Households' Domestic Energy Consumption in Informal Settlements of *Woreda 12,* Yeka Sub City, Addis Ababa

Nibretu Kebede Desta

Dissertation Submitted in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Development Studies (Environment and Development)

Addis Ababa University
College of Development Studies
July, 2022

Households' Domestic Energy Consumption in Informal Settlements of *Woreda 12,* Yeka Sub City, Addis Ababa

Nibretu Kebede Desta

Supervisors:
Degefa Tolossa (Prof.)
Tamirat Tefera (PhD)

Addis Ababa University
College of Development Studies
Ethiopia

July, 2022

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
DISSERTATION APPROVAL

This is to certify that the dissertation prepared by Nibretu Kebede entitled: Households' Domestic Energy Consumption in Informal Settlements of *Woreda 12*, Yeka Sub City. Addis Ababa and submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in Development Studies (Environment and Development Studies) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee:

-------------------------------------	-----------------------	---------------------
Chair, Examining Committee	Signature	Date
-------------------------------------	-----------------------	---------------------
External Examiner	Signature	Date
-------------------------------------	-----------------------	---------------------
Internal Examiner	Signature	Date
-------------------------------------	-----------------------	---------------------
Advisor	Signature	Date
-------------------------------------	-----------------------	---------------------
Advisor	Signature	Date

Chair of the Center or Graduate Program Coordinator

Declaration

I, the undersigned, declare that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation are fully acknowledged.

Name:	Nibretu Kebede Desta
Signature:	----------------------------------
Date:	----------------------------------
Place:	Addis Ababa
Date of submission:	----------------------------------

This dissertation has been submitted for examination with my approval as University supervisor.

Supervisor name:	--------------------------------
Signature:	--------------------------------
Date:	--------------------------------

Dedication

This dissertation is dedicated to my late father who passed on March 3, 2021. I duly acknowledge the contributions made by Dr. Tamirat Tefera, Habtamu Dagne and Tigzaw Lamesginew in helping me get registered during this time.

Acknowledgments

Primarily, I would like to express my sincere thanks to Professor Degefa Tolossa (a professor in Geography and Development Studies) and Dr. Tamirat Tefera (Head, Center for Environment and Development) for providing thoughtful and insightful comments since the inception of the research proposal through analyzing data and revising the manuscript to the final work of this dissertation. I thank you all for your guidance, comments and suggestions, follow up, professional and technical support in the process of submitting articles for publication. I also learned a lot from your patience, encouragements and friendly communication during the study period. It has much contribution for my future career too.

My indebtedness also goes to Dr. Tesfaye Zeleke (Dean, College of Development Studies) and Dr. Abebe Beyene (a researcher in the Institute of Policy Studies) for their significant contribution in framing this dissertation since the proposal development stage. They put their utmost effort in making this study a reality. The critical comments and suggestions provided by Journal Reviewers and Editors have contributed much to improve my work and soften expressions that expose me to the belligerent readers in the field. They supported me much on language use and solving syntax problems. However I am responsible for infliction of words and sentences that could be apprehensive to some others. These words and explanations were chosen simply for the communicability of my ideas and thoughts, not to show language proficiency.

I owed much debt to Alemayhu Lemessa, Mehamed Seid, and Belete Debebe who provided me technical support during data analysis stage. Their services contributed much in improving the quality of my work.

I am grateful to the following organizations and individuals that contributed to my success: Addis Ababa University (College of Development Studies) for providing admission and financial support, St. Mary’s University for providing 40% load reduction during my study, sampled households in *Woreda*[1] 12 Administration for providing information during the high time (COVID 19 pandemic) and Temesgen Molla, Tesfaye Berhanu and Shiberu Zegeye for their relentless effort and time spent during data collection process; and Ato Abrham Elfe, W/o Yemserach Engida, Ato Aramde Wudu and Ato Smuel Bulto who let me to get access to confidential information on the status of informal settlers and writing enclosed letters to enumerators who are assigned to gather data on my behalf. I am indebted to all of them and data collection was not possible without the willingness and cooperation of households, data collectors and those individuals in the *Woreda* Administration.

Special thanks go to Ato Genene Seyoum for his charity (a laptop and transportation service provided during data collection process), cooperation in every social affairs, deep concern and encouragement for the successful completion of my study. Words do not express his tribute and close support. Let God pay him for his generosity and cooperation in all endeavors. I also like to express my sincere appreciation to Ato Shegaw G/Medhin from St. Mary's University in reading and editing the Amharic version of the questionnaire designed for gathering information and moral support provided during my study.

The scarification paid by my wife, Meaza Sahilue and my children were immense so that I worked towards the required level. Though I had mixed views on her, I owed much for unspoken encouragement and family support.

Nibretu Kebede

---

1. *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.*

Publications Incorporated in this Dissertation

This thesis is organized based on articles-based dissertation compilation guideline of Addis Ababa University and emerged from articles already published in peer reviewed Journals and papers accepted for publication. The coauthors have made different levels of contribution to the publication of those articles on the basis of their area of specialty.

1. Nibretu Kebede, Degefa Tollesa and Tamirat Tefera, *Determinants of Energy Choice for Domestic Use in Informal Settlements of Woreda 12*, Yeka Sub City. Addis Ababa Journal of Science and Sustainable Development (JSSD), web link: https://www.ajol.info/index.php/jssd/issue/view/19909, ISSN: 2070-1748, Volume 8, December 2021 pp. 33-44 https://dx.doi.org/10.4314/jssd.v8.3.

2. Nibretu Kebede, Degefa Tolessa and Tamirat Tefera, *Households' Challenges to Access Electricity and their Coping Strategies: A Reference to Informal Settlements in Woreda 12, Yeka Sub City. Addis Ababa,* accepted for Publishing in Vol.43 (2) of Ethiopian Journal of Development Research (EJDR).

3. Nibretu Kebede, Degefa Tollesa and Tamirat Tefera, *Adoption of Improved Cook Stoves by Households in Informal Settlements of Woreda 12, Yeka Sub City. Addis Ababa,* Journal of Energy, Sustainability and Society (JESS), Springer International Publishing (accepted for publication).

4. Nibretu Kebede, Degefa Tollesa and Tamirat Tefera, *Impacts of Access to and Use of Electricity on Households' Economic Status in Selected Informal Settlement Areas of Woreda 12, Yeka Sub City, Addis Ababa*, ERJSSH (accepted for publication).

Table of Contents

Contents Page

Acknowledgments .... *iv*
Publications Incorporated in this Dissertation .... *vi*
List of Figures .... *x*
List of Tables .... *x*
Acronyms/Abbreviations .... *xii*
Abstract .... *xiv*

Chapter 1: Introduction........1
1.1. Background of the Study 1
1.2. Statement of the Problem and Rationale for the Study 4
1.3. Objectives of the Research 9
1.4. Key Research Questions 10
1.5. Scope of the Study 10
1.6. Significance of the Study 12
1.7. Limitations of the Study 13
1.8. Conceptual and Theoretical Underpinnings 14
1.8.1. Informal Settlement: Conceptualization and Causes 14
1.8.2. Potential Sources of Energy in Informal Settlements 15
1.8.3. Modalities to Solve Energy Problem and Approaches to Energy Choice 16
1.8.4. Electric Pricing and Payment Systems 20
1.9. Analytical Frameworks 22
1.10. Research Methodology 25
1.10.1. Description of the Study Area 25
1.10.2. Research Design and Philosophical Orientation of the Study 27
1.10.3. Sample Design and Sampling Method 30
1.10.4. Data Sources and Analysis Methods 34
1.11. Structure of the Dissertation 36

Chapter 2: Determinants of Energy Choice for Domestic Use in Informal Settlements in *Woreda 12,* Yeka Sub City, Addis Ababa........37
2.1. Introduction 37

2.2. Research Methodology 40

2.3. Results and Discussion 41

2.3.1. Demographic and Household Factors 41
2.3.2. Energy Source Related Factors.. 45
2.3.3. Households' Food Consumption Behaviors 48
2.3.4. Shelter Condition and Other Factors.. 50
2.4. Determinants of Households' Electric-Use Status: The Binary Logit Model...... 52

2.4.1. Demographic and Household Characteristics (DHCs) 53
2.4.2. Energy Source Related Factors (ESRFs) 54
2.4.3. Households' Food Consumption Behaviors (HFCBs) 55
2.4.4. Other Factors.. 56
2.5. Conclusions 58

2.6. Recommendations 59

Chapter 3: Impacts of Access to and Use of Electricity on Households' Economic Status in Selected Informal Settlement Areas of *Woreda 12,* Yeka Sub City, Addis Ababa..60
3.1. Introduction.. 61

3.2. Method of Data Analysis and Model Specification 65

3.3. Results and Discussion 69

3.3.1. Socio-Economic Profiles of Households 69
3.3.2. Households' Energy Consumption Levels in Informal Settlements 75
3.3.3. Impact of Electric Use on Family Income: The ESR Model......................... 78
3.4. Conclusions 83

3.5. Recommendations 84

Chapter 4: Households' Challenges to Access Electricity and their Coping Strategies: A Reference to Informal Settlements in *Woreda 12,* Yeka Sub City, Addis Ababa 85
4.1. Introduction.. 86

4.2. Method of Data Analysis 89

4.3. Results and Discussion 90

4.3.1. Demographic Profiles of Informal Settlers 90

4.3.2. Challenges to Use Electricity in Informal Settlements 91
4.3.3. Households' Coping Strategies to the Challenges of Electricity 94
4.3.4. Households Coping Strategies to the Challenges of Electricity: Binary Logit Model 104
4.4. Conclusions and Recommendations 110

Chapter 5: Adoption of Improved Cook Stoves by Households in Informal Settlements in *Woreda 12,* Yeka Sub City, Addis Ababa ... 113
5.1. Background 114
5.2. Data Analysis Methods 119
5.3. Results and Discussion 120
5.3.1. Factors Affecting Energy Efficient Stove Use: Descriptive Analysis 120
5.3.2. Duration of ICS Adopted by Households and Fuel Consumption Trends 127
5.3.3. Financing Sources and Challenges to Use Energy Efficient Stoves 128
5.3.4. The Use of Solar Energy and Electrical Appliances 130
5.3.5. The Use of ICS in Informal Settlements: The Multinomial Logit Approach 132
5.4. Conclusions and Implications 138

Chapter 6: Synthesis, Conclusion and the Ways Forward 140
6.1. Synthesis 140
6.1.1. Determinants of Households' Energy Choice 140
6.1.2. The Impact of Access to Electricity on Households' Economic Status 141
6.1.3. Challenges to Access Electricity and Informal settlers' Coping Strategies 142
6.1.4. Households' Adoption of Improved Cook Stoves 142
6.2. Conclusions 143
6.3. The Ways Forward 145
6.4. Contribution of the Study and Future Research Direction 147

References 149
Annexes 165

List of Figures

Figure **Page**

Figure 1: Households' Income Level and Energy Ladder 18
Figure 2: A Framework for Analyzing Rural-Urban Migration and Settlement Decision 24
Figure 3: A Framework of Energy Choice Indicators, Challenges, Coping Strategies, and Expected Outcomes in Informal Settlements 25
Figure 4a: Map of Addis Ababa and Yeka Sub City 26
Figure 5b: Location Map of the Study Area, *Woreda 12* 27
Figure 6: Households Alternative Energy Sources and Family Income 48
Figure 7: Number of Days Households Baked in a Week... 73
Figure 8: Households' Monthly Income and Number of Fuels Used 77
Figure 9: Strategies to Change Households' FCB based on Electric Use Status 98
Figure 10: Households Energy Conservation Strategies Based on Electric Use Status 99
Figure 11: Households Energy Consumption Levels if Income Doubles 110
Figure 12: Typical *Mirt* Stove Owned by Households in Informal Settlements 124
Figure 13: Period Improved Cook Stoves Owned by Households 127
Figure 14: Sources of Financing Energy Saving Stoves 129
Figure 15: Electric-Users' Reasons for Choosing Electrical Appliances...................... 131

List of Tables

Table **Page**

Table 1: Informal Settlers in *Woreda 12* based on Specific Sites and Electric Use Status 31
Table 2: Selected Sites and Number of Households based on Electric Use Status 32
Table 3: Sampled Households based on Site and User Status 33
Table 4: Households' Demographic and Socio-Economic Factors................................ 44
Table 5: Households' Monthly Expenditures for Alternative Energy Sources 47
Table 6: The Influence of Households' Food Consumption Behaviors on Energy Choice.. 49

Table 7: Determinants of Households' Electric Use Status: The Binary Logit Model . 57
Table 8: Households' Food Consumption Behaviors Affecting Energy Choice 72
Table 9: Factors Influencing Households Electric Use Status 72
Table 10: Type of Home Business Activities, Energy Sources and Households Income from these Activities based on Electric Use Status 75
Table 11: Households' Monthly Energy Expenditures (*Birr*) 76
Table 12: Factors Affecting Family Income: The ESR Model 80
Table 13: The Impact of Energy Sources on Electric-users' Energy Expenditure and Family Income: The ESR Model 81
Table 14: Impact of Electric Use on Family Income: The ESR Model 83
Table 15: Households' Challenges for Lack of Access to Electricity (%)....................... 93
Table 16: Non-users Speed of Adoption of Modern Energy Sources, ICS and Reasons for Switching Failure 94
Table 17: Households' Alternative Energy Sources 95
Table 18: Households' Reasons for Using Alternative Energy Sources based on their Electric Use Status (%) 96
Table 19: Households' Reasons for Substituting Existing Energy Sources (%) 97
Table 20: Households Coping Strategies to the Challenges of Electricity (%) 100
Table 21: Households Perspectives on Policy Options to Access Electricity............. 104
Table 22: Factors Influencing Households Willingness To Pay (WTP) for Improved Electric Service and Electric Use Status: The Binary Logit Model 107
Table 23: Criteria to Set Electric Tariffs and Households' WTP for Improved Service based on Electric Use Status 109
Table 24: Households' Demographic and Socio-Economic Backgrounds and Stoves Owned (%).. 122
Table 25: Key Factors Affecting Households' Choice of Stove.................................... 126
Table 26: Households' Problems to Use ICS 130
Table 27: Factors Affecting the Choice of Energy Efficient Stoves: The Multinomial Logit Model 136

