

$Xh_{ij=}$the actual value of household response score for indicator i and energy sources j,

$X_{ij(min)}$ = the minimum value of hhs response score for indicator i and energy source j,

$X_{ij(max)}$ = the maximum value of hhs response score for indicator i and energy source j,

X is the mean response score about energy inconvenience,

h is household, i is the type of inconvenience indicator, j is type of energy sources and

Min and max are the minimum and maximum scores for indicator i and energy source j

b) Computing energy inconvenience index (EII) at energy source level

$EII_{hj} = \frac{\sum_{i=1}^{n} Xhij}{Nij}$---*(1.2)*

Where: EII_{hj} is the energy inconvenience index for a given energy source j in household h

$\sum_{i=1}^{n} Xhij$ is the sum of inconvenience index i for a given energy source j uses by hhs.

N is the number of inconvenience indicator for a given energy sources.

For example: Fire wood N= 7, Charcoal N=7, Kerosene N= 7 and LPG N= 6.

c) Estimating the total Energy Inconvenience Index (TEI) for each household

It is computed by aggregating the Inconvenience Indexes for all energy sources j used by a single household h, weighting them by the share of an energy sources (in kwh) for total households .

It is measured as $TEI_h = \sum_{j=1}^{4} \frac{KWhj}{\Sigma KWhj}(EII_{hj})$ ---*(1.3)*

Where: TEI_h is the Total Energy Inconvenience Index for household h, from energy mix.

$\frac{KWhj}{\Sigma KWhj}$ is the share of energy in kilowatt hour from the given energy sources j

d) Setting the total energy inconvenience threshold (TEIT)

It is the energy poverty line in terms of the energy inconvenience. The TEIT cut-off point for African countries is 0.30.It implies that households are considered to be as energy poor (WEO, 2004). If TEII>0.3 , the households with high energy inconvenience. i.e. have difficulty to access or acquire a given energy or suffers from energy poverty. Whereas, If TEII ≤0.3 or 30%, the households are with low energy inconvenience (WEO, 2004).

TEIT > 0.3--*(1.4)*

2) Measuring of the Energy Inconvenience Excess (EIE) at household level-

The EIE measures the gap between the actual inconvenience suffered for in the households and the inconvenience line (Mirza, et.al, 2010).The total energy inconvenience scores are converted in to percentages relative to the threshold level. Then, the degree of inconvenience beyond the threshold level (TEIT) is referred to as the EIE. If EIE_h is negative, it indicates that the households are in the state of excess of inconvenience. Whereas, a positive result indicates that households are in the state of convenience. It can be estimated as

$EIE_h = (\frac{TEIh-TEIh}{TEITh})$ *100--(2)

Where: EIE_h is the Energy Inconvenience Excess for household h and expresses in percentage,

$TEI_{h:}$ Total Energy Inconvenience for household h and

$TEIT_h$: Total Energy Inconvenience Threshold

3) Estimating of household energy shortfall (quantity based energy poverty estimation)

Energy shortfall is a situation when households do not consume sufficient energy amount to meet their energy needs. It is also the difference between the required energy per capita per month and actual energy consumption in per capita per month. It helps to measure the amounts of energy short falls in terms of kilo watt hour. It is computed as

$ES_h = (\frac{AECh-TER}{TER})$ *100---(3)

Where; ESh is Energy Short fall

AERh is Actual Energy Required or consumption on per capita base from energy mix.

TER is Total Energy required or the threshold energy requirement of household in kwh.

The estimation was based on the assumption of four family members who live in one household on average bases. It can also be calculated on the basis of toe per annum per-capita per month required to attain 0.8HDI. The data comes from secondary data sources. It used as energy short fall threshold line. The energy short fall can be derived by

1toe = 11,630kwh =0.8HDI

Xtoe = Xkwh =0.799HDI.It is a maximum threshold line of total energy required

for developing countries and it indicates as reference for Ethiopia(WEO,2004 and WEO, 2010).

11,630kwh =0.8HDI

Xkwh =0.799HDI.

