The Determinants of Energy Choice for Domestic Use in Informal Settlements of North Addis Ababa.

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Abstract

This paper analyzed the determinants of energy choice for domestic use in informal settlements of North Addis Ababa based on the data generated from 450 households in Yeka Sub-city, Woreda[42] 12 using multitier questionnaire. The study identified demographic and household characteristics; energy source related factors; food consumption behaviors; and other variables that influenced informal settlers' energy choice. The binary logit result showed that household heads[43] from 30-60 years of age, education above grade 4, number of dependent families from 1-4, the suitability of dwelling place to the urban plan, number of years a household lived in the area, availability and reliability of energy sources, availability and cost of appliances, and food consumption behaviors significantly affected households access to electric power. It is found that, among households who lived more than 9 years, 74% are electric-users while 26% are non-users of electricity. The findings also indicated that families with higher levels of income, especially when household heads are employed on permanent basis, households living in a very good shelter, and increased number of rooms have better access to electricity while sex of the household head, family size[44], marital status, land title and size, electric tariffs and connection fees and proximity of the home to electric line have no relationships with households electric-use status.

Keywords: Determinant; Energy choice; Domestic use; Informal settlement; Electric use; Addis Ababa

[42] *Woreda is a local term that refers to the lowest administrative unit of Addis Ababa city administration. It is equivalent to county in western countries*

[43] *Household head is the one who has an income and decision making power in family affairs (a husband for married people).*

[44] *Family size refers to the number of people living in one home as family members.*

1. Introduction

Energy is vital for economic and social life of households. In Ethiopia, however, the majority of households heavily rely on traditional resources (plant and crop residues, animal dung, firewood and charcoal) (Muller & Yanb, 2018). The gap between supply and demand for biomass is growing, and the proportion of income spent on energy in urban areas is increasing (Getachew, et al., 2018). The socioeconomic variables affecting households' energy consumption patterns, and the availability and price of biomass vary based on spatial and temporal differences (Ayele & Demel, 2018).

On top of this, informal settlement is an ever growing problem caused by population growth, housing shortage, high cost of living in urban areas, inefficient land provision, illegal land grabbing, and lack of regular legal measures by local governments. This is often associated with the expansion of residential areas in the peripheries of the city. Houses characterized by low quality are constructed on lands where occupants have no secure tenure, and in the absence of inadequate infrastructure and social services (Weldegebriel, 2011; Bosena, 2019). These situations, together with the diverse nature and continuously swelling number of informal settlers, have made the supply of reliable energy more difficult and created high disparity between the urban center and the periphery (Chance, 2009; Prasad, 2010; Sheng, et al., 2017; Bouzarovsk & Herrero, 2017).

Furthermore, the proportion of the population living in urban Ethiopia is growing significantly leading to the ever increasing demand for housing and energy. However, the energy problem of informal settlers' (most are new immigrants) is much worse and deeper than that of the urban and rural people due to their illegal and scattered settlement, lack of secured tenure, low quality housing, low level of electric consumption, inability to pay connection fees and electric services, distance from the electric grid and service providers, and lack of trust on them (Butera, et al., 2016).

Documented evidences indicate that access to electricity in Ethiopia is the lowest (about 58%); the per capita energy consumption is about 100 kWh per year (PIERG, 2017); only about 27% are connected to the grid; energy demand is rising 10-14% per year (WB, 2018); electric supply remained still limited and unreliable generating only 4,284 MW (MWIE, 2017).

In Addis Ababa, informal settlers, with little or no access to electricity, are about 18.3% of the population (Butera, et al., 2016). They face multi-faceted challenges such as lack of access to clean, reliable and affordable energy, frequent interruption and fluctuation of power resulting in damages to households' appliances, and power outages for long hours. The availability of electric power also varies from place to place and in some places, it is difficult to have grid expansion and is expensive to connect (JICA, 2011; Kovacic, et al., 2016).

Availability, reliability and the expensive pricing structure of electric supply are the most important impediment to use clean energy sources in developing countries (Getachew, et al., 2018), and the tariff structure for electric power has now reached a prohibitive level to informal settlers and low-income households.
As a result, residents are forced to use low-grade fire, less heat and more smoke producing traditional fuels that cause a wide range of health problems associated with indoor air pollution. Since these fuels have become a major threat to the environment, consume a lot of time and family labor, households are forced to buy power from private suppliers and expensive candles (Moeen, et al., 2015; Soltani, et al., 2019; O.O., et al., 2016). Biomass remained the major source of lighting, cooking and heating and has no substitute for cooking traditional foods (Belay & Aberham, 2015).

Because of the current land ownership system and low economic status, electricity is primarily used by households for lighting, refrigeration, charging batteries, watching television and listening to radios as they do not require much energy; however, it is still vital for cooking and baking.

A number of studies have been conducted to relate decision on energy consumption of households with their socio-economic characteristics and climate variability. They emphasized on the influence of income, per capita energy expenditure, price of energy, gender and education on households' energy choice in rural and urban areas (Bisu, et al., 2016; Makonese, et al., 2018; Rahuta, et al., 2019; Yonas, et al., 2016). But less attention has been given to informal settlers' socio-economic backgrounds, current settlement patterns, and the influence of land ownership on energy choice.

This paper, therefore, examined what really determines informal settlers' choice of energy sources and analyzed the factors that determined access to electricity for domestic use in North Addis Ababa. It showed informal settlers' access to energy sources and the relationship between informal settlers' access to electricity and land

tenure, housing condition**,** physical location, employment condition, income levels, education and the length of time a household lived in the area. It mainly considered the availability, reliability and affordability of energy sources for domestic use and food consumption behaviors of households in the decision of energy choice.

It provides firsthand information for decision makers in the energy sector and gears the trajectory of the government towards up-scaling, creating alternative energy options and identifies households entitled to get subsidy and outreach service. It also provides information to creditors, donors and funding agencies working with the poor and marginalized sections of the society, by indicating a promising way to improve the living condition of informal settlers.

The remaining part of the paper is organized in five sections. The second section presents the literature reviews and some empirical findings. Section three explains data sources and methods used in the research including description of the study area, justification for selecting the area, and sample design. Section four presents the results of the study and discusses their implications in relation with prior studies. The final section presents the conclusion by providing major findings and policy implications.