Acronyms/Abbreviations

ATE	Average Treatment Effect
ATET	Average Treatment Effect on the Treated
ATEU	Average Treatment Effect on the Untreated
CET	Conventional Energy Technologies
CFL	Compact Fluorescent Lights
CO2e	Carbon Dioxide Emissions
CRGE	Climate Resilient Green Economy
DHC	Demographic and Household Characteristics
DID	Difference In Difference
ECS	Energy Conservation Strategies
EEP	Ethiopian Electric Power
EEU	Ethiopian Electric Utility
EUM	Expected Utility Model
ESR	Endogenous Switching Regression
ESRF	Energy Source Related Factors
FAO	Food and Agricultural Organization
FCB	Food Consumption Behaviors
FDRE	Federal Democratic Republic of Ethiopia
GHG	Green House Gas
GIS	Geographical Information System
HAS	Households' Adaptive Strategies
HFCB	Households' Food Consumption Behaviors
ICS	Improved Cook Stoves
IEA	International Energy Agency
IV	Instrumental Variables
LED	Light Emitting Diode

LPG	Liquefied/Light Petroleum Gas
MLR	Multinomial Logistic Regression
MTF	Multi-Tier Framework
MW	Mega Watt
MWIE	Ministry of Water, Irrigation and Electricity
NNM	Nearest Neighbor Matching
PSM	Propensity score matching
PV	Photovoltaic
REDD	Reducing Emissions from Deforestation and Degradation
REP	Rural Electrification Program
RET	Renewable Energy Technologies
SDG	Sustainable Development Goals
SHS	Solar Home Systems
SSA	Sub Saharan Africa
UEAP	Universal Electricity Access Program
UNDP	United Nations Development Program
WTP	Willingness to Pay

Households' Domestic Energy Consumption in Informal Settlements of *Woreda 12, Yeka* Sub City, Addis Ababa

Abstract

The objective of this study is to examine households' domestic energy consumption in informal settlements of Woreda 12, Yeka Sub City, Addis Ababa. Quantitative and qualitative data were gathered from 450 households using questionnaires, interviews, documentary reviews and analyzed using descriptive statistics and regression models. The findings showed that the education level of the household head; size and stability of income; shelter size and condition; suitability of the dwelling place to the urban plan; years lived in the area; and availability and reliability of energy sources affect households' access to electricity. Food Consumption Behaviors (FCB) such as the taste and flavor of food stuff, and cooking cultural dishes also determine the choice of energy. However, sex of the household head, size and title of land held, and proximity to electric line do not show any discernible effect on access to electricity (Objective 1). Yet sources of energy determine households' home-based business activities and income generated from those businesses (Objective 2). Households' low and unstable income, unaffordable connection fees, progressive electric tariffs, inadequate power supply and frequent interruption are the key challenges of households. These challenges forced them to change FCBs, take energy conservation and coping strategies, share electric meters in groups, accept temporary and less power consuming electric services (Objective 3). The adoption of Improved Cook Stoves (ICS) depends on households' electric-use status, education level, years lived in the area and home type owned, availability of energy sources and subsidies, and the quality and price of the stove. However, land title and income levels have no relationships with ICS use and electric-users are found using more three-stone stoves than ICS (Objective 4). The study noted the need to revise electric tariffs based on energy sources, households' proximity to electric facility and seasonal variations in power supply, load shifting by setting responsive electric tariffs, and avoid progressive tariff set indiscriminately for all. The government on its part should legalize informal settlers and provide electricity based on the number of years households lived in the area; suitability of the land held to the urban plan; involve a broad range of private suppliers; and direct subsidies and discounts only to households using electricity for primary functions, during off-peak hours, ICS and solar home systems. Other actors such as the private sector, non-profit foundations, and households should also take their part in solving the energy problem in informal settlements.

Keywords: *Coping strategies; Domestic use; Electric access; ICS; Informal settlement*

Chapter 1
Introduction

1.1. Background of the Study

Energy is vital for all human beings. Nowadays it is connected to everything - baking, cooking, lighting, heating, refrigeration, and other home applications that people use. However, all sources of energy are scarce and their respective prices are rising terrifically and access to public services is very limited. Especially, informal settlers across the globe endure insecure rights over land; inadequate and substandard housing; live far from the urban center, suffering every day to travel to work places, lack of basic services and infrastructure, live in unsuitable geographical locations and close to rivers, rugged and waste disposal areas (UN-Habitat, 2008; Jones, 2017).

In Africa, two-thirds of the population do not have access to affordable and reliable electricity (Olaniyi, 2017) and many of them suffer from extensive power outages, technological deficiencies, corruption, mismanagement and absence of financial support from banks (Jarrett, 2017). The energy problem of informal settlements in Sub–Saharan cities is more severe. In cities with a million and above population, 50-80% does not have access to electricity (UN-Habitat, 2014; Butera, Caputo, Adhikaria, & Facchini, 2016). The per capita energy consumption of Sudan, Nigeria and Kenya, for example, is 114, 150 and 168 kWh respectively (Figueroa, 2016; Butera, Caputo, Adhikaria, & Facchini, 2016; Olaniyi, 2017). In Ethiopia, access to modern energy is the lowest (about 46%), the per capita energy consumption is about 100 kWh per year, energy demand rising 10-14% per year and electric supply still remains limited and unreliable (Lloyd P. , 2014; PIERG, 2017; World Bank, 2018; Getie, 2020; MWIE, 2017).

The energy sector is characterized by the development of alternative energy sources and improvements in energy technologies (Domnikov, Khomenko, Chebotareva, & Khodorovsky, 2017). The renewable energy source potential in Ethiopia has the capacity to generate over 60,000 MW where hydropower accounts about 45,000 MW (86%), wind and solar 5,000-10,000 MW (8%) and geothermal 5,000-10,000 MW (6%) (Power Africa, 2016; EEP, 2016; MWIE, 2017). The government has planned to achieve a Climate Resilient Green Economy development in 2025 (IEA, 2014). Currently, it generates only 4,284 MW of which 3810 MW or 89% is hydropower (MWIE, 2017).

In 2030 the number of people living in urban Ethiopia is expected to rise to 36.9 million or 26.4% of its population (World Population Review, 2021) requiring energy while the nation is exporting 90 MWs to Djibouti and 250 MWs to Sudan and planned to export 400 MWs to Tanzania and 2,000 MWs to Kenya (EEP, 2016; MWIE, 2017).

However, the availability of renewable energy sources varies from place to place and the best renewable energy sites are often far from big cities in Ethiopia. This makes expensive to connect (JICA, 2011) and biomass remained the major source of lighting, cooking and heating (Damte, et al., 2011; Belay & Aberham, 2015). Together with the inadequacy of infrastructural and social services, this forced households to use low-grade, less heat and more smoke causing fires that consume a lot of cooking time and labor. On the other hand, biomass has no substitute for cooking traditional foods and its scarcity and raising price over time urges households to consume few hot meals and adopt meals that can be cooked fast (Getachew, 2016). Slow transition to modern energy sources in Ethiopia has created a challenge not only to substitute traditional sources but also present a major threat to the socio-economic performance of the nation and the overall dwindling of traditional energy sources.

The depletion of natural resources could also be correlated with the increase in electric tariffs. Since December 2018, EEU has made dramatic and successive price increase after a long period of time. This problem together with power shortages has restrained households from access to electricity. When societies are squeezed between declining fuel supplies and soaring out prices, they tend to reduce their reliance on fuels and the provision of clean, safe, affordable and reliable energy remained a major challenge.

Above all, the subjects of this study are households in informal settlements caused by large flow of people from rural to urban areas, inefficient land provision, high cost of living in the urban areas and illegal land grabbing (Weldegebriel, 2011). The Government has failed to plan and administer urban land in line with urban land policy, energy policy, the long term development plan of the nation, and the housing strategies to address the housing needs of the society.

Lack of effective urban planning and control of urban land, rapid urban population growth and increased spatial expansion of the city have led to poor urban services and inadequate infrastructure provision. Nowadays, informal settlement has become a growing problem in Ethiopia associated with the expansion of residential areas, houses constructed on lands where occupants have no legal claim and low in quality (Bosena, 2019). These actions result in socio economic problems, environmental deterioration, increased demand for basic services (housing, potable water and electricity) (Jones, 2017). Formalizing and electrifying informal settlers could further aggravate unsustainable and undesirable urban land use and unplanned expansion (Gaunt, et al., 2012; UNEF, 2017).

Kovacic, Smit, Musango, Brent, & Giampietro (2016) contend that electrification of households in informal settlements is complex due to residents' lack of legal land rights and the difficulty of grid expansion. The electric supply in Ethiopia is solely owned by the Ethiopian Electric Utility (EEU), Government owned enterprise. It legally excludes informal settlers from getting electric connection and reluctant to provide electric service. Subbiah, Mansoor, Misra, Jaffer, & Tiwary (2016) and UNEF (2017) indicated that this is mainly associated with households' lack of permanent address, scattered settlement, low paying capacity, high risk of financial default associated with unreliable income and less electric consumption. Electric providers worry about the profitability of servicing informal settlers' and the linkages between housing, infrastructures, and income generating activities (Lowe & Schilderman, 2001; Majale, 2002). Assessing the determinants to use energy sources, analyzing the impacts of access to electricity and exploring the implications underlying energy shortage, the challenges to access electricity and coping strategies to the electric problem, and assessing the adoption of ICS in informal settlements are the pillars of this dissertation and studied in depth and tested empirically based on the data gathered from April to June, 2020 on households selected in *Woreda* 12, Yeka Sub City, Addis Ababa.

1.2. Statement of the Problem and Rationale for the Study

The challenges to achieve economic development and improve livelihoods in the world of increasing population, wealth and social inequality are complex (Coyle, Grimson, Basu, & Murphy, 2014). One of these challenges is lack of access to energy that undermines efforts to improve productivity, reduce food insecurity and inequality (Kovacic, Smit, Musango, Brent, & Giampietro, 2016). It greatly affects the livelihoods of people in all spheres of life including materials, services, activities, and opportunities to meet basic needs.

However, the concept of access to energy is not equally understood by all people. For instance, Perera, Boyd, Wilkins, & Itty, (2015) used access to electricity to mean availability, adequacy, reliability, affordability, convenience to use, legality, clean and safe source for use across households and communities while many others associate it only to mean adequacy, reliability, and legality of energy sources. According to Clancy (2006), high energy price leads to a reduction in the quality of life of the poor, reduced number of cooked meals and increased work load of women and children.

Besides the ongoing debate on the concept of access to energy is the belief that many people have towards traditional fuels. According to Figueroa (2016), they consider traditional energies are the cheapest, most easily accessible and ubiquitous sources and play a vital role in the energy mix. People can easily substitute among fuel wood, charcoal and animal dung. However, excessive use of these resources builds up environmental catastrophes and leads to land-use/land-cover change, indoor air pollution, and climate change (Bazilian, et al., 2011). Lack of technologies, scattered settlements, households' social and behavioral problems, power supply shortages and interruptions intensifies environmental degradation and the continued deforestation ultimately leads to the vicious circle of increasing firewood scarcity, rising cost of biomass, and the threatening of livelihoods. Because of this it has been frequently blamed that Ethiopia's economic development is highly dependent on unsustainable use of natural resources, losing ever-increasing share of GDP to fuel imports and the availability and quality of biomass resources are deteriorating considerably (FDRE, 2011; Howell, 2011). Figueroa (2016) explained that changing households' energy consumption behaviors and transcending to modern sources could reduce those impacts and help to realize cost savings.

With the continuous rise in oil prices, depletion of natural resources and reduction of traditional fuel use, the IEA has outlined critical steps for 2030 that include energy conservation measures, the introduction of energy efficient and low carbon generation technologies, and shifting to and integration with renewable energy sources (IEA, 2014). Such measures contribute to improve households' living condition, reduce cost of electricity, and improve health. The issue of how Ethiopia should mix alternative energy sources, shift to renewable sources, ensure affordability, and improve the lives of informal settlers remained a critical question. On the one hand the nation has a huge electric generation potential and on the other hand its current electric supply capacity and the per capita energy consumption is the least.

Rich households in urban areas have the opportunity to fuel choice, adopt improved stoves, take conservation measures, minimize depletion of energy sources and ensure emission reduction (Alem, Beyene, Köhlin, & Mekonnen, 2013; Gebreegziabher, Mekonnen, Kassie, & Köhlin, 2012; Figueroa, 2016). In general, people choose energy sources considering the social and behavioral factors, their culture, attitudes and values (Lewis, 2000). But differences in wealth make higher income groups to be unfair in resource utilization as they can bear the costs of negative externalities (WEF, 2014).

When the supply of modern energy is lacking, unreliable, and its price is rising up, many people living in the off-grid informal settlements spend their income for energy services (10-30% of their income in Sub Saharan Africa), shift to cheaper energy sources, and reduce non-energy expenditures and the overall energy consumption (Mele, 2014; UNEF, 2017). The poor in particular are more challenged to generate income and forced to use their assets for energy.