$TER = \frac{11{,}630kwhs*0.799HDI}{0.8HDI}$

TER=11,615.5kwh/annum, or

TER=11,615.5kwh/12months = 967.9kwh/month /household

TER = 968kwh/month /household= Energy short fall line

If the energy short fall index is negative, it indicates that households have energy short fall (Energy poor). Whereas, if the value is positive, it indicates that households do not have energy short fall (energy non poor). By combing the previous two indexes, energy poverty index is as follow

4) Measuring socio-physical energy poverty Index by

$SP\text{-}EPI_h = \frac{1}{2}(EIE_h + ES_h)$--(4)

Where: EPI is the Energy Poverty Index that measures the degree (intensity) of energy poverty.

EIE is Energy Inconvenience Excess.

ES is Energy Short fall.

If the SP- EPI value becomes negative, the households are energy poor, i.e. Households spend more their time and efforts for buying or accessing different energy sources (fire wood, charcoal, kerosene and LPG) and households have energy shortfall .i.e. households do not use sufficient quantity of energy to meet their energy needs.

If the SP- EPI value becomes positive, the households are energy non poor, i.e. Households have different access to clean, efficient or modern energy sources.

Econometric analysis of multi-dimensional energy poverty

The study households were first categorized into two groups (Socio-physically energy poor and Socio-physically energy non-poor) based on their access to different energy sources. Binomial logistic regression model was used to find the main determinant of household energy poverty. The logit model used for the analysis is written as

$Prob(1|X_i) = L_i = \ln(\frac{Pi}{1-Pi}) = Z_i = \beta_1+\beta_i X_i + \varepsilon_i$

Where: $Prob(1|X_i) = \ln(\frac{1}{0}) = 1$, if the household$_i$ do not have energy short fall(consumes more than 968kwhs) per month and he /she is energy non poor household.

$Prob(1|X_i) = \ln(\frac{0}{1}) = 0$, if the household$_i$ has energy short fall(consumes less than 968kwhs) per month and he /she is an energy poor household.

P_i:= the probability of being energy non poor,

$1-P_i$= the probability of being energy poor

$\ln(\frac{Pi}{1-Pi})$ = log odds ratio of the two probabilities in favor of being energy non-poor

β_i parameters to be estimated,

X_i is a vector of household characteristics, and εi is an error term.

RESULTS AND DISCUSSION

Descriptive analysis of Energy poverty from Socio-physical (energy inconvenience) aspect

The socio-physical or energy inconvenience approach measures the degree of physical difficulties or inconvenience involved in acquiring and using a particular energy source to meet households' energy need.. In this part, first, we estimated inconvenience index for each inconvenience indicator at each energy source level. Next, Total Energy Inconvenience Index (TEI) is also estimated for each household. Then, the energy inconvenience excess (EIE) at household level and the energy shortfall (quantity based energy poverty estimation) is estimated. Lastly, energy poverty index is estimated as a whole.

Table 1 shows, the estimated results of inconvenience index for each inconvenience indicator such as purchasing frequency per month, means of transport, distance covered by households from market to home, time spent per month, household involvement for purchasing of energy, indoor air pollution and child or children participation for accessing of different energy. From the given seven energy inconvenience indicators, children involvement, purchasing frequency and air pollution are the main indicators for measuring of fire wood, charcoal and kerosene inconvenience index. They nearly contributed 64%, 67% and 61% of inconvenience to its own index measurement, respectively. In the case of LPG, children involvement, purchasing frequency and means of transport indicators are the three factors used for measuring the LPG inconvenience index.

In general, children involvement and buying frequency indicators are the main energy inconvenience indicators for all types of energy (firewood, charcoal, kerosene and LPG). Besides, air pollution is the major factor to all except LPG since it is a clean energy type that does not cause indoor air pollution at the time of using. Time spent is the least factor of EII for all types of energy. Charcoal has more energy inconvenience index (3.11). That means accessing of charcoal is more inconvenient than other energy types, due to its price becoming expensive from time to time, it also comes from the city neighborhood town and needs transportation, and sometimes government controls the distributions of charcoal. etc. Thus, households' that spend more labor effort, time and money to access it. It is followed by kerosene (2.43) and fire wood (2.12). Accessing of LPG (0.57) is more convenient than others because of the LPG has lower value of EII than others. This is manifested by the households possibility to buy more at a time, travel short distance to the market, do not use human labor to bring LPG to their home(mostly by own or public transport), spend less time, no indoor air pollution, no child or children involvement for acquiring LPG .