2. Literature review

Understanding the key factors determining households' energy choice and consumption level is very essential either to apply developmental fuel switching path of energy ladder hypothesis or to integrate multiple energy sources with the concept of energy stacking (Agizew, 2017; Ateba, et al., 2018; Soltani, et al., 2019). The energy ladder hypothesis is an extension of consumers' economic theory that contends as consumers' income increases, households substitute inferior goods by luxury goods. On the other hand the concept of fuel stacking provides multiple fuel use options (both from the lower and upper levels in the energy ladder) to households due to shortages of modern energy sources, fluctuating energy prices, households prior energy consumption habits, resistance to adopt new energy sources, high cost of modern appliances and the reasons for choosing energy sources are different for different locations (Bisu, et al., 2016; Muller & Yanb, 2018).

Empirical studies indicated that households' energy choice and consumption patterns are influenced by socio-economic factors (such as sex, age and educational level of the head of the household, family size and income), availability and price of energy sources, the prevailing weather condition /season of the year/, house ownership, type

and condition of home owned, nearness to the energy sources and familiarity of household to the energy source (Danlami, et al., 2015; O.O., et al., 2016; Butera, et al., 2019; Soltani, et al., 2019). A relationship between energy consumption and appliances used with house condition and number of rooms owned by households was also established (Wiesmann, et al., 2011; Muller & Yanb, 2018).

The research findings of these studies pointed out that all factors are not equally important in explaining households' consumption behaviors, the factors are significant at different levels and some results are even contradictory (Danlami, et al., 2015; Amoah, 2019). For example, wealthy households and families headed by individuals with higher education levels are less likely to use kerosene and more likely to depend on electricity. They spend relatively more on clean energy sources, decreases in per capita energy use as family size increases and female-headed households are more likely to use fuel wood and kerosene (Rahut, et al., 2017; Muller & Yanb, 2018).

Several others revealed that as income rises, multiple energy source approach (fuel stacking) describes households' fuel-choice behaviors. They explained this idea based the expenditure approach. That is, when households' total expenditures rise, the number of fuels used and the amount expenditures made for fuels increase and fuels such as wood and charcoal are not even considered as inferior goods (Alemu & Köhlin, 2008; Fantu, et al., 2015; Agizew, 2017).

According to Young, et al., (2018) and Soltani, et al., (2019) wealthier households adopt modern energy sources and energy efficient technologies and the poor are forced to use biomass energy is found irrelevant. This is because non-economic factors such as unreliable electric supply, prohibitive energy prices, and food consumption habits, preferences and cooking practices that are part of the local culture are gaining momentum and guide households' energy consumption decision (Ateba, Prinsloo, & Fourie, 2018). For example, in Ethiopia and Iran increased use of electric power leads to progressive tariff increments (Soltani, et al., 2019) and this has become a barrier to shift to electricity. On the other hand, studies from Nigeria revealed that households living in traditional houses are less likely to choose natural gas and electricity over fuel wood and access to electricity had no significant association with households' cooking practices as Nigerians relay more on kerosene (Baiyegunh & Hassan, 2014; Ifegbesana, et al., 2016) and a higher education level induces households to move away from firewood dependence towards the use of

kerosene and LPG in Nigeria and electricity and solar energy in Ethiopia and Kenya (Baiyegunh & Hassan, 2014; Gebreegziabher, et al., 2012; Lay, et al., 2013). Yet households tend to use more cleaner and expensive fuels and less traditional fuels.

2. Data and Methods

2.1. Description of the Study Area

This study was conducted in North Addis Ababa, Yeka sub city, *Woreda* 12. The city of Addis Ababa is located at about 9°3'2"N, 38°52'41"E and found at 2,450 meters above sea level. Like any other developing cities, it has faced multiple development challenges such as urban expansion in a sprawling manner resulting in an estimated 46% of unutilized or underutilized land, extremely high density (up to 30,000 people per square km) at the city center, while the national average is 108 people per square km, and around 30% of the population living on 8% of the city's land with poor living conditions (UN, 2018)**.**

Geographically, the study area is situated in the outskirt of Addis Ababa (Fig. 1). According to the residents, 78% of the informal settlers have access to roads and transportation, 80% have access to education and health centers, 20% of the inhabitants live around river banks and low laying areas, 47% live close to forest resources, and 38% are located in a rugged topography/hilly areas. Based on the pilot survey, there are very large numbers of informal settlers in the *Woreda.* They are specifically located in sites such as *Kotebe Gebriel*, *Hibret Amba*, *Rediet*, Happy Village, *Mesalemia*, Sara Park, Kara and *Demamit* sites.