The proportion of urban population is increasing dramatically leading to squatter settlement, ever increasing demand for urban services. According to Butera, Caputo, Adhikaria, & Facchini (2016), these people (most are new immigrants) constitute 18.3% of the total population of Addis Ababa. They are characterized by illegal and scattered settlement, live in poor and unsecured housing, poor capacity to pay connection fees and electric service (most earn low and unstable income), live far from the electric grid and lose of service providers' trust. As a result, households tend to face equity problems in getting access to electricity face frequent power interruption, fluctuation that oversupply sometimes damages households' durables, and power outages for long hours. These situations have made the supply of reliable energy more difficult and created high disparity between the urban center and the periphery (Chance, 2009; Prasad, 2010; Bouzarovsk & Herrero, 2017; Sheng, He, & Guo, 2017). It severely affected the households' day-to-day economic activities, disrupted water supply and health services, households' long run development and the poverty alleviation efforts of the Government.

Residents are often seen using traditional sources of energy, candles and buying electricity for lighting from their neighborhoods. It generally threatens their livelihood and currently becoming a major source of anxiety and discontent among them. Furthermore, this issue is raised when the Ethiopian Government is claiming that it is exporting energy to the neighboring countries in East Africa (Sudan, South Sudan, Djibouti, Kenya, etc.). The destitute life of informal settlers and the need to create a relationship between households' socio-economic backgrounds and access to electricity has initiated the study under the title "households' domestic energy consumption in informal settlements in *Woreda* 12, Yeka Sub-City, Addis Ababa." The study area is selected using multistage sampling process as described in the research methodology section and the link between informal settlement and energy access has never been studied before.

Howell (2011), Dawit (2014) and Chen (2016) studied on Ethiopia's environmental policy and renewable energy potentials, energy security and energy-environment nexus in different areas. These studies pointed out Ethiopia's huge energy potentials, the available alternative energy sources, how to harnesses each source in the rural settings, and the need to invest on renewable energy sources (notably on hydropower). Specifically, Weldegebriel (2011) conducted a study on the situation of informal settlement in Bahir Dar; Butera, Caputo, Adhikaria, & Facchini (2016) on energy efficiency measures in informal settlements in Latin America and Africa, Bosena (2019) on informal land use in Nefas Silk-Lafto (Addis Ababa); and Abebe and Koch (2013) on the adoption of clean fuel-saving technology in urban Ethiopia. Mustefa & Lika (2016), tried to show the nexus between energy and gender based on female-headed households residing in Arba-Minch town. The study made by Ali & Megento (2017) revealed that electricity is likely to reach nearly all households in urban areas while no considerable switching has occurred from firewood use to electricity. Above all those studies raised each issue independently and the studies were made on formal urban dwellers and rural areas, not on informal settings.

This study is designed to clearly understand the situation of informal settlers, their access to electricity and helps to fill the research gap in the area. It provides comprehensive picture about households' energy use status, empirical evidences on the criteria used to give electric service, the capacity to pay electric bills, proximity to the electric facility and the impacts of access to electricity on the socio-economic status of households using descriptive and regression models. The study helps to enrich the existing energy policy and make an advance in implementing energy policies that directs the government to scale-up energy sources, encourage energy efficient use and design subsidies. For this it is relevant to policy makers, development partners and other actors in designing successful intervention strategies, circumvent the energy problem of informal settlers. It also serves as a basis for similar research in the future.

The study assumes that lack of formal access to land and electricity exposes households to numerous challenges that in turn widen economic inequality among citizens. On the contrary, access to electricity improves the economic status of households and changes the structure of their home-based business activities. The sources of energy and consumption levels are, in turn influenced by households' socio-economic backgrounds, food consumption behaviors, and energy source related factors. Factors such as illegal settlement and proximity to the electric facility could inhibit informal settlers from getting access to electricity /lead to energy poverty/ and the cost and availability of energy sources and cooking appliances influence the adoption of ICS. Households, therefore, should have their own means to cushion the energy problem and this study tries to assess such issues and balancing the benefits of those factors is still an academic challenge that requires critical investigation.

1.3. Objectives of the Research

The main objective of this study is to examine households' domestic energy consumption in informal settlements of *Woreda* 12, Yeka Sub-city, Addis Ababa. The specific objectives of this study are:

1. to see the determinants of energy choice for domestic use[2] in informal settlements,
2. to discuss the impact of access to electricity on households' economic status (income generation and saving energy cost) in selected informal settlement areas,
3. to analyze households' challenges to get access to electricity in informal settlements,
4. to assess households' coping strategies in informal settlements, and
5. to assess the adoption of Improved Cook Stoves (ICS) by households in informal settlements.

[2]. *Domestic use refers to energy consumed by households for cooking and baking purpose, not for lighting, entertainment and charging batteries. All households in informal settlements are assumed to have access to the latter group of services.*

1.4. Key Research Questions

The study posed several critical questions which provided answers in the subsequent chapters. The main research questions addressed in this study are:

1. What factors determine households' source of energy and the criteria considered by the EEU to provide electric service?
2. What is the spatial accessibility of energy sources and facilities in the study area?
3. How does access to electricity affect the economic performance of households in informal settlements?
4. What are the key challenges that households face in order to get the electric service?
5. How households managed the electric challenge (adoption strategies)? Why they use the stove currently owned? What factors determine to the use of improved cook stoves (ICS) in informal settlements?
6. What roles do the various stakeholders (households, local authority, and the EEU) play in improving the energy supply in informal settlements and implementing the energy policy?

1.5. Scope of the Study

Before entirely excluding households from urban services associated with squatter settlement and poor housing condition, their settlement patterns and the availability of energy resources should be studied carefully. This study is confined to assess the following key research areas: 1) the factors that determine households' energy choice, access to electricity and consumption level, and their socio-economic backgrounds, 2) economic impacts of lack of access to electricity, 3) challenges and coping strategies to the electric problem, and 4) the adoption of ICS in informal settlements using cross-sectional data. It applied both quantitative and qualitative data generated from field surveys, desk reviews, interviews and secondary sources of information. The study has taken place on the Northern part of Addis Ababa, Yeka sub city in *Woreda 12* that includes households' electric-users[3] and non-users[4] of electricity drawn from three sites (Hibret Amba, Kotebe Gebriel, and Demamit/Demeka).

Studying all the determinants to get access to electricity for a household, however, is very complex. Assessing its economic, social, environmental and political implications is more complicated and beyond the scope of this study. Although these outcomes are expected and interrelated to one another, this study paid much attention to socioeconomic backgrounds of informal settlers, their housing condition associated to land holding status, the impacts of these problems on their economic status and livelihood situation, adoption of energy efficient technologies and their coping strategies to the energy problem.

The study underlines the need to consider alternative energy sources based on households socio economic backgrounds and the importance of targeting subsidies and providing support to households (units of analysis) requiring assistance according to local context.

3 *Electric-users are households currently using electricity for cooking, baking, lighting, entertainment, refrigeration, charging and other purposes. These households obtained the service from the EEU legally or from their neighborhoods by sharing electric price.*

4 *Non-users of electricity refer to households who either use electricity only for illumination and charging of batteries or do not use it at all. They purchase this service from their immediate neighbors and depend on traditional energy sources for cooking and baking.*

1.6. Significance of the Study

Investigating households' domestic energy consumption in a country where informal settlements and the housing sector is growing at a rapid rate is one of the timely and most critical issues in urban development planning and management. The study describes clearly households' socio-economic factors and food consumption behaviors associated with energy choice; availability, reliability and price of energy sources; and home type, condition, and size owned influence informal settlers' energy choice for domestic consumption and their electric use status.

Research on electric-use status and current state of informal settlers' domestic energy consumption, the effect of access to electricity on households' economic status, challenges to access electricity and their copping strategies, and adoption of ICS in informal settlements are very crucial and very limited in Ethiopia. It helps to implement energy efficiency policies that are vital to address economic, social and environmental challenges of informal settlers and devise evidence based execution strategies.

The study imparts important knowledge and disseminates valuable information to the various groups of stakeholders. It gives insights to ICS suppliers, government bodies promoting energy efficiency, development partners working with the poor and marginalized sections of the society and trying to solve households' problems in getting access to electricity, creditors and households themselves. It recognizes households' socio-economic realities, challenges to access electricity, its impact on their economic status and copping strategies. It explains why some households in informal settlements have access to electricity and adopt ICS while others do not, the effect of access to electricity, the need to transform from traditional to modern energy sources, and when to use multiple energy sources.

1.7. Limitations of the Study

The study noted the number of informal settlers' swells continuously due to the existence of housing problems in the city and lack of regular monitoring measures by the local government. Their number varies frequently and the *Woreda* Administration does not update its records regularly. Besides these, they are diverse in nature that span from poor to high income, those who hold a small plot of land to a large acre of land, houses made of wood and mud to buildings made of cement and steel, etc. These situations together with shortage of up-to-date data has made the study more complicated and forced this study consider only those households recognized by the city government. Because of this the aerial photograph of Addis Ababa taken in 2005 and the data developed thereof for electric-users is used for the study while the actual number of electric-users and non-users of electricity existed at the time of this survey is expected to increase considerably.

It was also difficult to get informal settlers and obtain information about them. Some are not comfortable to provide the required information and relate this study as government sponsored. This could have led them either provide unreliable information or reject the filling out the questionnaire provided and forced the researcher to substitute those respondents by others in the nearby areas.

Finally, due to the limited finance and time available, this study was conducted on the basis of cross sectional data gathered from two groups of households (electric-users and non-users of electricity) found in three sites. It did not try to capture panel data needed to evaluate the impact of electric use on the economic status of informal settlers over time. To circumvent the problems associated with using cross sectional data, the study considered non users of electricity as comparison group to evaluate the impact of electric use on informal settlers' economic status.

1.8. Conceptual and Theoretical Underpinnings

1.8.1. Informal Settlement: Conceptualization and Causes

There is no consensus among scholars about the concept and characteristics of informal settlement. It is known by varying terms like squatter, irregular, uncontrolled or unplanned settlement; situated between the urban centers and the cultivated edge of rural areas and far from facilities; and occupied small and unsecured public areas illegally (Majale, 2002). The terms have different applications according to historical, political, and socio-economic conditions (Corburn & Karanja, 2014; Jones, 2017).

They are considered as provisional aberrations by governments, not recognized as permanent features of the urban landscape and their needs tend to be ignored by urban policy-makers (Lemaire, 2015). These areas have limited access to services such as drinking water, constantly experienced with disease, and high possibility of eviction at short notice (Onyekachi, 2014). The Latin American and African experience indicated that residents are relatively weak in socio-economic activities, earn irregular income, and loose the financial benefits of clean energy use and energy providers trust (Butera, Caputo, Adhikaria, & Facchini, 2016).

Due to unsecured tenure and poor housing condition, they are often prevented from gaining access to electricity (Subbiah, Mansoor, Misra, Jaffer, & Tiwary, 2016). They suffer from economic and social exclusion, food insecurity, marginalized from basic human rights; and kept away from the benefits of global economy (Sverdlik, 2011; Jones, 2017; Lawana & Booysen, 2018; Subbiah, Mansoor, Misra, Jaffer, & Tiwary, 2016).

The characteristics of informal settlers in Ethiopia are not different from those characteristics mentioned above. According to Luhar (2014), the inability of the economy to supply housing for the low income groups, high population growth associated to rapid rural to urban migration, and expansion of informal businesses contribute more to informal settlement. OnYekachi (2014) explained that this is mainly resulted from the housing and urban development policies that only favor the formal sector and often found mixed with formal settlements (UN-Habitat, 2008). Their access to electricity is very low and power interruption is frequent affecting the quality and quantity of water supply, food and health care services.

1.8.2. Potential Sources of Energy in Informal Settlements

In addition to traditional sources, renewable sources can be considered as an alternative and opportunity to meet the energy requirements of informal settlements. Once the initial investment is made, they are more affordable than kerosene. Among this, hydropower is the cheapest to explore compared to all other renewable sources. It requires about 1.2 million USD/MW followed by solar energy (2.03 million), wind 2.1 million, and geothermal 4.67 million (MWIE, 2017). However, generating hydropower is affected by the seasonality of the water in reservoirs due to weather conditions and uneven distribution of water resources over Ethiopia (JICA, 2011; World Bank, 2018). This leads to power shortage during dry seasons while causing damages on reservoirs during wet seasons (Hailu, 2010). Geographically dispersed settlements also require high investment cost to construct infrastructural facilities and distribute power generated from large-scale hydropower projects.

Solar energy is an alternative to hydro energy which is freely available in abundant amounts, the most reliable, and easily accessible source of energy in dispersed settlements (Kovacic, Smit, Musango, Brent, & Giampietro, 2016). However, the initial installment cost is very high. The Ethiopian Government has developed a policy to address the energy requirements in scattered settlements using this energy. It encouraged the private sector involve in solar energy investment (JICA, 2011). The centralized solar energy also requires a huge investment and a vast amount of natural resources, most notably land and the costs for Solar Home Systems (SHS) are relatively high unless shared by households in the neighborhoods. Because of these, solar energy is the least utilized energy source (World Bank, 2018).

Wind and geothermal energy also help to diversify electricity generation, attain resilience against seasonal differences in water levels and contribute to Ethiopia's carbon-neutral status (FDRE, 2011). Currently, Ethiopia's total installed wind energy is very low and the government explained that this is because wind energy requires massive amount of steel, harmful noise and the infrasound it produces on the nearby residents and requires a huge amount of land.

Because of the huge capital requirements, investments energy in renewable resources are, therefore, unaffordable that forced households heavily rely on kerosene (Dawit, 2014). Though old data, UN-Habitat (2008) indicated that about 1.7% of informal settlements in Addis Ababa do not cook at all. Thus, one has to look at economic benefits, equity problems and environmental concerns that expose to a deep contradiction in the renewable energy transition; households coping strategies to the electric problem and its environmental catastrophes and the vicious circle it creates on increasing the scarcity and cost of firewood.