Table 1. Energy inconvenience index for fire wood, charcoal, kerosene and LPG

Indicators	***Fire wood***		***Charcoal***		***kerosene***		***LPG***	
	EII	%	EII	%	EII	%	EII	%
Buying frequency / month	0.42	19.8	0.7	22.5	0.51	20.9	0.13	22.8
Means of transport	0.27	12.9	0.28	9	0.29	11.9	0.09	15.7
Distance	0.2	9.5	0.33	10.6	0.29	11.9	0.07	12.3
Time /month	0.07	3.3	0.1	3.2	0.13	5.4	0.06	10.5
Hhs involvement	0.22	10.4	0.32	10.3	0.23	9.5	0.08	14.1
Indoor air pollution	0.4	18.8	0.57	18.3	0.43	17.7	0.0	0.0
Child/children involvement	0.54	25.5	0.81	26.1	0.55	22.7	0.14	24.6
Total	***2.12***	100	***3.11***	100	***2.43***	100	***0.57***	100

% indicates that the contribution of each inconvenience indicator for total inconvenience index.

EII: Energy Inconvenience Index

Source: Household survey, 2012/2013.

NB: We assumed that EII of electricity is 0.00 because accessing electricity is not measured by indicators like frequency of buying or collecting energy, distance from home to market travel, means of transport to bring the electricity, time spent to buy, children involvement, and causes of household health problems due to indoor air pollution. However, the time requires for bill payment was not included in data collection because the indicator does not affect the consumptions of it. As a result, accessing of electricity is convenient for all households for this purpose.

After estimating the inconvenience Index for each indicator, the aggregate energy inconvenience index for each energy source uses by the households can be computed. It is an un-weighted average of the inconvenience index because it is divided by the number of each energy inconvenience indicator for a given energy source. The numbers of inconvenience indicators are seven for fire wood, charcoal and kerosene and six are for LPG. Therefore, the energy inconvenience indexes on average are EII for fire wood =2.12/7 = 0.30, EII for charcoal = 3.11/7 = 0.44, EII for kerosene = 2.43/7 = 0.35, EII for LPG = 0.56/6 = 0.10 and EII for electricity = 0.00

Among the given energy type, charcoal has more energy inconvenience index (0.44). That means accessing charcoal is more inconvenient than other energy types. This can be due to the price increases from time to time, it also comes from the city neighborhood town and needs transportation, and sometimes government controls the distributions of charcoal. etc.

Thus, households' spend more labor, time and money to access it. It is followed by kerosene (0.35) and firewood (0.30). Whereas, accessing LPG (0.10) is more convenient than others because of the LPG has lower value of EII than others.

After estimating the EII at energy source level, we also estimated the Total Energy Inconvenience Index (TEI) for each household. It is computed by aggregating the inconvenience indexes for all energy sources use by a single household, weight them by the share of an energy source (in kilowatt hour) from total household energy use. The total energy inconvenience index for energy sources are as follows

TEII for fire wood= $(\frac{36,406.49\text{kwh}}{180,105.25\text{kwh}})$(0.30) =0.20(0.30) =0.069

TEII for charcoal=$(\frac{113,507.50\text{kwh}}{180,105.25\text{kwh}})$(0.44)= 0.63(0.44) = 0.277

TEII for kerosene= $(\frac{25,080.75\text{kwh}}{180,105.25\text{kwh}})$(0.35)= 0.14(0.35) = 0.050

TEII for LPG= $(\frac{5,110.17\text{kwh}}{180,105.25\text{kwh}})$(0.10)= 0.03(0.10) = 0.003