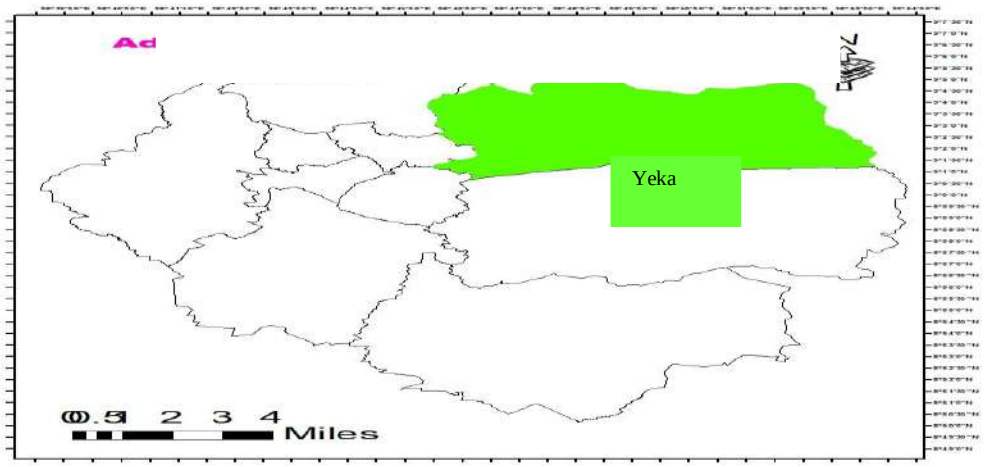

Figure 1: Map of Addis Ababa City Administration

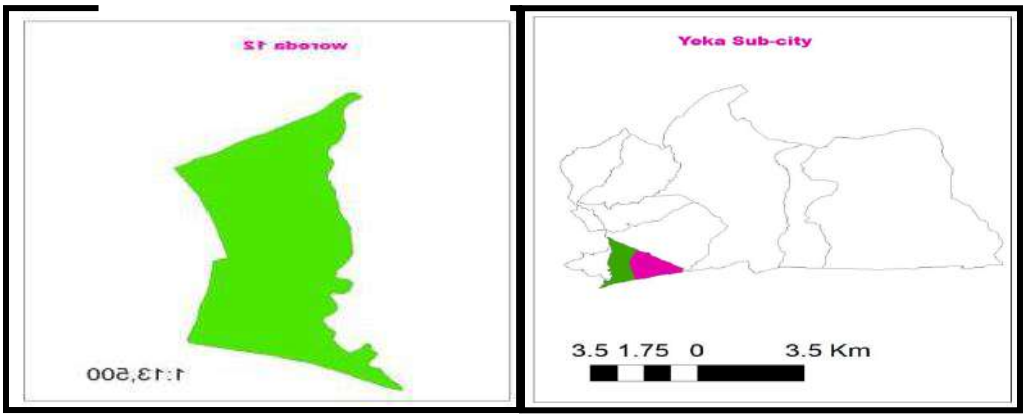

Fig. 1b: Yeka Sub-City and its *Woredas* study site

Fig. 1c: *Woreda* 12, the specific

Note: When the study began, the purple color was part of Woreda 12. But now it is a separate district (Woreda 14)

Figure1: The physical location of the study area

2.2. Sampling and Data

Considering the existence of a very large number of informal settlers and the availability of energy saving stoves, our analysis is down-scaled to district, site and household level and samples were drawn in three stages. First, North Addis Ababa, where *Woreda* 12 of Yeka sub-city is located, was purposively selected based on the pilot survey. In the second stage, a list of seven sites of electric-users[45] (2026 households) and three sites of non-users[46] of electricity (664 households) were identified. These data were obtained from the registry book and the electronic data base of *Woreda* 12 Administration and served as a sample frame. Then, two sites from electric-users (*Kotebe Gebriel* and *Hibret Amba*) and two from non-users of electricity (*Kotebe Gebriel* and *Demamit*) were selected on non-random or purposive sampling method to have a balanced number of households from each site. Finally, the 450 sampled households were selected on proportional method that gave equal

[45] *Electric-users are households using electric power for cooking and baking, in addition to lighting. They get this electric power from the Ethiopian Electricity Utility legally or from their neighbor by sharing electric cost.*

[46] *Non-users refer to households who either use electric power from their neighbors only for illumination purpose or those who do not use it at all.*

chance to each site. However, due to lack of legal living status of informal settlers, strict randomization was not possible to select households for the study.

Primary data were obtained using a multi-tire questionnaire that helped to capture information about informal settlers' energy sources, the purpose of energy use, the factors influencing their energy choice, and estimates of households' energy consumption levels. The questionnaire was structured to cover households' socioeconomic characteristics, food consumption behaviors, energy source related and other factors. It was administered on 450 randomly drawn households found in *Kotebe Gebriel*, *Hibret Amba* and *Demamit* representing 2690 informal settlers. The survey was managed by the researcher and properly selected, well trained and closely supervised enumerators. The list of informal settlers that served as sample frame was obtained from the registry book and computerized data base of *Woreda* 12 Administration. The data were collected in April and May 2020.

In descriptive research, since opinions and attitudes are often susceptible to distortion and personal biases, field observation is very critical. To this end, the landscape and the availability of physical infrastructures of the study areas were observed during the pilot survey and data gathering stage. Then the validity and reliability of data were checked first by closely monitoring the activities of data collectors, and then the completed questionnaire and the consistency of the answers provided by the respondents were validated.

2.3. Method of Data Analysis

One of the most potent and versatile tools used to analyze the determinants of households' electric use and their consumption patterns in informal settlements is binary logit model supplemented by descriptive statistics. The study was carried out based on the premise that sources of energy and consumption patterns vary among urban dwellers based on their land ownership status, income groups and the residents' geographical location. It assumes a value of 1 if the household is electric-user for domestic use, and a value of 0 for otherwise, and measures the odds of using electric power. The dependent variable of this model is households' access to electricity where some have electric connection and use electric power for domestic use while others do not. The model used to estimate the probability of a household using electric source is (Soltani, et al., 2019):

$$Y_i = \beta_0 + \beta_i X_i + \varepsilon_i$$

Where Y_i denotes dependent variable (i.e., electric use status); β_i are parameter estimates; X_i are factors affecting households' electric use status; and ε_i are error terms.

This model helped to determine the regression coefficients and the significance level of each considered factor. The independent variables of the regression model, hereafter called determinants of energy choice, are Demographic and Household Characteristics (DHCs); Energy Source Related Factors (ESRFs), Households' Food Consumption Behaviors (HFCBs) and other factors.

3. Results and Discussion

3.1: The Determinants of Households' Energy Choice: Descriptive Analysis

3.1.1. Demographic and Household Characteristics (DHCs)

1. Sex and Age*:* Gender-based electric-use status survey showed that, from the total of 450 households, 63% were male headed households while 37% were female headed. In terms of electric use status, 60.24% of male headed households and 39.74% of female headed households used electric power for domestic purpose. On the contrary, 33.94% of male headed households and 66.06% of female headed households were non-users of electricity. Similarly, among males, 48.59% were electric-users while 51.41% were non-users of electricity, whereas, among females, 54.82% were electric users while 45.18% were non-users of electricity. These results suggest absence of relationship between the gender of the household head and his/her access to electricity. On the contrary, the findings of Rahuta, et al (2019) showed that female-headed households were more reliant on fuel wood.

In terms of subjects' age, about 88.65% of electric-users and about 85.52% of non-users were between 30-60 years. Although the difference between the number of electric-users and non-users in the same age interval was narrow, it implied that there is still relationship between the status of households' electric-use and age brackets. In other words, household heads from 30 to 60 years of age had a positive effect on their electric access. But the energy consumption experience of rural households in Nigeria generally indicated that when the age of the household head increases, they tend to shift away from natural gas and use more fuel wood while Ethiopians are more likely to consume charcoal and less kerosene and electricity

(Gebreegziabher, Mekonnen, Kassie, & Köhlin, 2012; Baiyegunh & Hassan, 2014). On the other hand, the study conducted in Iran revealed that there was inverse relationship between electricity consumption and the age of household head, i.e., a reduction in the age of household head led to nearly 50% increase in the electricity consumption (Soltani, et al., 2019).