1.8.3. Modalities to Solve Energy Problem and Approaches to Energy Choice

Access to energy sources in informal settlements can be governed by various modalities. These modalities provide the essential domestic services and flexibility needed in all kinds of households; help to optimize connection fee; and involve different stakeholders. The modalities and approaches are presented and discussed hereunder and all are applicable in this study under different conditions.

1. *Access to off-grid model*: provides energy to communities with land insecurity, informal settlements, and for people with low level of electric consumption (Butera, Caputo, Adhikaria, & Facchini, 2016).
2. *Shared resources or rental model:* This creates opportunities to get access to capital-intensive technologies. This approach becomes appropriate due to households socio-economic factors such as insecure land tenure and exposure to eviction, financial factors and awareness level of the community on technology use.
3. *The financial sustainability model:* Provides energy depending on the households' perceived value, the willingness and ability to pay (minimal safety deposit and affordable fee for the service) and access to local financing. It balances between the amount to be paid by the households and the time required to break-even and the quality of services designed for the service. Nevertheless, the model does not properly monetize the social costs and benefits.
4. *The energy ladder or substitution approach:* Assumes traditional sources of energy are found at the bottom of the energy hierarchy and often used by low-income households using low energy efficient and high polluting equipment (Mele, 2014). But as families socio-economic status grows, households abandon the primary sources of energy (dung, crop residues and fuel wood) and progress to intermediate fuels (charcoal and kerosene) and finally switch to more advanced energies at the top of the energy ladder (biogas, LPG and electricity). The latter group of energy sources is more efficient, requiring less labor, and producing less pollution (Fig. 1). For example, kerosene is 3-5 times more efficient than fire wood for cooking, petroleum 5-10 times more efficient than crop residues and dung, improved fuel wood stoves saves up to 38% of fuel bills (Clancy, 2006; Butera, Caputo, Adhikaria, & Facchini, 2016).

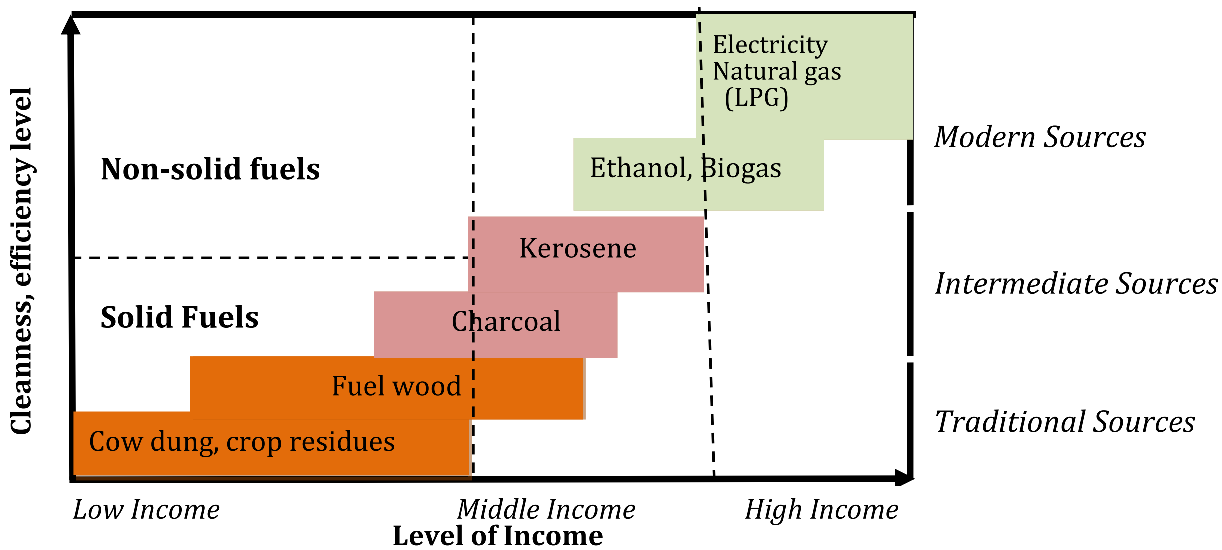

FIGURE 1: Households' Income Level and Energy Ladder

Source: Adopted from (Clancy, 2006; Mele, 2014; Getachew M. M., 2016; Butera, Caputo, Adhikaria, & Facchini, 2016).

This approach is crucially important and the concept is widely applicable when there is energy crunch and energy cost rises dramatically (Melchorjr, 1981). Melchojr suggested that these situations force life styles to shift to modern energies, change from material to service consumption, and encouraging the growth of service industries. Karatasou, Laskari, & Santamouris (2014) also explained that households need to make one-time investment in new technologies and purchasing household appliances that save energy; adopt energy conscious usage behaviors such as turning off the lights when leaving a room, conservation by lowering thermostat settings, installing fluorescent lamps, using a resource carefully, and take maintenance-related actions or servicing appliances.

The application of this approach, however, varies based on the specific local condition, the availability of resources, energy efficiency technologies and types of activities. A complete dependence on a single fuel also makes households more vulnerable to higher prices and unreliable services. According to Clancy (2006), the inaccessibility of higher-level energy sources and the high cost of connection fees for electricity, purchasing of LPG cylinders and electric appliances are significant barriers to switch to modern energy sources for low-income households.

5. *Fuel stacking /the integrated/ approach:* This approach is applicable when households' lack reliance on a specific energy source and due to the different uses of each source. In effect, households do not simply progress from one type of energy source to another along the energy ladder. Especially as family income grows, households prefer to use a combination energy sources at the same time with the concept of "*fuel stacking or the multiple energy sources.*" This approach provides a sense of security and energy source at higher level cannot completely supplant the existing energy supply (Butera, Caputo, Adhikaria, & Facchini, 2016).

This approach broadens energy sources, facilitate socio-economic growth, environmental resource management, avoid indirect consequences and tackle energy problems (Alahdad, 2014; Yang & Chen, 2016; Chen, 2016; Subbiah, Mansoor, Misra, Jaffer, & Tiwary, 2016). It also contends while every available and economically viable source of energy can be pursued, some energy sources like solar energy provides an immediate solution at different scales. In view of this, the Nigerian experience shows that the provision of off-grid or mini power solar energy directly to homes avoid expensive interstate pipelines (Olaniyi, 2017).

Clancy (2006) also noted that *extra-household factors* (such as availability of biomass and property tenure) and *intra-household factors* (such as households' preference and the taste of particular foodstuffs, pots not fitting new stoves and gender issues) prevent transition from wood or charcoal to modern energies. As a result, even in urban areas where modern energy is available, households may prefer to use biomass (Heltberg, 2004; Alemu & Köhlin, 2009). Hence, a number of questions can be raised about the energy ladder hypothesis such as which source of energy is easily accessible, saves the user's time and effort, cheaper, clean and healthy and gives more flavors to food staffs.

1.8.4. Electric Pricing and Payment Systems

In addition to land arrangements and urban land plans, pricing systems of electric service have significant contribution in improving the livelihoods of informal settlements. It takes one of the three forms.

1. Complete removal of subsidies on *fuels and adopting market-based pricing systems*. It shifts ownership and management from public to private occupancy on the assumption that it leads to technological advances, institutional and financial strength and energy service improvements in terms of cost and reliability that benefits the poor through trickling dawn effect (World Bank, 2000; Barja & Urquiola, 2001; Clancy, 2006). But charging the exact investment cost of energy and increasing electric tariffs based on market principle on the urban does not facilitate transition to modern energy.

2. Designing targeted subsidies: This is setting low connection fee and electric service for the poor and households that consume less power (Butera, Caputo, Adhikaria, & Facchini, 2016). Households in informal settlements are far from the network and more expensive to connect and targeted subsidy to these people lowers the cost. It has a greater impact on the livelihood of the poor by covering a larger portion of the expense and causes fewer distortions in consumption decisions than poorly targeted or untargeted subsidies.

Corollary to providing electricity to households at affordable price is supporting them to use energy efficient appliances (such as efficient refrigerators and long life light bulbs) together with education on how to use them (Clancy, 2006). In view of this, the New Energy Mix project in Johannesburg provided residents in informal settlements with gas stoves or appliances freely; reduce peak electric load using recharging energy storages, set affordable and tailored tariffs, demand-side management through smart metering, load limiting, and provided 3kW utility-scale rooftop solar PVs for 6-10 households (Oliveira, 2017).

Since energy efficient equipment require huge initial cost and locally unavailable, providing capital and assisting households buying electrical appliances and offering incentives for efficiency measures enhance the utilization of alternative energy sources and improve the quality of life of low-income households (increase spending on food, clothing, health, education and health by reducing expenditure on fuels) (Dawit D. , 2014).

3. Providing broad-based subsidy: This protects all citizens from potential tariff increases rather than protecting only low-income households. It charges one flat connection fee and monthly service fee for electricity service from all households. For this, the subsidy can be delivered by transferring directly to the household as a cash payment or making the cash payment to the utility provider (Butera, Caputo, Adhikaria, & Facchini, 2016). That is, the government shall subsidize utility service by considering the living standards of citizens. Nevertheless, when subsidies are untargeted, there is a general tendency of underpricing and abusing services.

Even if the price of electricity in Ethiopia is subsidized for low consumption levels and progressive as consumption increases indiscriminately, the connection fee is the same for all income groups.

Financial instruments such as limit to access finance, payment methods, payback periods, risk aversion, bureaucratic issues, lack of autonomy in decision-making about expenditures and other priorities are the crucial issues in electricity access and improving energy efficiency (Wohlfarth, Eichhammer, Schlomann, & Worrell, 2018). The simplest method that keeps service costs low is using individual electricity meters. The *fixed invoice periodic payment system can be applied* based on an estimate of the likely average consumption of electricity with the type of residential appliances (Butera, Caputo, Adhikaria, & Facchini, 2016).

Recently, customers purchase power through prepaid cards. This approach has the advantage of no risk to the supplier falling into arrears and likewise no need to maintain service crews to disconnect for non-payment in informal settlements. Prepayments can also be made using vending machines and through internets via cell phones. Nevertheless, when cell phone users are out of time, clients might have intermittent access to power.

1.9. Analytical Frameworks

Whilst conceptual framework is analysis plan outlining a research question and steps needed to conduct the study, analytical framework is designed to guide logical analysis and often interchangeably used with conceptual and theoretical frameworks. Like conceptual framework, it is schematic diagram or visual display that depicts the factors influencing households' energy consumption, how the different socio-economic factors and energy sources of households are interrelated, enables the researcher to critically consider multiple facets of the problem, how to investigate them and clarify the scope and objectives of the study (Getachew M. M., 2016).

Analytical framework presents the natural progression of the phenomena, the series of actions that the researcher intends to carry and the thinking of the whole research process (Ravitch & Carl, 2016), helps to synthesize studies made by others on related topics or what is already known, information gaps and data collection techniques (Grant & Osanloo, 2014; Latham, 2017; Regoniel, 2015), shows the possible outcomes of the research and remedies to the problem (Akintoye, 2015; Adom, Hussein, & Agyem, 2018). In line with these and based on the statement of the problem and research objectives, the following analytical framework is developed for the study.

Fig. 2 displays the main causes of informal settlement (that is, migration from rural to urban areas), the pushing factors, the expected benefits or pulling factors confounding this decision and the possible challenges associated with households electric use status. It helps to identify the main factors contributing to energy choice and explain the socio-economic characteristics of households in the study areas. It is crucially important to address the determinants of energy choice (objective 1) and become the bases for analyzing other objectives.

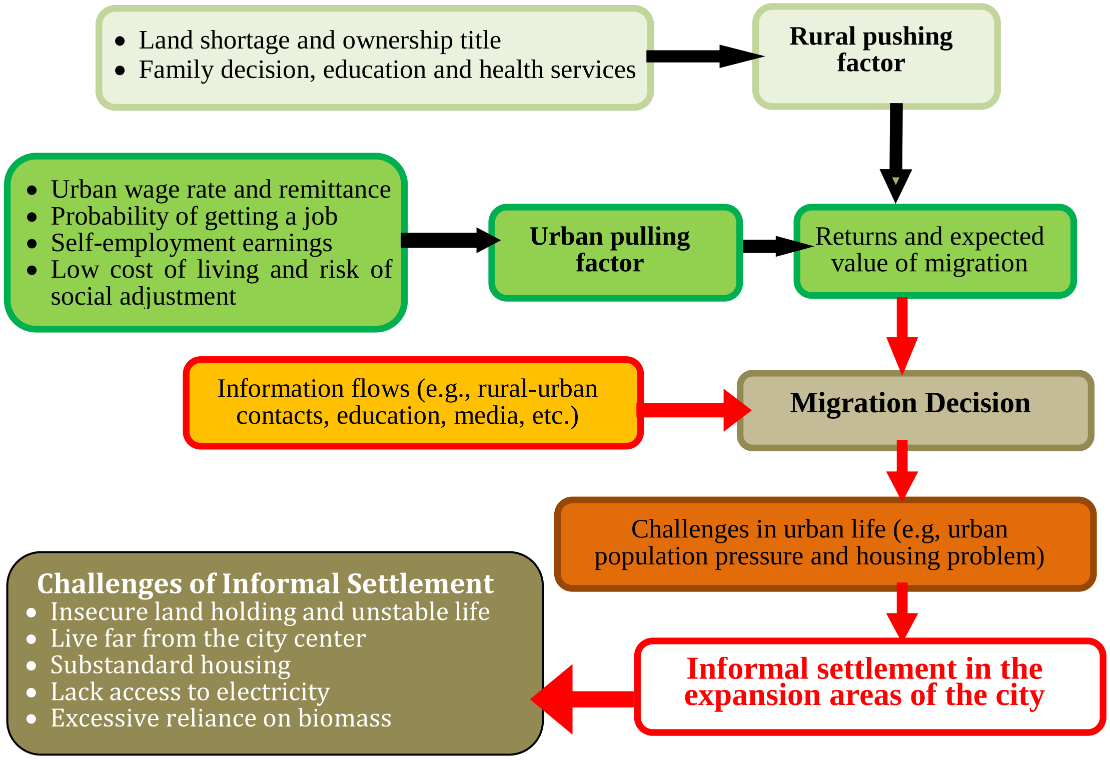

FIGURE 2: A Framework for Analyzing Rural-Urban Migration and Settlement Decision

Source: Adopted from Todaro & Smith (2012)

The various literatures indicated the drivers, legal implications, socio-economic consequences of informal settlement. Their energy sources are influenced by resource constraints. Fig. 3 depicts the five major interacting capitals and challenges that determine households' energy source. This in turn, determines their socio-economic status, intervention strategies and the possible outcomes. Finally, the intervention measures and the expected outcome have a circular effect on energy choice decisions and guide the actions of various stakeholders. This framework helps to analyze the factors affecting informal settlers' energy choice and the impacts of energy problem.