TEII for all types of energy = the weighted mean value of EII = 0.399 = 0.400

In the study, 40% of populations have energy inconvenience. i.e, have difficulty to access different energy sources. Then, the Total Energy Inconvenience Threshold (TEIT) is applied to determine the bench mark or line of energy poverty. The TEIT cut-off point for African countries is 0.30. It implies that a household is considered to be energy poor if she/he has little or no access clean cooking energy or is not benefited from energy services supplied by modern energy. It is lined as TEIT = 0.3. After setting the threshold line, the Energy Inconvenience Excess (EIE) is estimated for households. EIE measures the degree of inconvenience beyond the threshold level. In this step, the total energy inconvenience index is computed in relation to the threshold level. It can be interpreted as if it has a negative value index; it indicates that households are in the state of excess of inconvenience. If it has a positive value, indicates that households are in the state of convenience.

It is computed as EIEIh = $(\frac{0.3-0.40}{0.3})$*100 = $(\frac{-0.1}{0.3})$*100 = -0.33 = -33%

The finding indicates that 33% of the households have energy inconvenience excess. i.e. Accessing of different energy sources in the city requires high degree of effort and it has difficulty in all dimensions of the inconvenience indicators for energy poor households. Besides, it clearly indicates that energy access in the city has opportunity costs, i.e. the households spend more time to travel long distance, purchase many more times in a month, use human labor to access them.

Household energy shortfall is also estimated by energy amount. Energy shortfall is a situation when households are not using sufficient energy amount to meet their basic needs. It is computed by considering the actual energy consumption per capita in kwh for all energy sources and total energy required on per capita bases. From our analysis, actual energy required or consumed on average basis (AER) in the survey is 559.11kwh /month/ household, total energy consumption for total households is 260,545.40kw and TER= 968kwh/month /household. It is energy shortfall threshold line for developing countries including Ethiopia.

Energy short fall index is estimated as

$ESI_h = (\frac{559.11kwhs - 968kwhs}{968kwhs})*100 = (\frac{-408.89kwhs}{968kwhs})*100 = (-0.422)*100 = -42.2\%$

Or, in total energy consumption base and needs of total households energy consumption base

$ESI_h = (\frac{260,545.40kwhs - 451,088kwhs}{451,088kwhs})*100 = (\frac{-190,542.6kwhs}{451,088kwhs})*100 = (-0.422)*100 = -42.2\%$

The ES_h index indicates that 42.2 % of the households have energy shortfall .i.e. households are extremely energy poor because their energy consumption is not sufficient amount for domestic energy activities.

Finally, the socio-physical energy poverty index at city level is computed as follows

The SP-EPI = 1/2 (EIE+ES) = ½((-33%+(-42.2%)) = ½(-75.2%)

The SP-EPI = -37.6%

The SP- EPI indicates that 37.6 % of the households are energy poor. i.e. the households are categorized as extremely energy poor with sever energy poverty. It also indicates that the households spend more of their time and efforts for buying or accessing different energy sources (firewood, charcoal, kerosene and LPG) and have energy shortfall .i.e. households have not consumed the required amount or quantity of energy to meet their energy needs. This finding is in line with the works of Mirza, et.al.(2010) and WEO(2010). The remaining, 62.4 % of the households are energy non poor. That means, the households have different access to clean, efficient or modern energy sources (see Table 2).

Generally, 40% of the households have energy inconvenience, 33 % of the households have energy inconvenience excess, 42.2 % of the households have energy short falls and 37 % of households have energy inconvenience excess and energy shortfall. The overall result indicates that large numbers of households have energy inconveniences in the city.

Table 2. Energy poverty index by socio-physical measurement approach

Categories of energy poverty	EII		EIEI		ESI		EPI	
	%	HC	%	HC	%	HC	%	HC
Energy poor	40	186	33	154	42.2	197	37.6	175
Energy non poor	60	280	67	312	57.8	269	62.4	291
Total	100	466	100	466	100	466	100	466

HC: Head count
Source: Own computation

Econometric analysis of Energy poverty from Socio-physical (energy inconvenience) aspect

With regards to logit estimation of quantity based or energy shortfall energy poverty analysis, family size, maximum education at post-secondary, owning of electric meter and total energy expenditure are found to be statistically significant at 1% and 5% precision level. It indicates that the variables listed above have power to explain energy poverty.