2. **Family size***:* According to Peng, et al., (2010) and Soltani, et al., (2019), under citrus paribus assumption, as family size increases, households' energy consumption increases. In this study, 12% of households had less than 3 /family members, 54% had 3-4 and 34% had more than 4 family members. Among electric-users, 11% had less than 3 family members, 53% have 3-4 family members, and 35% had more than 4 family members. The number of families using firewood and charcoal also fluctuates indicating there is no predictable pattern of relationships between family size and type of energy consumed by households in informal settlements.

3. **Marital status***:* The survey data showed that among electric-users, 85% were married, 12% were single, and 3% were divorced, widowed and separated. Among non-users of electricity, 71% were married, 24% were single and 5% were divorced, widowed and separated. These data showed that, although married electric-users constituted the majority, still this group made up the largest among the non-users of electricity. This implies that marital status does not guarantee households' access to electric power.

4. Education level of household heads: In this study, 30% of households were less educated (below grade 9) of which 75% were non-users of electricity. Among households who were better educated (grade 9 and above), 63% were electric-users. Specifically, among electric-users, 2.62% (6 households) were below grade 4, 12.23% (28 households) were from grade 4-8, 25.76% (59 households) were from grade 9-Diploma, and 59.36% (136 households) were degree holders and above. These data showed that with higher levels of education, the number of households using electricity increased consistently and in a progressive manner. Studies by Ayele (2019) and Yonas, et al., (2016) also revealed that households headed by individuals with higher levels of education were less likely to use kerosene and more likely to depend on electricity. As described by Yonas, et al., (2016) and Bisu, et al., (2016), this is because education speeds up cultural changes on households' energy consumption behaviors and a key variable to switch from lower level energy sources to clean energy sources.

3. **Family income***:* It is expected that households' access to electricity is influenced by family income. With an increase in income, households are more likely to shift to clean energy sources and the percentage of biomass use is expected to decrease (Rahuta, et al., 2019). In this study, the number of households using electricity and biomass for domestic use increased with an increase in family income. The increase in the consumption of firewood and charcoal by non-users of electricity was mainly due to the low income of the family.

To corroborate the relationship between family income and electric use status, data on household heads' employment status and type of employment was organized. The result showed that 56% were hired, 38% were self-employed. 4% were unemployed, and 2% were retired. The proportion of electric users that were hired was 68% while non-users of electricity was 32%. This implies that hired household heads are more likely to get access to electricity than those who are unemployed because the former have stable income to pay for electric bills.

Furthermore, 91% of hired household heads were permanent employees, 8% were contract, and the rest 1% were daily and/or hourly laborers. Among the permanent employees, 71% were electric-users indicating that there is a higher chance of getting electric power if a household head is employed on permanent basis.

3.1.2. Energy Source Related Factors (ESRFs)

1. **Availability and reliability of energy source***:* Households in informal settlements commonly use firewood, charcoal and electric power for domestic use. The study result indicated that 5% of the electric-users and 49% of non-users of electric power consume firewood and charcoal for baking and only 2% of electric-users and 47% of non-users of electricity use the same source for cooking. Similarly, among the electricity users, 48% use electricity for baking purpose, and 51% consume the same source for cooking.

The availability and reliability of energy supply determines households' energy choice in informal settlements. The study result on Fig. 2 below showed that firewood and charcoal were widely available and reliable (67%), followed by electric power (32%). Specifically, 53% of electric-users indicated that electricity was available 3-5 days per week, 42%, 6-7 days per week, 3% 1-2 days per week,

and 2% none at all. The overall electric supply situation in informal settlements was found to be moderate as rated by 60% of current electric-users and the remaining 40% indicated the existence of frequent interruption and power fluctuation.

2. Price of energy sources*:* The most expensive energy sources in the study area, as described by 47% households, were kerosene and LPG, whereas 35% reported that electricity was the most unaffordable source and the remaining 18% reported that they could afford firewood and charcoal (Fig.2). This implies that traditional sources are the cheapest source of energy while kerosene and LPG are the most expensive sources of energy in informal settlements.

In an effort to evaluate the existing electric tariff, 33% of households considered it cheap as it is a subsidized source, 45% said it is cost effective, and 21% rated it expensive. Generally, 78% of the households considered electric tariff is either low or covers its cost. The residents expressed their concern that because of excessive population growth, increased energy use and energy shortages may escalate electric prices in the future. The high price has no effect on the status of households' electric use. Instead, 61% of non-users of electricity were willing to share the electric meter with their immediate neighbors and pay the service charge together.

The survey data revealed that the cost of electric connection in the study area ranged from 650-10,000 birr[47] depending on the proximity of the house to electric line and the period when the electric connection was made.

[47] *Birr is the currency of Ethiopia. The average official exchange rate in April 2021 was 1USD = 41 Birr*