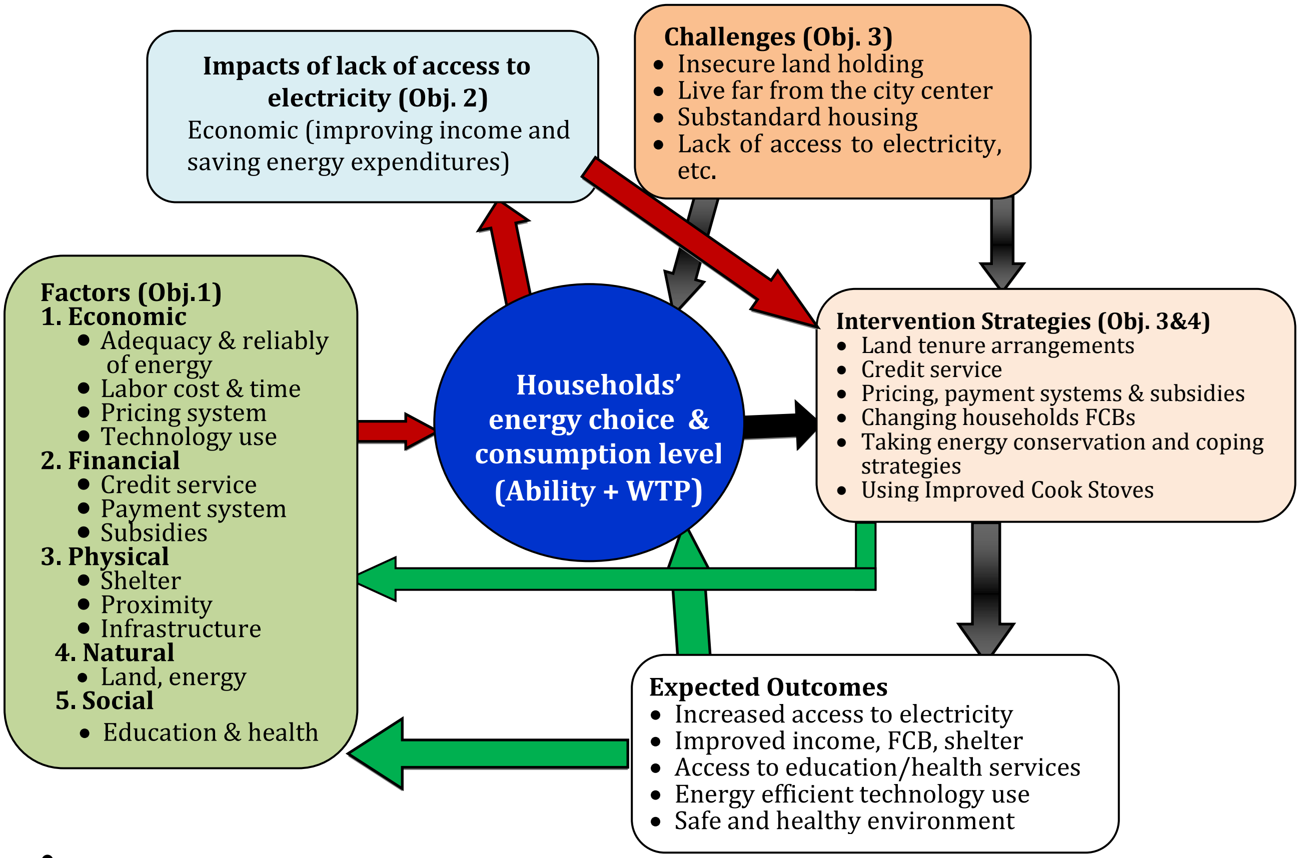

FIGURE 3: A Framework of Energy Choice Indicators, Challenges, Coping Strategies, and Expected Outcomes in Informal Settlements

Source: Developed by the author based on literature reviews, April, 2021

1.10. Research Methodology

1.10.1. Description of the Study Area

Like any other developing cities, the city of Addis Ababa is expanding in a sprawling manner and around 30% of the population lives with poor living conditions (Young, Anderson, & Naughton, 2018; World Population Review, 2021). The city has ten sub cities and four of them are found at the city center while the rest six are bordering to the rural *Kebeles*[5] in the surrounding region (Fig 4). Among the sub cities found in the vicinities of Addis Ababa, Yeka sub-city has a ragged topography; many households

[5] *Kebele is the lowest Administrative area (next to Woreda) in the rural area.*

live close to forests; and the sub-city is bordering the longest distances to the surrounding region extending from *Entoto Mariam* to *Legetafo*. These situations have drawn the attention of the researcher to focus on this sub-city.

Yeka sub-city, in turn, consists of 13 *Woredas* and 5 of them are found in the expansion areas. Among the 5, *Woreda* 12 shares the largest territory with the cultivated ages of the rural areas, situated in the vicinities of Addis Ababa and informal settlers are found in eight sites. The *Woreda* is located at about 9°3'2"N, 38°52'41"E, 2,450 meters above sea level. It is found approximately 11 km from the city center situated around the holy church of Kotebe Gabriel and Kotebe Metropolitan University.

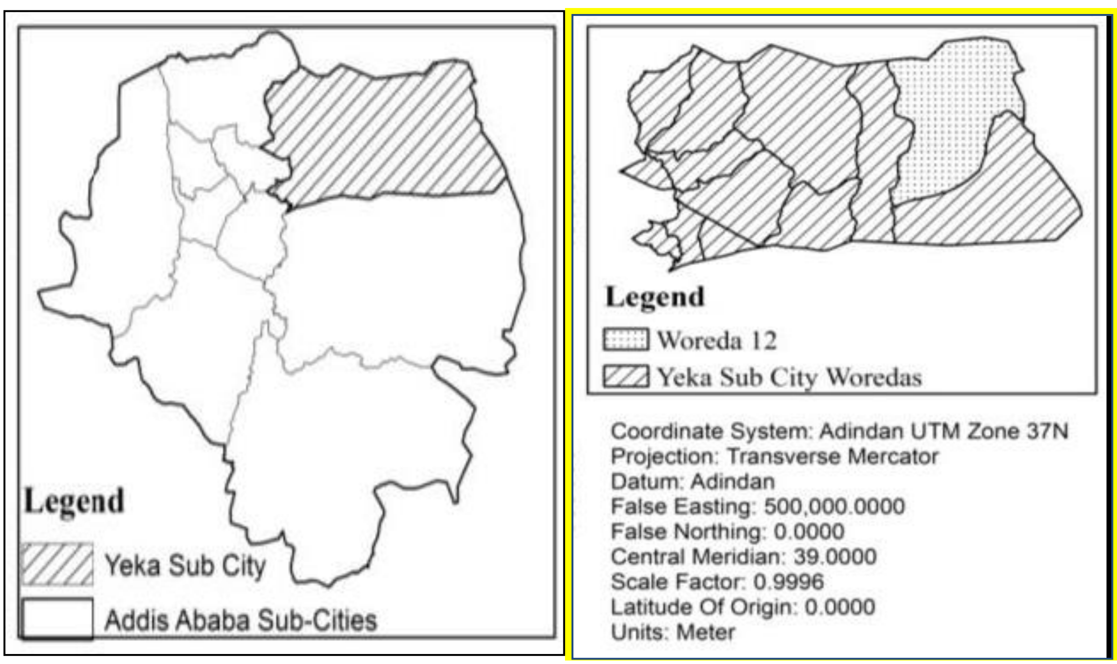

FIGURE 4a: Map of Addis Ababa and Yeka Sub City

Source: Modified from EthioGIS shape file, Oct., 2021

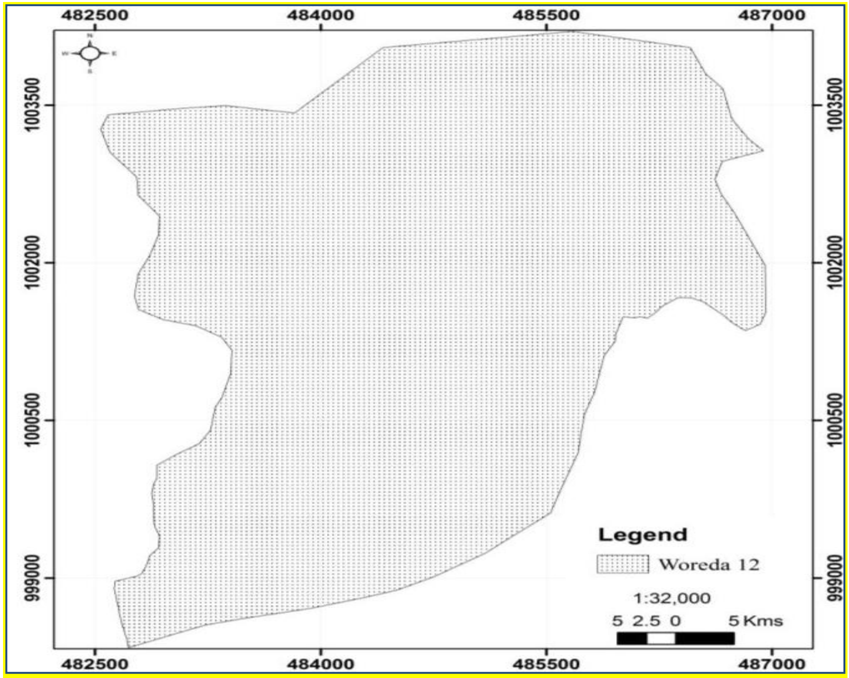

FIGURE 5b: Location Map of the Study Area, *Woreda 12*

Source: Modified from EthioGIS shape file, Oct., 2021

Based on the data compiled from the respondents, 78% of informal settlers have access to roads and transportation, 80% to education and health centers, 20% live around river banks and low laying areas, 47% live close to forest resources, and 38% located in a rugged topography. They are specifically located in eight sites namely, Kotebe Gebriel, Hibret Amba, Rediet, Happy Village, Mesalemia, Sara Park, Kara and Demamit.

1.10.2. Research Design and Philosophical Orientation of the Study

The study applied a mix of qualitative and quantitative approaches to address the objectives stated. It believes that only the combined approach generates sufficient data and reliable information for the study and enhances the understanding of social realities. It involves households in informal settlements and relevant stakeholders operating in the area and the method includes economic, social and environmental costs and benefits of energy consumption and the future energy transition possibilities.

According to Tolossa (2005) and Carnaghan (2018) qualitative research is a soft approach that applies intensive methods in a particular case and believes research is a social process influenced by theory and the investigator's value judgment and experience, central to the study of social activities, human behaviors, beliefs/views, people's experiences and theories, It is prominent due to its capacity to understand and interpret social realities, communicate results and the limitations of quantitative research that describes the reality using statistical models (Bauer, Gaskell, & Allum, 2000).

Research philosophy deals with the source, nature and development of knowledge and the belief about the ways in which data should be collected, analyzed and used. The assumptions shape how the research questions understood, the methods to collect data, procedures to analyze and interpret the findings are used. In view of this, the following philosophical foundations and values largely remain influential today and serve as interpretive frameworks and guide the qualitative and empirical component of this study supplemented by relevant theories (Creswell, 2012; Carnaghan, 2018).

1. Ontological view: Believes on the existence of single reality independent of human perception with multiple truths about it; socially constructed; constantly changing; relative meanings, explores various evidences from different perspectives and the experiences of individuals (Ed H. , 2018; Carnaghan, 2018). It shapes the way in which researchers interpret elements of the study; integrate human interest into a study; and access to reality only through social construction. They ask broad and general open-ended questions about what exists, understands nature and its essential properties, the social interaction process; historical and cultural settings of participants in the study area, causes of being and the basis of knowledge which is solely observable facts (Tashakkori & Teddlie, 1998; Lisahunter, Emerald, & Martin, 2013; Tolossa, 2005).

In view of this perspective, extensive information is sought on households' energy choice for domestic use in informal settlements, patterns of energy consumption for domestic use, perception about the alternative energy sources, households' socioeconomic and environmental conditions influencing energy consumption in informal settlements.