The coefficient of family size is positive. It indicates that, households with more family member are more likely to have energy short fall or to be energy poor than small family household. i.e. households with more family members are more likely to have energy shortfall . It means that, if the family size increases by one member, keeping other variables constant, household's short fall increases This implies that large family size has less opportunity or possibility to buy and use more modern energy sources to feed their family members than small family.

The coefficient of household head education level at post-secondary level is negative. It indicates that, households with more education level are less likely to have energy short fall or to be energy poor than uneducated family. i.e. households with post-secondary education level are less likely to be energy poor than less educated family members. The more educated households earn more income, spend more for energy, and consume more amount of clean energy than the households with less education level. This leads to decline the energy short falls.

The coefficient of owning of electric meter is positive. It indicates that, households with owning of electric meter at their home are more likely to be less energy shortfall than households without owning the electric meter. This might be due to the easy access to electricity at any time, permitting the households to use more electric power with different energy appliances. This leads to increase total energy amount for domestic uses.

The coefficient of total energy expenditure is positive. It indicates that, households with more energy expenditure are more likely to be less energy short fall or to be energy poor t. i.e. households with more energy expenditure are more likely to be energy non poor. Because, that households consume more types and amounts of energy especially the modern energy by expending more. It also leads to use more quantities of energy. Those findings are similar to the researches of Pachauri, et.al. (2004), Mirza, et.al.(2010), WEO(2010), Nussbaumer, et.al(2011) and ESCAP (2012).

Table 3. Logit and WLS Estimation of Socio-Physical Energy Poverty Index

Explanatory variable	**Logit estimation of the household's energy shortfall, 1 if ≥968kwh/month for no energy shortfall , otherwise, 0**	**WLS estimation of household's Energy shortfall in log Tkwh**
Age(log)	- 4.233 (3.512)	-0.119** (0.049)
Marital status	- 0.814 (0.733)	0.012 (0.106)
Family size(log)	6.033** (2.652)	0.190*** (0.032)
HH head post primary education level	0.416 (0.636)	-0.001 (0.013)
HHs head post-secondary education level	- 2.262** (0.975)	- 0.048*** (0.012)
Own house	- 0.231 (0.596)	- 0.005 (0.010)
Own refrigerator	0.339 (0.667)	- 0.002 (0.010)
Own electric meter	0.749*** (0.212)	0.032*** (0.011)
Total energy expenditure (log)	16.785*** (3.458)	0.761*** (0.042)
Total expenditure(log)	- 1.018 (2.784)	- 0.074*** (0.034)
Constant	-41.475*** (9.953)	1.000*** (0.140)
Pseudo R^2	0.554	-
R^2	-	0.746
LR $chi^2(10)$	120.54(0.000)	-
F(10,455)	-	133.99(0.000)

*** Significance at 1%, ** significance at 5%, * significance at 10%, Figure in bracket is standard error

Results of Weighted Least Square Estimation

After identifying the variables to be estimated for energy poverty estimation, Ordinary Least Square (OLS) method is used to estimate the explanatory variables on continuous dependent variables of average energy deprivation counts. Multicolinearity is tested through Variance Inflating Factor (VIF), Tolerance (TOL) test and Spearman correlation coefficient matrix for energy poverty model. The results of the tests show that there is no high correlation coefficient among the explanatory variables. Heteroscedasticity is also tested by Breusch-Pagan test. The test assures the presence of heteroscadasticity (has no constant variance in the ε_i). OLS regression was thus not best linear unbiased estimators (BLUE) when the error terms have no constant variance. As a result, the Weighted Least Square (WLS) method was used for estimation of energy poverty as

$$SP\text{-}EPI_{kwh} = \beta_1 + \beta_i \log X_i + \varepsilon_i$$

Where: W_{TEE} is energy budget share in log form

$SP\text{-}EPI_{kwh}$ is Socio-physical aspect of energy poverty index in kwh in log form

β_i is parameter to be estimated,

X_i is a vector of household characteristics and εi is an error term.