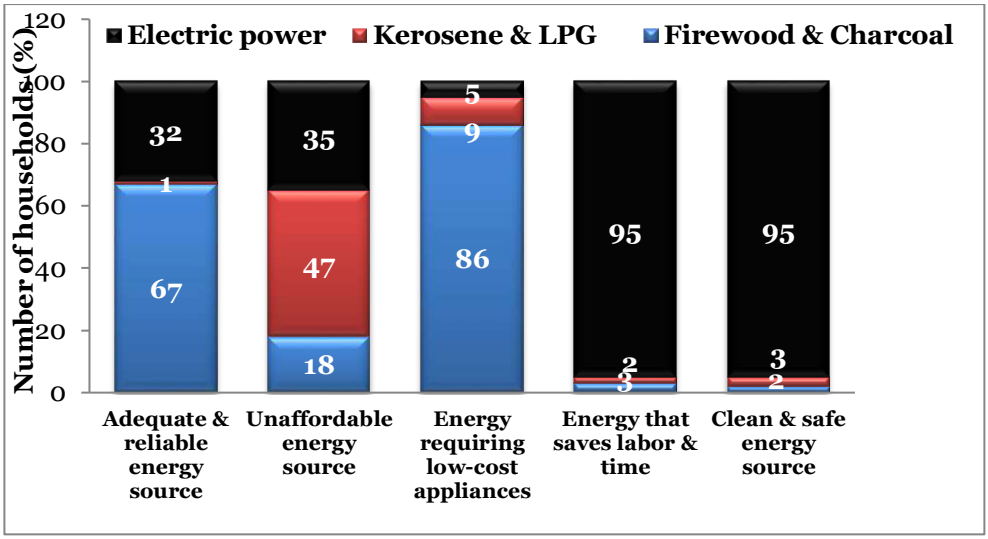

Fig.2: Energy Source Related Determinants

3. Technological, socio-economic and environmental reasons*:* Households also choose energy sources based on their short and long-term effects. Some choose due to the availability of efficient appliances at low cost in the market (technological reasons). Others use energy sources that save family labor, time and reduce the work loads of women and children (socio-economic reasons), and still others choose energy sources that are clean and healthy (environmental reasons). For example, 86% of the households chose firewood and charcoal, and 14% electricity, LPG and kerosene for technological reasons. On the other hand, 95% of the households chose electricity and 5% chose firewood, charcoal and kerosene for socio-economic and environmental reasons (Fig.2). This implies the need to balance households' technological, socio-economic and environmental requirements.

It is also observed that 86% of electric-users and 99% of non-users used firewood 1-3 times per week for baking (Table 1). This implies that electric-users used both electricity and biomass while non-users of electricity solely relied on traditional energy sources for baking. For cooking purpose, 69% of electric-users and 52% of non-users used firewood at least once a day indicating that when non-users of electricity do not use firewood, they either do not cook at all or cook using charcoal. But for electric-users, in addition to electric power, they had two options (firewood and charcoal). Because of this, 97% of electric-users and 68% of non-users cooked food 1-2 times per day using charcoal whilst electricity was solely used for baking

and cooking by households who had access to it. These empirical evidences showed that in addition to electric power, electric-users used more charcoal than non-users of electricity and such unfair use of scarce resources may raise controversies among citizens.

Table 1: Households' Frequency of Energy Use

Energy source	Purpose of energy use	User status	Frequency of energy use (%)				
			None	Once	Twice	3-times	Above 3
Firewood	Baking/week	Electric-users	23	54	15	7	1
		Non-users	-	3	70	26	1
	Cooking/day	Electric-users	31	60	9	-	-
		Non-users	48	15	25	7	5
Charcoal	Cooking/day	Electric-users	1	62	35	2	-
		Non-users	1	15	53	18	13
Electricity	Baking/week	Electric-users	-	11	61	21	6
	Cooking/day	Electric-users	1	6	50	37	6

The average, minimum and maximum energy expenditure per month and the number of households using each source is compiled from survey results and provided in Table 2. Based on these data, the average expenditure for firewood was the highest. This may be associated with shortage and increasing price of charcoal, and most households' lack access to reliable electric supply.

In terms of households' status of electric-use, except for firewood, the proportion of electric-users consuming all energy sources was higher than the number of non-users of electricity. The main reason for this was that those who already had access to electricity were using traditional sources, and the overall effect of this practice is unfair utilization of natural resources, air pollution, and posing series health problems to human life.

Table 2: Households' Monthly Expenditures for Alternative Energy Sources Based on Electric Use Status

Energy source	Monthly expenditures (Birr)			Number of households	
	Mean	Min.	Max.	Electric-users	Non-users
Firewood	402	60	1200	204	219
Charcoal	248	50	800	226	221
Kerosene	132	20	400	96	76
Electric power	301	25	1200	229	165
All sources	938	200	2100	229	221

Table 3 shows the influence of households' family income on the consumption of various energy sources. When we try to relate expenditures made for energy sources with family income, the number of households expending for each source increased consistently with the increase in family income up to 9,000 birr, and then sharply dropped after this point. This was mainly because, with higher income levels, the number of households earning high income generally decreases. Specifically, households whose family income per month was below 9,000 birr mainly used firewood and charcoal while those whose family income was above 9,000 birr used more charcoal and electricity. They spent on average 402 birr for fire wood and 248 birr for charcoal. This indicates that while firewood was more used by low-income households, charcoal and electricity were used by high income groups. Furthermore, the usage rate of charcoal is high, whereas Kerosene is the least utilized energy source, and is used temporarily or for emergency purposes.

Table 3: Number of Households, Average Monthly Energy Use Based on Family Income and Energy Source

Energy expenditure (Birr)	Family Income per month (Birr)				
	Up to 3,000	3,001-6,000	6,001-9.000	Above 9,000	Total
Firewood					
Up to 285	8	23	71	53	155
285-570	7	42	73	30	152
Above 570	3	32	69	12	116
Total	18	97	213	95	423

Charcoal					
Up to 188	8	28	80	61	177
189-376	7	50	92	37	186
Above 376	2	23	53	6	84
Total	17	101	225	104	447
Kerosene					
Up to 95		9	29	34	73
96-190	1	5	31	21	58
Above 190	1	9	24	8	41
Total	2	23	84	63	172
Electricity					
Up to 294		63	96	23	194
295-588	12	17	69	68	157
Above 588	3	6	26	11	43
Total	15	86	191	102	394

3.1.3. Households' Food Consumption Behaviors (HFCBs)

As presented in Table 4, informal settlers' choice of energy is influenced by households' food consumption behaviors. This is measured by the number of households using each energy source. In light of this, influenced by cultural factors and individual's long standing consumption habits, households preferred using animal dung, firewood and charcoal to add to the taste and flavor of food staffs, to roast coffee beans and prepare coffee, to fry and dry cereals such as sweet corn and potato chips, and to cook traditional dishes such as *'Doro Wot*[48]' and *'Shiro Wot*[49]*'*. In relation to this, one respondent said that *"Let alone women and old people, even children can identify the taste and flavor of foods cooked by traditional energy sources and* enjoy the heat and fume of biomass.'' They associated their energy choice with the way they grew up (cultural influences). However, some disagreed with the claim *'the type of energy used gives the preferred taste and flavor to food staffs'* and strongly believed that was due to the way the food is cooked or baked.

[48] *Doro wot (chicken sauce) is chicken cooked occasionally, often during holidays, and the best cultural dish in Ethiopia.*

[49] *Shiro wot (sause), which is prepared from grounded peas, beans and other cereals, is a regular food for most poor people in Ethiopia.*

Many households used electricity for baking *Injera*. This was because it is quicker and/or saves family labor and time, plus it is clean and healthy source of energy. On the other hand, many electric-users and non-users preferred to use a mix of two or more energy sources to get a variety of food staffs, take enough meals per day, cook foods frequently, and get fresh foods on time. This could be mainly associated with lack of one reliable source of energy, low power supply in the area, especially during peak hours, the need to save labor and time by using two sources at the same time, and during emergencies.