2. Epistemological approach: This is about what constitutes acceptable, valid and legitimate knowledge, how to communicate it to others, asks questions about what is known, how knowledge is gained about the reality from the participants being studied on the characteristics, principles and assumptions that guide the process of knowing, sharing and repeating knowledge to assess the quality of the research and the reliability of findings (Vasilachis de Gialdino, 2011; Lisahunter, Emerald, & Martin, 2013). Subjective evidences are assembled based on individual views (Carnaghan, 2018), the reality is constructed by the perceptions of people interacting with one another (Ed H. , 2018), measures the cause-effect relationships between variables and makes generalizations free from investigator's value judgment (Winchester, 2000). It believes that there is no access to reality or data independent of our minds, does not exist prior to the activity of investigation, and ceases to exist when the researcher no longer focuses on it (Smith J. , 1983).

3. Axiological approach refers to the role of values and ethics in the research process, questions about how researchers deal with own values and the research participants (Lisahunter, Emerald, & Martin, 2013). It makes the researchers' values, biases and information gathered from the field to ensure legitimacy and quality of research and complement quantitative research. In our case, for example, the researcher reports the most feasible energy sources in informal settlements based on the theoretical frameworks, empirical data gathered from the field and the researcher's value judgment. It governs the analysis of informal settlers' energy choice for domestic use and their response measures.

Hence, due to the contextuality and subjectivity of knowledge and the incompatibility and inherent differences in philosophies underlying the qualitative and quantitative research, this study used combined approach to generate sufficient and reliable data. Mixing the three approaches enhances an understanding of social realities, helps to examine the different facets of a phenomenon, discover contradictions, paradoxes, expand the breadth and scope of the study (Denzin & Lincoln, 1994; Greene, Caracelli, & Graham, 1989).

1.10.3. Sample Design and Sampling Method

Considering the existence of very large number of informal settlers, their similarity and the difficulty to cover all sites in a given time and financial constraints, the sample design (the Sub City, the study *Woreda,* and specific sites) is down-scaled to household level and respondents were drawn in three stages as follows.

1. Among the ten sub cities in Addis Ababa, Yeka Sub City is selected *purposively* due to the reasons explained above. It consists of 13 *Woredas* and 5 of them are found in the expansion areas. Among these**,** *Woreda* 12 was also chosen purposively due to its location in the expansion areas and the longest territory it shares with the neighboring region relative to the other four *Woredas* in Yeka sub-city.

2. Based on the GIS data taken in 2005 and documentary evidences of *Woreda* 12 Administration, electric-user informal settlers' are 1926 and found in seven sites

and non-users of electricity are 664 and located in three sites (Table 1). In the process of *formalizing the informal settlers,* both groups of households registered in 2005 received confirmation letter that gives them partial legal land entitlement and supporting letter to get access to utilities (such as electric and water services). However, households settled after this period are treated as non-users of electricity and highly liable to eviction with short notice.

TABLE 1: Informal Settlers in *Woreda 12* based on Specific Sites and Electric Use Status

Informal settlement sites in *Woreda* 12	Electric-users	Non-users of electricity	Total
1. Demamit/Demeka	658	269	927
2. Kotebe Gebriel	451	247	698
3. Happy village	469	-	469
4. Hibret Amba	116	-	116
5. Rediet	113	-	113
6. Mesalemia	85	-	85
7. Sara Park	34	-	34
8. Kara	-	148	148
Total	**1926**	**664**	**2590**

Source: Data organized by the author from documentary reviews, April, 2021

These numbers are still very large and used to develop *a sample frame*. As a result, two sites from electric-users (Kotebe Gebriel and Hibret Amba totaling 576 informal settlers) and two sites from non-users of electricity (Kotebe Gebriel and Demamit totaling 516 informal settlers) were selected purposively. This helped to develop balanced number of households from each group, from different geographical locations and make the sample size manageable within the given time and financial resources (Table 2).

TABLE 2: Selected Sites and Number of Households based on Electric Use Status

Selected sites in *Woreda* 12	Electric-users	Non-users of Electricity	Total
Kotebe Gebriel	451	247	698
Demamit/Demeka	-	269	269
Hibret Amba	116	-	116
Total	**576**	**516**	**1083**

Source: Data organized by the author from documentary reviews, April, 2021

3. Too small samples hardly represent the population and may lead to erroneous conclusions. Hence, adequate sample size is selected by considering (1) the variance in the underlying population and the need for disaggregated information (i.e., the bigger the variance, the larger the sample size); (2) the required precision level in the estimates (often 95% confidence interval is widely used as a benchmark); (3) the maximum likely response rate; (4) the available financial, manpower, time and material resources for the study; and (5) the study objective and the nature of the problem (Pearce & Ozdemiroglu, 2002). Then, once the population of interest (sample frame) is specified, the representative sample sizes for study considering relative heterogeneity between sites and relative homogeneity among households within the same site is determined as follows (Kothari, 2004):

$$n = \frac{Z^2.N.p.q}{\sigma^2(N-1)+(Z^2.p.q)}$$

Where, N_i *and* n_i = Population and sample sizes respectively

p = Maximum possible proportion (p = 0.5 and q = 1-p) that gives the largest number of sample sizes compared to any other combinations for P and 1-P.

σ = Precision level or margin of error at 0.05

Z = The number of standard deviations at 95% confidence level

Using this formula, sampled households from each group were determined as follows:

Electric-users: $n_1 = \frac{Z^2 N.P.q}{\delta^2(N-1)+(Z^2 Pq)} = \frac{1.96^2 X 567 X 0.5 X 0.5}{(0.05)^2(567-1)+1.96^2 X 0.5 X 0.5)}$ **= 229(51%)**

Non-users of electricity: $n_2 = \frac{Z^2 N.P.q}{\delta^2(N-1)+(Z^2 Pq)} = \frac{1.96^2 X 516 X 0.5 X 0.5}{(0.05)^2(516-1)+1.96^2 X 0.5 X 0.5)}$= **221(49%)**

The total number of households selected for this study **450(100%)**

These households are selected from Kotebe Gebriel, Hibret Amba and Demamit using *proportional sampling method* and the households served as a *unit of analysis* (Table 3). This gives equal chance of inclusion of households from each site, fairly represents households from electric-users and non-users groups, and minimizes sampling errors. First, electric-users were selected *randomly,* then non-users of electricity were chosen using the *Nearest Neighborhood Method (NNM).*

TABLE 3: Sampled Households based on Site and User Status

Study sites selected	Electric-users	Non-users of electricity	Total	
			Freq.	%
Kotebe Gebriel	184	104	288	64
Demamit/Demeka	-	117	117	26
Hibret Amba	45	-	45	10
Total	**229**	**221**	**450**	**100**

Source: Data organized by the author from documentary reviews, April, 2021

1.10.4. Data Sources and Analysis Methods

Primary data was obtained using surveys that involve multi-tier questionnaires and interviews. The questionnaire helped to capture information on households' socio-economic characteristics, informal settlers' energy sources and factors influencing energy choice, income generated from home-based business activities, food consumption behaviors, energy saving stoves adopted by informal settlers', the reasons for using the stoves currently owned, adoption level of ICS and challenges encountered in using ICS. It covers both quantitative and qualitative data and the questionnaire was administered on 450 randomly selected households found in Kotebe Gebriel, Hibret Amba and Demamit. The qualitative data helped to understand households' energy consumption behaviors, coping mechanisms to the energy problem, interpret the research findings and causal effects.

The questionnaire was managed by the researcher and properly selected, well trained and closely supervised enumerators. The total number of enumerators varies on daily bases (on average 5-6 persons were involved on daily basis). Most of these enumerators are professionals and experienced in data collection and analysis. The list of informal settlers' was obtained from the registry book and computerized data base of *Woreda* 12 Administration.

The data were collected from April to June, 2020 and the period when data were collected do not affect energy consumption and expenditure levels of the household. This is because the questionnaire was designed to gather the average of three months data.

Fieldwork during data gathering stages helped to observe the general housing condition, the landscapes, availability of infrastructures in the study area and closely monitor the activities of data collectors. To minimize distortions and personal biases associated with respondents' opinions and attitudes, the validity and reliability of the data gathered was verified carefully using statistical software (SPSS and Stata).

However, due to lack of legal living status of informal settlers, strict randomization was not possible and some are even reluctant to fill the questionnaire or unavalable during surveys. Such problems were managed and the margin of errors was minimized by substituting these households by others using the nearest neighborhood method.

Documentary review: This helped to develop literatures and develop a list of informal settlers' that served as a sample frame. The later was obtained from the registry book and computerized data base of *Woreda* 12 Administration.

Descriptive statistics and the binary logit model were used to analyze data and establish a relationship between households' socio-economic backgrounds, energy source related factors, Food Consumption Behaviors (FCB), shelter condition and other factors with their electric use status (Chapter 2). In Chapter 3, regression models such as *endogenous switching regression (ESR) and the treatment effect* of electric-use were applied. They helped to assess the impact of electric use on households' economic status. To analyze the challenges to access electricity and strategies to cope up the energy problem, descriptive approach and the binary logit model were used (Chapter 4). The model helped to identify factors affecting households' willingness to pay (WTP) for improved electric supply and criteria to set electric tariffs for domestic use. It helped to estimate the significance level of each predictor and ensure the robustness of the findings through descriptive analysis. To analyze the adoption of ICS, households were classified based on their electric use status and descriptive statistics and the *multinomial logit model* were used (Chapter 5). The model established a relationship between the ICS use and factors affecting the choice.

1.11. Structure of the Dissertation

This dissertation is organized based on journal article publication guideline set in thesis compilation guideline of Addis Ababa University. It is organized in six chapters: The first begins with the Introduction Chapter that sets the context of the study, statement of the problem, research questions and objectives, significance, scope and limitations of the study, the theoretical and conceptual frameworks, and the research methodology (the study approach, sampling design, data sources and analysis methods). Chapter 2 provides determinants of energy choice for domestic use in informal settlements. Chapter 3 deals about the impact of access to and use of electricity on the economic status of households in informal settlements. Chapter 4 explores the challenges to access electricity and households' coping strategies. Chapter 5 analyzes the adoption of ICS by households in informal settlements. Since chapter 2-5 are articles submitted to separate Journals for publication and the main pillars of this dissertation, they stand alone that presents abstract, background, research methods, results and discussion, and conclusions subsections. The last part of this dissertation (Chapter 6) presents the synthesis of the whole study on households' domestic energy consumption in informal settlements of *Woreda 12,* Yeka Sub City, Addis Ababa. It draws the key findings on the basis of the articles developed so far and shows the connections among them. It also provides conclusions, policy implications on domestic energy use and future research directions.

Chapter 2

Determinants of Energy Choice for Domestic Use in Informal Settlements in *Woreda 12,* Yeka Sub City, Addis Ababa[6]

Abstract

This paper analyzed the determinants of energy choice for domestic use in informal settlements of Addis Ababa based on the data generated from 450 households in Yeka Sub-city, Woreda 12. The descriptive analysis showed that household heads from 30-60 years of age, education above grade 4, suitability of the dwelling place to the urban plan, number of years lived in the area, availability and reliability of energy sources, and food consumption behaviors heavily affect households access to electricity. Households who lived more than 9 years, families with higher levels of income, employed on permanent basis, living in a good shelter (made from blockets and steel) and large number of rooms has better access to electricity while land title and size held, electric tariffs and proximity to electric line have no relationships with households' electric-use status.

Keywords: *Determinant; Domestic use; Informal settlement; Electric use; Addis Ababa*

2.1. Introduction

Understanding the factors that determine households' energy choice and consumption levels is the key to apply either developmental fuel switching hypothesis or integrate multiple energy sources (Agizew, 2017; Ateba, Prinsloo, & Fourie, 2018; Soltani, et al., 2019). The energy ladder approach is an extension of consumers' economic theory that contends as income increases, households substitute lower level energy sources (biomass and kerosene) by higher level energy

[6]. *Paper published in the Journal of Science and Sustainable Development (JSSD), ISSN: 2070-1748, Volume 8, pp. 33-43 https://dx.doi.org/10.4314/jssd.v8.3.*

sources (LPG and electricity). On the other hand, due to shortages of modern energy sources and prior energy consumption habits, households use both sources from the lower and upper levels in the energy ladder with the concept of fuel stacking. High cost of modern appliances and the different reasons for choosing energy sources in different locations also forces consumers to use multiple energy sources (Bisu, Kuhe, & Iortyer, 2016; Muller & Yanb, 2018).

Energy choice and consumption behaviors are also influenced by households' socio-economic factors; the availability and price of energy sources; the prevailing weather condition; home ownership, size, type and condition (Danlami, Islam, & Applanaidu, 2015; Butera, Caputoa, Adhikaria, & Mele, 2019; Olugbire, et al., 2016; Soltani, et al., 2019). However, all factors are not equally important in explaining households' fuel consumption behaviors (Danlami, Islam, & Applanaidu, 2015; Amoah, 2019). For example, wealthy households headed by higher levels of education are less likely to use fire wood, kerosene and Liquefied Petroleum Gas (LPG) and consume more electricity and solar energy (Gebreegziabher, Mekonnen, Kassie, & Köhlin, 2012; Lay, Ondraczek, & Stoever, 2013; Baiyegunh & Hassan, 2014; Soltani, et al., 2019). The total energy expenditures and the number of fuels used also increases with higher levels of income (Alemu & Köhlin, 2008; Fantu, Abebe, & Tadele, 2015; Agizew, 2017).

Unreliable electric supply, prohibitive energy prices, and cooking practices guide households' energy consumption decision (Ateba, Prinsloo, & Fourie, 2018). Households living in traditional houses are also less likely to choose natural gas and electricity (Weldegebriel, 2011; Luhar, 2014; Dadzie, Runeson, Ding, & Bondinuba, 2018). Instead they heavily rely on 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 is increasing (Getachew, Abera, Edwards, & Troncoso, 2018). The socio-economic variables affecting households' energy consumption patterns and the availability and price of biomass also vary based on time differences (Ayele & Demel, 2018).