With regards to energy short fall poverty estimation, household age, family size, household head education level at post-secondary level, owning electric meter, total household expenditure and total energy expenditure are also the main determinant factors for estimating the quantity base energy poverty. Those variables are statistically significant at 1% and 5% precision level.

The coefficient of household age is negative. It indicates that, the household head age increases by one more year, leads to decline energy shortfall. It means that, if the family head age increases by one more year, keeping other variables constant, household's energy short fall decreases by 0.119%. This implies that old age family head members have more opportunity to have more income and wealth than the young family head. This is because of old age family head may have more experience in their work, more labor in their family members and wealth than the younger ones. This situation may lead to have more income and expend more for energy than the young family head.

The coefficient of family size is positive, indicating that households with large number of family members have higher Energy short fall. It means that, if the family size increases by one member, keeping other variables constant, household's energy short fall increases by 0.190%. This implies that large family size has less opportunity or possibility to buy and use modern energy sources to feed the family than small family.

The coefficient of household head’s education level at post-secondary level is negative, indicating that households with heads of higher education level have less energy short fall than households with heads of less education. It means, if the household’s head education upgrades to post-secondary level, keeping other variables constant, household’s energy short fall decreases by 0.048%. This can be due to the increased earning by educated families that enables them to use more modern energy and different energy appliances (refrigerator, stove, etc) compared to those households with less educated heads.

The coefficient of owning of electric meter is positive. It indicates that, households with owning of electric meter at their home are more likely to be less energy shortfall than households without owning the electric meter. It means, if the households’ probability of owning electric meter increases, keeping other variables constant, total energy consumption (electricity) increases by 0.032%. This might be due to the easy access to electricity at any time, permitting the households to use more electric power with different energy appliances. This leads to increase total energy amount for domestic uses.

The coefficient of total energy expenditure is positive. It indicates that, households total energy expenditure positively influences total amount of energy consumption. It means, if households’ energy expenditure rise by 1%, other variables held constant, total amount of energy consumption increases by 0.761%. This can be attributed to household ability to spend more money to buy and use more energy options for domestic activities. It also leads to use more quantities of energy.

The coefficient of total household expenditure is negative. It indicates that, as households total expenditure or income increases, the energy short fall decreases. i.e. if households total income rise by 1%, keeping other variables constant, The energy short fall decreases by 0.074 %. This might be due to more income creates more energy consumption to households. It leads to decline energy short fall.

Evaluation of Energy Poverty Regression Model

In logit regression analysis, the log-likelihood ratio which is distributed as a chi-square is computed to test the overall performance of the model. As we have seen in Table 3, the LR/ chi-square is 120.54. It is statistically significance, rejecting the null hypothesis that the overall explanatory variables in the model could not explain the dependent variable. Thus, the predictor variables in the logistic regression model are collectively important in explaining the behavior of energy poverty in Addis Ababa city. Besides, the Pseudo R-square value is 0.55, implying that the model can explain 55 percent of the energy poverty in the city.

In Weighed Least Square analysis, the overall significance test of the model, F-test, is computed to be 133.96 (Table 3) which is statistically significant indicating that the given predictor variables in the model are collectively important and explain the behavior of energy poverty in Addis Ababa city. In addition, the Coefficient of determination or R–square value is 0.75 which indicates that the model explained about 75 percent of the energy poverty model.

CONCLUDING REMARKS

In Addis Ababa city, 40% of the city households have energy inconvenience, 33% have energy inconvenience excess, 42.2 % of the households have energy shortfall and 37.6% of the households are energy poor from socio-physical aspect of energy poverty. The result indicates that, the energy poor households spend more their time and efforts for buying or accessing different energy sources (firewood, charcoal, kerosene and LPG) and Households have energy shortfall .i.e. households do not consume the required amount of energy to meet their energy needs. The key energy poverty factors identified by the study include family size, household head's education level at post-secondary, owning electric meter, total energy expenditure and total household income.