Table 4: Households' Food Consumption Behaviors and Energy Choice

Purpose of energy	Firewood & charcoal		Kerosene & LPG		Electric power		Two or more sources	
	Users	Non-users	Users	Non-users	Users	Non-users	Users	Non-users
1. To add the taste and flavor of food staffs	150	117	-	3	1	4	78	96
2. To roast and boil coffee	209	192	2	3	6	18	12	8
3. To dry and fry cereals	222	199	2	4	3	17	2	1
4. To prepare cultural Ethiopian dishes	164	145	2	3	38	39	25	34
5. To bake Injera[50] and bread	37	78	1	4	164	107	27	32
6. To get food variety	8	38	-	2	41	11	220	169
7. Frequently cook food and get fresh food	1	3	-	10	6	32	222	174
8. To increase the number of meals in a day	21	8	-	2	2	24	206	186

[50] *Injera is flatbread traditional staple food made from fine iron-rich Teff (agricultural product typically grown in Ethiopia) sometimes mixed with wheat, barley or sorghum flour.*

3.1.4. Other Factors

1. **Shelter type***:* The data indicated that 76% of the households lived in either good or very good house conditions and 24% in very poor houses made of wood and mud. Among electric-users, 86% lived in good or very good houses and 14%, in poor houses. On the other hand, among non-users of electricity, 66% lived in either good or very good homes, and 34% lived in poor homes. These figures illustrate that households living in a very good housing condition are more likely to get electric access followed by those who have mixed type or good homes. That is, as households' shelter type and condition improves the tendency to get access to electric power increases.

2. **Number of dwellings in the house***:* The survey data showed that the number of electric-users who owned one room were 3%, who owned two rooms were 20%, who owned three rooms were 32%, and who owned more than three rooms were 46%. But the number of non-users of electricity who owned more than 2 rooms were less than the number of electric-users. This simple comparison indicates that as the households' number of rooms increases, informal settlers' access to electric power increases. This corresponds with the findings in Mozambique where house size measured by the number of rooms has direct association with the adoption of electricity (Arthur, Zahran, & Bucini, 2010).

3. **Number of years lived in the area***:* The number of years households lived in the area varies considerably, and significantly affects households' access to electricity. For example, 77% of electric-users and 38% of non-users of electricity lived more than 6 years in the area. On the other hand, the number of electric-users connected to electric line in the last 5 years was 36% and those before 5 years was 64%. All these indicate that informal settlers' likelihood of getting access to electricity increases when the number of years lived in the area increases.

4. **The suitability of the living area to the urban plan***:* In an effort to know the opinions of the households on the suitability of the dwelling space for living in accordance with the urban plan, 68% of electric-users and 50% of non-users believed their homes are not located in a suitable living area and convergent with the urban plan. This situation affected households access to electricity.

5. Land title and land size*:* The informal settlers owned land through different means. The households described that 71% of them owned land through purchasing from private land owners or native people in the expansion areas of the city; 6% through informal means; and 23% reported that they inherited it from their parents.

According to the land policy of Ethiopia, individuals have the right to use the land under their custody but cannot sell or transfer it to a third party by any legal means except through inheritance. In view of this, about 77% of all sampled households were typical informal settlers, and 23% were legally recognized as formal urban dwellers. Surprisingly, however, all households who inherited land from their parents were still considered as informal settlers, and because of this, 41% of them did not use electric power for baking and cooking. Conversely, 48% of typical informal settlers had access to electric power. The respondents believed that the main reasons for owning land through purchasing or other illegal means were excessive population growth, shortage of urban land, restrictive housing policies that favors the formal residents, but gives less attention to the housing sector.

The minimum land size under the custody of a household in the informal settlements was $71m^2$ while the maximum was $400m^2$, and the average land size was $172m^2$. By the way, 88% of them owned below $240m^2$. Among these households, 48% were electric-users, whereas 52% were not. This implies that there is no discernible pattern of relationship between land size owned by informal settlers and their access to electricity. But among households who owned more than $240m^2$ land, 73% were electric-users while 27% were not.

6. Proximity of households' home to electric line*:* Distance between non-users' home and the nearest electric line or a transformer can also restrict access to electricity. Survey results showed that non-users of electricity lived between 8 to 700 meters away from the nearest electric pole or a transformer, the average being 105 meters. About 89% of non-users of electricity were situated within 200 meters radius from the electric facility.

However, compared to electric-users, 60% of non-users of electricity were not far from the existing infrastructure and, most of them lived around one area. This indicates that proximity and geographical location of the home of non-users of electricity cannot be factors for restraining them from getting access to electricity.

Basically, the majority of non-users of electricity lived among electric-users, who are either legal or informal, but were given the privilege to use electric power. This result seems to contradict with the findings of Mekonnen & Kohlin (2008) that showed that households in Addis Ababa have better access to electricity and kerosene. However, this conclusion applies only to legal residents.

The households' choice of energy sources, consumption behaviors, and conservation measures in informal settlements also depend on socio-cultural factors, personal feelings and lifestyles. Survey results illustrated 68% of the households believed that socio-cultural factors influence their energy choice and 90% attributed their energy choice to their personal feelings, lifestyles and preferences.

3.2. The Determinants of Households' Energy Choice: Econometric Analysis

Determinants of households' energy choice can be measured by comparing electric users and non-users of electricity along a spectrum of relevant covariates using the binary logit model presented in Table 5. The model helps to evaluate the relationships between households' status of electric-use and the potential factors affecting it; estimate the coefficients of determinants of households baking and cooking; and explain the direction and strength of relationship between the outcome and covariate variables (Mwaura, Okoboi, & Ahaibwe, 2014).

The number of valid households considered for this analysis was 442 (98.22%), and the model fitting information described by the -2 Log Likelihood (-2LL) ratio represents the proportion of unexplained variance in the outcome variable. It assumes that the final mode is a better fit for our analysis because it helps to predict better than without those variables (intercept only model). Alternatively, the chi-square test (Pearson's goodness-of-fit) is significant, χ^2 (27) = 311.862, p<0.001, which is even below the standard cutoff point, 0.05. Similarly, though higher values of Pseudo R^2 closer to one indicates better fit of the model, the outcome of this study is above average (Pseudo R^2=0.5092).