Informal settlement is a growing urban problem caused by lack of regular legal measures by local government (Luhar, 2014; Dadzie, Runeson, Ding, & Bondinuba, 2018). They occupy illegal land, live in low quality houses constructed on lands where occupants have no secured tenure, located in areas between the urban center and the cultivated edge of rural areas. They are characterized by low electric consumption, earning irregular income and poor capacity to pay connection fees and electricity charges (Gaunt, et al., 2012; Onyekachi, 2014; Karatasou, Laskari, & Santamouris, 2014; Subbiah, Mansoor, Misra, Jaffer, & Tiwary, 2016; Butera, Caputo, Adhikaria, & Facchini, 2016). These situations forced them to rely on traditional energy sources that emit high carbon monoxide, smoke, and produce less heat (Yu, Yaoqiu, Ningsheng, Zhifeng, & Lianzhong, 2008; Karatasou, Laskari, & Santamouris, 2014).

Bisu, Kuhe, & Iortyer (2016), Yonas, Abebe, Köhlin, & Alemu (2016), and Makonese, Ifegbesan, & Rampedi (2018) tried to relate households' energy consumption decision with their socio-economic characteristics, climate variability, and the influence of various factors on households' energy choice. However, all targeted residents in rural and urban centers. Informal settlers' socio-economic backgrounds, current settlement patterns and the influence of land holding on energy choice are not given much attention.

In Addis Ababa, informal settlers are about 18.3% of the population (Butera, Caputo, Adhikaria, & Facchini, 2016). They lack access to clean, reliable and affordable energy. There is frequent power interruption, fluctuation, outages for long hours and sometimes oversupply that damages household' durables. The availability of electricity power also varies from place to place. This makes grid expansion difficult and expensive to connect (JICA, 2011; Kovacic, Smit, Musango, Brent, & Giampietro, 2016). The numbers of informal settlers are continuously swelling and urban sprawling is growing very fast that makes the provision of adequate, reliable, and affordable electricity supply difficult.

In *Woreda* 12, Yeka sub-city, informal settlers' use low-grade traditional fuels that cause indoor air pollution, produce less heat, and more smoke, hence a major threat to the environment. On one hand, these energy sources consume a lot of time and family labor and urge households to buy power from private suppliers. On the other hand, they are the only alternatives to cook traditional foods (Belay & Aberham, 2015).

This study, therefore, tries to identify the various factors influencing informal settlers' choice of energy for domestic use in *Woreda* 12, Yeka sub-city (Addis Ababa). It relates demographic variables and household characteristics; energy source related factors (such as availability, reliability, and affordability of energy sources); households' food consumption behaviors; and other variables such as land title and size of land held, shelter condition, location of the living area and length of time a household lived with access to electricity. This aims to stabilize energy prices, increase the supply of alternative fuels, reduce the pressure on wood resources, and maintain appropriate energy mix from renewable sources (JICA, 2011). The study provides some insight to energy suppliers and the government to focus on households that require special support, subsidy and/or outreach service.

2.2. Research Methodology

This part is presented in the general introduction chapter. To avoid unnecessary repetitions, only data analysis methods specific to this objective are presented in this section. To this end, the determinants of households' electric use status and their consumption behaviors in informal settlements were analyzed using descriptive statistics, analytical methods and the binary logit model. The study was carried out based on the premise that sources of energy and consumption patterns vary among urban dwellers' based on their land holding status, income groups, residents' geographical location and food consumption behaviors.

2.3. Results and Discussion

2.3.1. Demographic and Household Factors

Sex and age structure: Gender-based electric-use status survey showed that, from the total households interviewed, 63% are male headed while the rest are female headed. In terms of electric use status, 48.59% of male headed households are electric-users and 51.41% are non-users of electricity while 54.82% of female headed households are electric-users and 45.18% are non-users (Table 4). Since the difference between male and female electric-users is small, the relationship between sex of the household head and access to electricity is not significant. But the findings of Rahuta, Alib, Mottaleba, & Aryal (2019) show female-headed households are more reliant on fuel wood.

In terms of age, 88.65% of electric-users and 85.52% of non-users are 30-60 years. Although the difference is narrow, it implies that there is still a relationship between households' electric-use status and age brackets. That is, household heads[7] from 30-60 years of age have relatively better access to electricity (Table 4). However, studies conducted among rural household heads of Nigeria indicated that as age increases, they tend to shift away from natural gas and use more fuel wood (Baiyegunh & Hassan, 2014). In Ethiopia, they are more likely to consume charcoal and less

[7]. *Household head is the one who has an income and decision making power in family affairs. In Ethiopian culture, it mainly refers to the husband for married couples.*

kerosene and electricity (Gebreegziabher, Mekonnen, Kassie, & Köhlin, 2012). In Iran, the relationship between the household head age and level of electric consumption are inversely related (Soltani, et al., 2019).

Family size[8]*:* According to Soltani et al., (2019), as family size increases, households' energy consumption increases. In this study, 11% of electric-users have less than 3.53% have 3-4 and 35% have 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.

Marital status: Survey results show that among electric-users, 85% are married, 12% are singles, and 3% separated. From non-users of electricity, 71% are married, 24% singles and 5% separated. In both cases, married households constitute the majority implying being married does not guarantee households' access to electricity.

Education of the household head: In this study, 30% of household heads are below grade 9 where 25% are electric-users. From households with grade 9 education level and above, 63% are electric-users. From electric-users, 2.62% are below grade 4, 12.23% are from grade 4-8, 25.76% are from grade 9-Diploma, and 59.36% are degree and above (Table 4). These data show with higher levels of education, the number of households using electricity increased consistently. In line with this, Ayele (2019) and Yonas, Abebe, Köhlin, & Alemu (2016) revealed that households' headed by individuals with higher levels of education are less likely to use kerosene and more likely to depend on electricity. Yonas, Abebe, Köhlin, & Alemu (2016) and Bisu, Kuhe, & Iortyer (2016), described that this is because education speeds up cultural

---

[8]. *Family size refers to the number of people living in one home and their relationship is tied with blood.*

changes on households’ energy consumption behaviors and a key variable to switch from lower level to higher level energy sources in the energy ladder.

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, Alib, Mottaleba, & Aryal, 2019). In this study, as family income increases, the demand for biomass and electricity increases. This is because non-users lack of access to electricity and unreliable electric service to electric-users.

To corroborate the relationship between family income and electricity use status, data on household heads’ employment status and type of employment was organized. The result showed 56% are hired, 38% self-employed, 4% unemployed, and 2% retired. The proportions of electric-users already hired are 68% implying that hired household heads are more likely to get access to electricity than those who are unemployed. This could be due to their stable income and capacity to pay electric bills.

Furthermore, 91% of hired household heads are permanent employees, 8% are contract and the rest 1% are daily and hourly workers. Among permanently hired employees, 71% are electric-users showing the high chance of getting access to electricity (Table 4).

TABLE 4: Households' Demographic and Socio-Economic Factors

Characteristics		EU	NEU	Total	Percent
1. Sex:	Male	138	146	284	63
	Female	91	75	166	37
2. Age:	Below 30	19	23	42	9
	30-45	106	113	219	49
	45-60	97	76	173	38
	Above 60	7	9	16	4
3. Marital status:	Single	27	51	78	18
	Married	194	153	347	78
	Separated	6	14	20	4
4. Family size:	Up to 2 families	26	29	55	12
	3-4 families	122	120	242	54
	More than 4 families	81	72	153	34
5. Education level:	Below grade 8	34	102	136	30
	Grade 9-Diploma	59	75	134	30
	Degree and above	136	43	179	40
6. Employment status:	Hired	171	81	252	56
	Self employed	50	120	170	38
	Retired/unemployed	8	20	28	6
7. Employment type if hired:	Hourly and daily	2	2	4	1
	Contract	6	13	19	8
	Permanent	163	66	229	91
8. Family income:	Up to 6,000 *birr*	32	88	120	27
	Above 6,000 birr	197	133	330	73
9. Years lived in the area:	Up to 3 years	9	64	73	16
	4-6 years	42	72	114	26
	7-9 years	62	41	103	23
	Above 9 years	114	41	155	35
10. Home condition owned:	Poor (wood & mud)	31	75	106	24
	Good (wood & cement)	170	143	313	70
	Very good (steel & blockets)	25	3	28	6
11. Rooms owned:	1-2 rooms	50	118	168	38
	3 rooms	71	68	139	31
	More than 3 rooms	104	34	138	31
12. Land size held:	Up to $120m^2$	30	49	79	18
	$120\text{-}240m^2$	159	154	313	70
	Above $240m^2$	38	14	52	12

Source: Survey data, April, 2021

2.3.2. Energy Source Related Factors

Availability and reliability of energy source: Informal settlers commonly use firewood, charcoal and electric power for domestic energy. The study result indicated that 5% of electric-users and 49% of non-users used biomass (including plant residues) for baking and 2% of electric-users and 47% of non-users used biomass for cooking. From electric-users, 48% used electricity for baking and 51% for cooking. Further, 42% of electric-users described that electricity is often available (6-7 days per week), 53% from 3-5 days, 3% from 1-2 days a week, and 2% have no power at all. About 60% of electric-users rated the overall electricity supply situation as moderate while others indicated frequent interruption and power fluctuation that determined households' energy choice in informal settlements.

Price of energy: The most expensive energy source in the study area is kerosene and LPG as described by 47% of the respondents followed by electricity by 35%, and biomass by 18%. That is, relative to kerosene, LPG and electricity, traditional sources of energy are low in cost in informal settlements. Yet due to its convenience to use and cleanness, non-users of electricity want to get access to it and 61% of them are even willing to share electricity meters with their immediate neighbors and pay the service charges required together. The survey data revealed that, depending on the proximity to electricity lines and connection period, electricity connection fee ranges from 650-10,000 *Birr*[9].

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 and reduce time and the work loads

9. *Birr is the currency of Ethiopia. The average official exchange rate in April 2022 was 1USD = 52 birr.*

of women and children (socio-economic reasons). Others choose energy sources that are clean and healthy (environmental reasons). For example, 86% of households primarily choose firewood and charcoal and 14% kerosene, LPG and electricity for technological reasons (that is the availability of cooking apparatus and simplicity to operate them). On the other hand, 95% of households' chose electricity and 5% firewood, charcoal and kerosene for socio-economic and environmental reasons. 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. This implies that electric-users use both electricity and biomass while non-users solely rely on animal dung, firewood and charcoal. For cooking purposes, 69% of electric-users and 52% of non-users of electricity used firewood at least once in 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 could use firewood and charcoal. As a result, 97% of electric-users and 68% of non-users cook food 1-2 times per day using charcoal whilst electricity is solely used for baking and cooking by households that had access to it. These empirical evidences show, in addition to electric power, electric-users used more charcoal than non-users of electricity and such unfair use of electric power and forest resources by few people could raise controversies among citizens.

The average, minimum and maximum energy expenditure per month and the number of households that used each source is compiled in Table 5. Based on this data, the average expenditure for firewood is the highest and with the exception of firewood, the proportion of electric-users consuming all sources of energy is higher than non-users of electricity. The main reason for this is that those who had access to electricity were using traditional sources and the overall effect of this practice is unfair utilization of natural resources, air pollution, and a series of health problems to human life.

TABLE 5: Households' Monthly Expenditures for Alternative Energy Sources

Energy source	Monthly expenditures (*Birr*)			Number of households	
	Mean	Min.	Max.	EU	NUE
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

Note: EU=Electric-users; NEU=Non-users of electricity

Source: Data organized by the author, April, 2021

Figure 5 shows the influence of households' family income on the use of energy sources. Based on this data, as family income increased up to 9,000 *birr,* the number of households expending for each energy source increased and then sharply declined. This is mainly because the number of households' earning high income generally decrease. However, households with family income below 9,000 *birr* mainly used firewood and charcoal and those earning above 9,000 *birr* used charcoal and electricity. They spent 402 *birr* for firewood and 248 *birr* for charcoal per month. This indicates that firewood was more used by low income households while electricity was used by high income groups. Kerosene was least utilized energy source, often used temporarily or emergency purpose.