The findings imply the importance of enhancing households' income, education, ownership of electric meter, are instrumental for households to reduce energy short fall for city households. In this context, increasing of households income through education, more accessing of owning electric meter to each households which facilitates to promote more access to different energy sources especially the modern one to city households. It leads to decline energy shortfall.

At last, this study has attempted to address how to maximize household modern energy demand and reduce energy poverty in the city. Different evidences are provided with an extensive analysis of socio-physical aspects of energy poverty estimation at household level. It enables to generalize the results of the study apply to the city. However, there are few questions left open to answer and it suggests the following issues for further research: The energy short fall poverty measurement approach considers only the amounts of energy in kwh for analysis but does not consider the kinds and quality of energy. It suggests, it would be better to measure energy shortfall by quantifying the energy amount by kinds and quality. Besides, it also suggests use of panel data (cross sectional data with time dimension) for integrated energy poverty analysis in large area coverage. It helps to estimate and forecast the whole energy poverty level for urban Ethiopia properly.

REFERENCES

Alemu, M. and Koholin, G. (2008). Determinants of Household Fuel Choice in Major Cities in Ethiopia. Environment fo+r Development: Discussion paper series, EfD-DP-08(18): 1-23.

Betchani, H., Tehereni, M., Grobler, W. and Dunga, S. (2013).Economic Analysis of Energy Poverty in South Lunzu, Malawi. Journal of Economics and Sustainable Development, Vol 4(4), 154-163, 2013.

Bravo, V. (1979). Energy, Poverty and Social Issues in Latin American. Project No, 74:1-2.

Brundtland, C. (1987). World Commission for Environment and Development. Retrieved from http://www.energy for development.com on January 06/2012/energy poverty.html.

CGAA (2013). Annual Reports on Socio-Demographic Situation of Addis Ababa city, Ethiopia. Retrieved from www.addisababacity.gov.et.

CGAA-BOFED (2013). Regional Gross Domestic Products for Addis Ababa City Administration. Addis Ababa, Ethiopia.

CGAA-BPACSP (2010). Atlas of Key Demographic and Socio -Economic indicators of Addis Ababa in 2010.Addis Ababa, Ethiopia.

Collin, C. and Previnka,T. (2005). Micro Econometrics, Methods and Application. Cambridge University Press, UK.

CSA (2008). Ethiopian 2007 Population Census Final Report. Addis Ababa, Ethiopia.

CSA (2010). Ethiopian 2007 Population Census Summary Report. Addis Ababa, Ethiopia.

CSA (2012). Ethiopian Welfare Monitoring Survey in 2011. Summary Report, Addis Ababa, Ethiopia.

Dattalo, P. (2008). Determining Sample Size: Balanced power, Precision and Practicality. Oxford University Press.

DGEP (2011). Access to Different Energy Sources for Developing Countries in European Parliaments, Expo/b/deve/2011/19.

Dhanuska, T. (2008). Energy Poverty Estimating: The Level of Energy Poverty in Sri Lanka. Report No, 3 Submitted to Practical Action to South Asia Countries of Energy Poverty.

Edoumiekumo, S., Tombofa, S. and Moses, T.(2013).Multidimensional Energy Poverty in the South-South Geopolitical zone of Nigeria. Journal of Economics and Sustainable Development, Vol 4(20), 96-103, 2013.

EPA(2012).National Report of Ethiopia: United Nations Conference on Sustainable Development (Rio+20) , Addis Ababa, Ethiopia .

ESCAP (2012). Widening Energy Access and Enhancing Energy Security to Achieve the Millennium Development Goals in Asia and the Pacific. Energy Resources Development Series No, 42, Thailand.

ESMAP (2000). Energy and Development Report 2000: Energy Services for the World's Poor. Washington DC., USA.

Foster, V. and Wodon, Q. (2000). Energy prices, Energy efficiency and Fuel poverty. Latin American and Caribbean Regional Studies Program, World Bank, Washington DC, USA.

Goldemberg, J. (1990). One kilowatt per Capita. Bulletin of the Atomic Scientists, 46 (1):12-26.