Analysis of residuals associated while estimating outcomes of the logistic regression model indicated that the linearity and homogeneity of variance assumptions are met. This is because the points along the scatter plot are symmetrical, both above and below a straight line, and observations are almost equally spaced along the observed and predicted lines.

The existence of outliers was checked using the normalized residual table. Based on the cutoff point of the absolute value of 2.0 (Scalelive, 2016), and 14 values from extremely low and upper margins that together constitute 5 values or 4.3% of the total valid observations are outliers and, thus dropped from consideration.

The reference category or the base outcome was selected using the first, the last or the highest numbered category (UCLA, 2020). For this particular case, the largest number and first group in the order of presentation (that is, electric-users) were chosen. The parametric estimates of the determinants of households' electric use status, the standard errors, and the p values were estimated using binary logit model. The determinants considered were broadly classified into DHCs, ESRFs, HFCBs and other factors. Then each variable was compared to the reference category to determine whether it is statistically significant and enriches the determinants of energy use model meaningfully. The output of logistic regression analysis is presented in Table 5 below.

3.2.1. Demographic and Household Characteristics (DHCs)

According to Yonas, et al, (2016) and Makonese, et al., (2018), demographic factors such as household size, education, level of wealth and price of alternative energy sources determine households' fuel choice in urban Ethiopia and SSA. In this study, the influence of six DHCs (i.e., household heads' sex, age, education level, family size, family income per month, and number of dependent families in the household) on electric-use was tested. The result after long iterative process showed that age brackets between 30-60, educational attainment above grade 4, and the number of dependent families between 1-4 was statistically significant (Table 5).

For instance, given all other explanatory variables in the model constant related to electric-users, the number of non-users of electricity aged between 30-45 years was greater by 0.97 units, and those between 45-60 years by 1.90 units. This means, the number of non-users of electricity within 30-60 years of age was greater than that of electric-users; attesting an increase in the age of household head had no relationship with the likelihood of getting access to electricity.

Education wise, holding all other variables in the model constant, compared to electric-users, the number of non-users of electricity between grades 4-8 was less by

1.25, grades 9-diploma by 2.23, and above degree level by 2.75 units. This means, the number of non-users of electricity was less than that of electric-users at education level above grade 4. This indicates that electric-users were more educated than non-users of electricity and the likelihood of getting access to electricity increases when the education level of households increase.

Similarly, keeping all other variables in the model constant, compared to electric-users, the number of non-users of electricity with 1-2 dependent families was smaller by 1.06 and the number of those having 3-4 families was smaller by 2.19 units. This means non-users of electricity had smaller dependent families than electric-users; thus, as the number of dependent families in the household increases, the likelihood of getting access to electricity increases.

3.2.2. Energy Source Related Factors (ESRFs)

A relationship has been established between electric-use and factors such as availability and reliability of energy sources, affordability of monthly expenditures, the availability of energy efficient appliances, appliance cost, the effect on saving family labor and time, and clean and healthy energy source. From among those factors, only availability and reliability of energy source, availability of energy efficient technologies, and the cost of these appliances had significant p-value and determine the status of households' electric-use (Table 5). In line with this, controlling the influence of all other explanatory variables in the model constant related to electric-users, the availability and reliability of electric power for non-users of electricity was less by 3.15 units than that of firewood and charcoal. This implies that firewood and charcoal were relatively widely available for non-users of electricity, while electricity was relatively widely available for electric-users. In other words, availability and reliability of electric power determines non-users' access to electricity not only for lighting, watching TVs and charging their batteries and mobiles but also for baking and cooking.

In getting efficient and low-cost technologies (like electric stoves, florescent lights and other power saving appliances), holding all other variables in the model constant related to electric-users, the availability of low-cost electrical appliances was less by 2.45 but their cost was higher by 2.05 than that of biomass stoves and appliances for non-users of electricity. In other words, low-cost electrical appliances were less available and their cost was more expensive for non-users of electricity. On the

contrary, biomass stoves and appliances were better available and relatively cheaper for non-users of electricity.

3.2.3. Households' Food Consumption Behaviors (HFCBs)

To evaluate the influence of HFCBs on electric-use, variables such as food variety, cooking frequency, taste and flavor of food, number of meals taken in a day, roasting and boiling coffee, drying and frying cereals, cooking cultural dishes, baking Injera and bread were considered in the binary logit model. However, only two factors (drying and frying cereals and cooking cultural foods) were found statistically significant (Table 5). That means, keeping all other predictive variables in the model constant related to electric-users, non-users of electricity who dry and fry cereals using electric power were less by 2.59 than using biomass for the same purpose. This means, non-users of electricity used more biomass for drying and frying cereals than electric-users. This could be associated with non-users' low level of income.

Likewise, for cooking cultural dishes like Doro *Wot* and *Shiro Wot*, compared to electric-users, the number of non-users using electric power was less by 1.21. Those who use a mix of two and more energy sources by are less by 1.08 than those using firewood and charcoal. This implies that both electric-users and non-users of electricity prefer to use biomass to electricity to cook cultural dishes. This could be due to households' food consumption habits, lack of reliable electric supply and high electric tariff.

3.2.4. Other Factors

Finally, the effect of other factors such as dwelling place suitability to the urban plan, shelter condition (type and size), number of rooms in the house, years lived in the area, socio-cultural influences, and personal feelings, and lifestyles were assessed. But significant relationship was found only with suitability of the living area as described in the urban plan, number of years lived in the area, socio-cultural influences, personal feelings, and lifestyles (Table 5). For instance, though both users and non-users of electricity were informal settlers, 59% of them believed that their living area is not suitable to the urban plan. Therefore, given all other explanatory variables in the model constant related to electric-users, the number of non-users of electricity who believed that their dwelling place was suitable for residential purpose and the urban planning was less by 1.23 units than that of

electric-users. This means, electric-users' residential area was relatively better suitable as per the urban plan than that of non-users of electricity It seems that the Ethiopian Electric Utility (EEU) provided electric connection to the residents by considering the future possibilities of formalizing the informal settlers.

Likewise, under citrus paribus assumption, compared to electric-users, the number of non-users who lived in the area between 4-6 years was lower by 0.99, those who lived in the area for 7 to 9 years by 1.96, and those who lived in the area for more than 9 years by 2.57 units than those who lived for less than 4 years in the same area. This means, the electric-users lived relatively longer periods in the area than non-users of electricity indicating the strong relationship between the number of years informal settlers lived in the area and their likelihood of getting access to electricity.

Table 5: Determinants of Households' Electric Use Status: The Binary Logit Model

Number of obs	=	442
LR chi2(27)	=	311.86
Prob > chi2	=	0.0000
Pseudo R2	=	0.5092
User status	**Coef.**	**Std. Err.**
1. DHCs		
Age	0.9672***	
30-45	1.9010*	0.5525
45-60	1.1305	0.5968
Above 60		1.0130
Education	-	
Grade 4-8	1.2487***	0.7300
Grade 9-Diploma	-2.2291*	0.7181
Degree and above	-2.7536*	0.7331
Number of dependent families		
1-2 families	-1.0600**	0.4979
3-4 families	-2.1890*	0.5893
More than 4 families	-.0379	2.6524
	-2.3094	2.0014

2. ESRFs	3.1453*	0.4564
Availability & reliability of energy sources	-0.2233	1.4989
Kerosene and LPG	-2.4538*	0.6123
Electric power		
Availability of appliances	0.0975	0.6860
Kerosene and LPG	2.0498*	0.8272
Electric power		
Cost of appliances		
Kerosene and LPG		
Electric power		
3. HFCBs		
Dry and fry cereals	1.9511	
Kerosene and LPG	-2.5880*	1.9628
Electric power	-2.9412	0.9404
The mix of two/more		2.0318
Prepare cultural dishes	-	
Kerosene and LPG	2.5822***	1.5163
Electric power	-1.2076**	0.5038
The mix of two/more	-1.0771**	0.4913
4. Other Factors		
Living area suitability to the urban plan: No	-1.2295*	0.3605
Number of years lived in the area		
4-6 years	-0.9930**	0.5024
7-9 years	-1.9605*	0.5700
Above 9 years	-2.5667*	0.6136
Socio-cultural influences: No	0.7652**	0.3503
Personal feelings and lifestyles: No cons	2.1973*	0.7934
	5.1261*	1.0548
Electric users	**(Base outcome)**	

Note: **,** and *** statistically significant at P<0.01, P<0.05 and P<0.1 respectively*

4. Conclusions

This study identified energy sources and the factors determining households' electric use for domestic purpose in informal settlements in North Addis Ababa, Yeka Sub-City, *Woreda* 12, and analyzed the data using both descriptive methods and binary logit model.

Owing to the socio-economic differences of households, all factors do not have equal importance in determining their energy choice and consumption levels. Accordingly, those households who had access to electricity were found using more biomass and even consumed higher amount of charcoal than non-users of electricity. Analysis of DHCs revealed that sex and marital status of the household head and family size had no relationship with the status of households' electric-use, while age and education of the household head, family income, employment type of the head, and the number of dependents in the family were related to electric-use. Based on this, households with higher levels of education, and hired on permanent basis were more consistently associated with using electric power than those who had lower levels of education and were hired on contract, daily or hourly bases. Analysis of the logit model specifically identified household heads between 30-60 years, education above grade 4 and families with 1 to 4 dependents use more electric power.

Findings from ESRF indicated that availability and reliability of energy sources; the availability and cost of appliances; and socio-economic and environmental factors determine households' electric use. However, high electric connection fees and high electric tariffs did not prohibit households in informal settlements from access to electricity. On the other hand, although the prices of firewood and charcoal are increasing over time, due to excessive population growth, increased energy consumption and limited electric supply, they were better available and relatively cheaper than electricity.

Households in informal settlements use different energy sources due to their differences in food consumption habits. They often use biomass to add the taste and flavor of food staffs, to roast and boil coffee, to dry and fry cereals, and to cook cultural Ethiopian dishes. They use electricity to save family labor and time and to bake *Injera*. They also use a mix of two or more energy sources in order to get a

variety of food staffs /more nutrition/, cook foods frequently, get fresh foods, take enough meals per day, and as a backup for emergencies.

The survey result showed that land tenure and land size, and proximity of the living area to the electric facility had little or no relationship with electric use. But from the informal settlers who owned land through inheritance (23% of all households), only 59% had access to electric power. On the other hand, the number of years a household lived in the area, shelter condition/type, the number of rooms owned, and suitability of dwelling place to the urban plan had significant influence on access to electricity. In light of this, among households who lived in the area for more than 9 years, 74% were electric-users while 26% were non-users of electricity.

5. Policy Issues

Analysis of the survey data and empirical results obtained so far indicted that appropriate measures are needed to improve households' access to and use of electric power in informal settlements. These policy measures include properly recognizing and balancing the socio-economic backgrounds of the inhabitants, the legal and regulatory environment in which the energy sector operates, and the availability and affordability of alternative energy sources. Accordingly, some of the policy measures that could increase households' access to electricity in informal settlements include:

1. Providing electric service to informal settlers based on age, education level of the household head, family size, number of years a household lived in the area, shelter condition, and the number of rooms owned could encourage many people to extensive land grabbing and squatter settlement, unplanned urban expansion, and land use. To avert such challenges, electric suppliers shall make decisions based on the suitability of the land owned by households to the urban plan, and proximity of the homes to electric facility (the nearest electric line or a transformer). Ultimately, the government shall formalize the informal settlers based on these criteria.

2. Untargeted subsidies and progressive electric tariffs set indiscriminately for all groups of households could be thoroughly revised by considering the inadequate power supply capacity. Many low income households indicated that the initial connection fees and the ever rising monthly electric bills are unaffordable to

many informal settlers. To this end, subsidies shall be designed to target only the poor households and provide discounts and encouragements to those using electric power during off-peak hours such as at night time and rainy seasons when power supply is relatively better. The initial connection fee shall also take into account the residents' paying capacity and their willingness to share this cost by a group of two or more neighbors.

3. Another important policy measure is based on the conclusion that most households including electric-users used firewood and charcoal for cooking cultural foods, roasting and boiling coffee and drying and frying cereals. This requires government bodies to conduct aggressive awareness creation campaigns to change their existing food consumption habits and encourage them to use energy efficient stove technologies and switch to clean energy sources. In fact, this shall be accompanied by improving the supply of electric power.

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