GTZ-Sun (2010).Household Energy Base line Survey in Addis Ababa, Addis Ababa, Ethiopia.

Gujarati, D. (2004). Basic Econometrics. Fourth edition, TATA Magrawal Hill edition, India.

IEA (2006). World Energy Outlooks. Paris, France.

IEA (2010). Energy Poverty: How to Make Modern Energy Access Universal? Special Edition for Experts of World Energy Outlooks 2010 on the MDGs, Paris, France.

Karekezi, S .and Mojora, L. (2002). Improving Modern Energy Services for African Urban Poor. Energy policy, 30:25-33.

Khanderker, S., Barnes,D.and Samad,H. (2010). Energy Poverty in Rural and Urban India: Are the Energy Poor also Income poor? Policy research working paper, No, 5463.

Kothari, C. (2000). Research Methodology: Methods and Techniques. Published by K.k Gupta, New Age International Private limited, New Delhi.

Leach, G. (1987). Household Energy Hand Book. An International Guideline and References Manual 67. World Bank, Washington DC., USA.

McFadden, D. (1974). Conditional Logit Analysis of Qualitative Choice Behavior. Economic Theory and Mathematical Economics. Academic Press and Zarembka (ed), New York, USA.

Masera, O., Saatkamp, B. and Kammen, D. (2000). From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model. World Development, 28:2083-2103.

Masud, J., Sharan, D. and Lohani, B. (2007). Energy for All: Addressing the Energy, Environment, and Poverty nexus in Asia. Asian Development Bank, Philippines.

Mirza, B. and Szirmai, A. (2010). Towards New Measurements of Energy Poverty: A Cross Community Analysis of Rural Pakistan. United Nation University (UNU-MERIT), Maastricht Economic and Social Research and Training Center on Innovation and Technology, Energy working series, 024:1-39.

Modi, V. and Goldemberg, J. (2005). Energy Services for MDGs. Jointly Published by World Bank and UNDP, New York, USA.

NMA (2011). National Meteorological Agency of the Federal Democratic Republic of Ethiopia. Annual report for Meteorology in 2010. Addis Ababa, Ethiopia.

Nussbaumer, P., Bazallian, M., Modi, V. and Yumkella, K. (2011). Measuring Energy Poverty: Focusing on what matters: Oxford Poverty and Human Development Initiatives (OPHI). Oxford University working paper, No, 42.

Pachauri, S., Mueller, A., Kemmler, A. and Spreng, D. (2004). Measuring Energy Poverty for Indian Households. World Development, 32(12):2083–2104.

Palit, D. (2011). Lighting a Billion Lives. Presentation at the Regional workshop on Women, Energy and Enterprise Building, Thiruvananthapuram, India.

Reddy, A. (2004). Energy and Poverty: The Analysis of Household's Access to Clean Cooking Fuels in Cote d'ivory. Abidjan.,Cote d'ivory.

UNDP (2009). The Energy Access Situation in Developing countries. A Review of Focusing on Least Developed Countries and Sub Saharan Africa. New York, USA

UNDP (2013). The Rise of the South, Human Progress in a Diverse World. Published for the United Nations Development Program. ISBN 978-92-1-126340-4, New York, USA.

WEO (2004). Energy and Development Measurement Methodology. Chapter 10:329-362. Retrieved from http://www.worldenergy outlook.org/development on the date of Nov 25/2012.

WEO (2010). Energy and Development Measurement Methodology. Retrieved from http://www.worldenergy outlook.org/development aspects on date of November 25/2012.

World Bank (2000). Fuel for Thought: Environmental Strategy for Energy Sector. Washington DC., USA.

World Bank (2011a). Household's Cook stoves, Environment, Health, and Climate Change: A New Look at Old Problem. World Bank, Washington DC., USA.

Yonas, A., Abebe, D., Köholin, G.and Alemu, M. (2013). Household Fuel Choice in Urban Ethiopia: A Random Effects Multinomial Logit Analysis. Environment for Development, EfD -DP -13(12): 1-31.