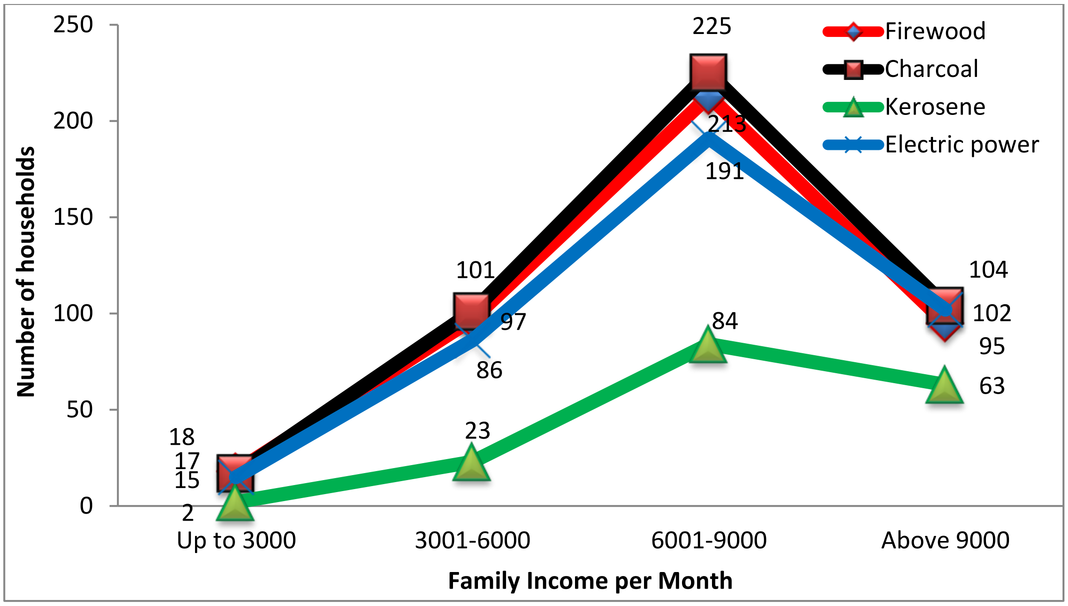

FIGURE 6: Households Alternative Energy Sources and Family Income

Source: Data organized by the author, April, 2021

2.3.3. Households' Food Consumption Behaviors

As presented in Table 6, informal settlers' choice of energy is influenced by households' food consumption behaviors. The study showed that many households preferred to use animal dung, firewood and charcoal to add the taste and flavor of food staffs, roasting and boiling coffee, fry and dry cereals like sweet corn and potato chips, and prepare *'Doro Wot* and *Shiro Wot*[10]*'* influenced by cultural factors and individual's long standing consumption habits. In relation with this, an interview made with one of our respondents in Kotebe Gebriel on April 5, 2020 indicated 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 associate their energy choice with the way they have experienced it from

[10]. *Doro Wot is chicken cooked occasionally and the best cultural dish in Ethiopia whereas Shiro Wot is a staple food prepared from peas, beans and other cereals.*

childhood. However, some disagree on the belief that “□□□□□□□ □□□ □□ □□□□ □□ □□□□□ □□□□ □□□□□□ □□□ □□□□□ □□□□□□□ □□□□ □□□ □□□□□” (instead of the type of energy used, the way food is cooked or baked gives the preferred taste and flavor). However, this certainly leads to environmental depletion and energy poverty that requires proper planning s to how to optimize the benefits of using alternative energy sources without jeopardizing environmental sustainability.

On the other hand, households preferred to use electricity for baking *Injera* mainly because it saved time and labor, and it is a clean and healthy source. However, since the electric supply is not reliable and low in power (especially during peak hours), many of the households used a combination of two or more energy sources to cook different dishes at a time, get fresh foods on time, and save labor and time.

TABLE 6: The Influence of Households’ Food Consumption Behaviors on Energy Choice

Purpose of energy	Firewood and charcoal		Kerosene and LPG		Electric power		Two or more sources	
	EU	NUE	UE	NUE	UE	NUE	UE	NUE
- Add the taste and flavor of food staffs								
- Roast and boil coffee	150	117	-	3	1	4	78	96
- Dry and fry cereals	209	192	2	3	6	18	12	8
- Prepare cultural Ethiopian dishes	222	199	2	4	3	17	2	1
- Bake Injera[11]	164	145	2	3	38	39	25	34
- To get a variety of food s	37	78	1	4	164	107	27	32
- Frequently cook and get fresh food	8	38	-	2	41	11	220	169
- Increase number of meals taken per	1	3	-	10	6	32	222	174
day	21	8	-	2	2	24	206	186

Note: EU=Electric-users; NUE=Non-users of electricity

Source: Data organized by the author, April, 2021

[11] *Injera is flat and circular baked traditional staple food made from fine iron-rich Teff typically grown in Ethiopia sometimes mixed with wheat, rice, barley or sorghum flour.*

2.3.4. Shelter Condition and Other Factors

Shelter type and condition: The data indicated that 76% of households live in a home made of steel, wood and cement/blockets. About 86% of electric-users and 66% of non-users live in a good home and above. Though the difference is small, these figures illustrate households living in a good and above housing condition are more likely to get access to electricity. That is, as households' shelter type and condition improves the tendency to get access to electricity increases.

Number of rooms owned: The survey data showed that the number of electric-users who owned more than 2 rooms are 78% and the number of non-users of electricity who owned more than 2 rooms are much smaller than the number of electric-users. This simple comparison indicates that as the households' number of rooms increase, informal settlers' access to electricity increases.

Number of years lived in the area: The number of years households lived in the area significantly affects households' access to electricity. For example, 77% of electric-users and 38% of non-users of electricity lived over 6 years in the area. The number of electric-users connected to electricity lines in the recent 5 years were 36% and those before 5 years were 64% indicating informal settlers' likelihood of getting access to electricity increases with the increase in the number of years lived in the area.

In an effort to know households' opinions on the suitability of the dwelling space for living and the urban plan, 68% of electric-users and 50% of non-users' homes were not located in suitable living area. This area is contradicting the urban plan. However, these situations did not prohibit 68% of households' from getting access to electricity.

Land title and size: Informal settlers held land through different means. Households described that about 71% held through purchasing land illegally from land owners in the expansion areas, 6% through land grabbing, and 23% through inheritance. Per the land policy of Ethiopia, individuals have the right to use the land under their custody and cannot sell or transfer to third party except through inheritance. In view of this, about 77% of households were typical informal settlers. Surprisingly, however, all households who inherited land from their families were still considered informal settlers and 41% of these households do not use electricity for baking and cooking. Conversely, 48% of typical informal settlers had access to electricity power. This could be due to poor governance and lack of responsive urban land management system. The survey data indicated that the minimum land size under the custody of households in informal settlements is $71m^2$ and the maximum is $400m^2$. The average land size is $172m^2$ and 88% held below $240m^2$. From households who held land below $240m^2$, electric-users accounted for 48% and from those who held more than $240m^2$, this group reached 73%. This implies that there is close association between land size held and higher chance of getting access to electricity.

Proximity of households' home to electric line: Distance between non-users' home and the nearest electricity line or a transformer can also restrain access to electricity. Survey results showed that non-users of electricity lived in between 8-700 meters away from the nearest electricity pole or a transformer (the average being 105 meters). However, 60% of electric-users and 89% of non-users of electricity were situated within 200 meters radius from the electricity facility. This indicates that non-users' proximity and geographical location to electricity facilities could not be a reason for restraining them from getting access to electricity. In the first place, most of non-users of electricity lived mixed with informal settlers currently given the privilege to use electricity.

2.4. Determinants of Households' Electric-Use Status: The Binary Logit Model

Households' energy choice determinants can be measured by comparing electric-users and non-users of electricity along a spectrum of relevant covariates using the binary logit model as presented in Table 7. The model helps to evaluate the relationships between households' electric use status and the potential factors affecting it, estimate the coefficients of determinants of households baking and cooking, explain the direction and strength of relationship between the outcome and the variables considered (Mwaura, et al., 2014).

The numbers of valid households considered for this analysis are 442 (98.22%) and the model fitting information is described by the -2 Log Likelihood (-2LL) ratio that represents the proportion of unexplained variance in the outcome variable. It indicates the model with the selected determinants of electric use status (the full model) better predicts the result than without those variables (null model). Therefore, the lower the value of -2LL, the better fit of the model. The Likelihood ratio chi-square test is alternatively used to test Pearson's goodness-of-fit. It 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 outcomes of this study is above average (Pseudo R^2=0.5092).

Analysis of residuals associated while estimating outcomes of the logistic regression model indicated the linearity and homogeneity of variance. This is because the points along the scatter plot are symmetrical, both above and below a straight line. The existence of outliers is 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 dropped from consideration.

The reference category (in our case electric-users) is selected based on the highest number and first group in the order of presentation (UCLA, 2020). The determinants considered are broadly classified into DHCs, ESRFs, HFCBs and other factors. Then, non-users of electricity are compared to electric-users to determine whether each variable considered is statistically significant. The output of the logistic regression is presented in table 7 on page 50.

2.4.1. Demographic and Household Characteristics (DHCs)

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 evaluated. The result showed that age brackets from 30-60, educational attainment above grade 4, and the number of dependent families from 1-4 affect households electric use status (Table 7).

For instance, given all other explanatory variables in the model constant and compared to non-users of electricity below 30 years, as the age of households from 45-60 increases by one year, their number increases by 1.9010. This implies that household heads from age 45-60 years have better chance of getting access to electricity than those below 30 years of age.

In terms of education, holding all other variables in the model constant and compared to non-users of electricity whose education is below grade 4, per unit increase in the education level of those household heads from Grade 4-8, Grade 9 to Diploma, and Degree and above, the number of non-users of electricity decreases by 1.25, 2.23 and 2.75 respectively. This implies that the number of non-users of electricity decreases at higher levels of education indicating electric-users are more educated than non-users of electricity and the likelihood of getting access to electricity increases when the education level of households increase.

With regard to the number of dependent families and its impact on electric use status of households, holding all other variables in the model constant and compared to those who have no dependent families, for households with 1-2 dependent families, as their dependent family's increases by 1, the number of non-users of electricity decreases by 1.06. Similarly, for non-users of electricity with 3-4 families, as their dependent family's increases by 1, the number of non-users of electricity decreases by 2.19. This means as the number of dependent families increase, the likelihood getting access to electricity increases. However, households above 4 dependent family sizes do not have this opportunity and the significance level drops sharply. This could be due to the influence of large number dependent families on households' ability to pay for connection fees and electric services.

2.4.2. Energy Source Related Factors (ESRFs)

A relationship has been established between 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 and electric use status. From these factors, only availability and reliability of energy source, availability of energy efficient technologies and the cost of these appliances have significant p-value and determine electric-use status of households (Table 7). In line with this, controlling the influence of all other explanatory variables in the model constant and compared to firewood and charcoal, as the availability and reliability of electricity increases by one unit, the numbers of non-users using electricity increases by 3.1453. This implies that availability and reliability of electricity significantly and positively influences non-users' access to electricity.

The availability of efficient and low cost technologies such as electric stoves and power saving appliances also determine households' access to electricity and their consumption level. Based on this data, holding all other variables in the model constant and compared to biomass stoves and appliances, as the availability of energy efficient stoves and electrical appliances increases by 1, the number of non-users of electricity decreases by 2.4538. This implies availability of ICS, electrical stoves and appliances alone does not guarantee access to energy efficient technologies and modern energy sources. It could be associated with non-users of electricity low level of income and lack of awareness on the new technologies. On the other hand, as electrical appliances and stoves becomes more affordable and if this affordability increases by a unit (i.e., when appliances become low in cost), the number of non-users demanding those technologies increase by 2.0498s and providing low-cost electrical stoves and appliances facilitates the transition of non-users to electric-users.

2.4.3. Households' Food Consumption Behaviors (HFCBs)

FCBs such as the variety of foods consumed, 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, and baking *Injera* were considered to evaluate their effect on households electric use status. However, only drying and frying cereals and cooking cultural foods affect households' electric-use status (Table 7). That is, keeping all other variables in the model constant and compared to biomass energy, as non-users of electricity start to dry and fry cereals using electricity and this number increases by one unit, their decreases by 2.588. This implies that as households in informal settlements change their FCB related to energy use, the number of households using biomass decreases while those using electricity gradually increases.

Likewise, under citreous paribus assumption, as non-users of electricity preparing cultural dishes such as *Doro Wot* and *Shiro Wot* using kerosene and LPG, electricity and a mix of energy sources increases by one unit, their number decreases by 2.5822, 1.2076 and 1.0771 respectively. This implies that, in relation with its contribution to add the taste and flavor of food staffs, non-users of electricity tend to use more biomass for cooking cultural dishes than other sources of energy.

2.4.4. Other Factors

The effect of other factors such as dwelling place suitability to the urban plan, shelter type and condition, number of rooms owned, number of years lived in the area, socio-cultural influences, and personal feelings and lifestyles on households electric use status are tested (Table 7). Based on this data, significant relationship is established between households' electric use status and the suitability of the living area to the urban plan, number of years lived in the area, socio-cultural influences and personal feelings and lifestyles.

Given all other explanatory variables in the model constant, as the unsuitability of living area (the residential place contradicts with the urban plan) increases by one unit, the number of non-users of electricity access to electricity decreases by 1.2295. That implies that suitability off the dwelling place to the urban is a decisive factor to get access to electricity.

Likewise, as non-users of electricity who lived in the area from 4-6 years, 7-9 years, and above 9 years increases by one additional year, their lack of access to electricity decreases by 0.993, 1.9605 and 2.5667 respectively. This implies that the longer the time period a household lives in the area, the likelihood of getting access to electricity increases and this could be due to the priority given to citizens lived for longer periods in the area.. The data also showed that 62.39% of non-users of electricity lived for relatively shorter periods in the area (below 7 years) while electric-users living in this period are only 22.47% indicating most non-users of electricity are settled in the recent years than in the distant past.

Socio-cultural influences and personal lifestyles and feelings could also influence households' access to electricity. Based on this data, as non-users of electricity believe that these forces have no or little influence on their energy choice and if this feeling increases by a certain level, their access to electricity increases by 0.7652 and 2.1973 respectively.

TABLE 7: 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

Electric use status	Coef.	Std. Err.	Z	P>/Z/
Non-users of electricity				
1. DHCs				
Age: 30-45	0.9672	0.5525	1.75	0.080
45-60	1.9010*	0.5968	**3.19**	**0.001**
Above 60	1.1305	1.0130	1.12	0.264
Education: Grade 4-8	-1.2487***	0.7300	**-1.71**	**0.087**
Grade 9-Diploma	-2.2291*	0.7181	**-3.10**	**0.002**
Degree and above	-2.7536*	0.7331	**-3.76**	**0.000**
Number of dependents: 1-2 families	-1.0600**	0.4979	**-2.13**	**0.033**
3-4 families	-2.1890*	0.5893	**-3.71**	**0.000**
More than 4 families	-0.0379	2.6524	-1.01	0.989
2. ESRFs				
Available & reliable source:				
Kerosene and LPG	-2.3094	2.0014	-1.15	0.249
Electric power	3.1453*	0.4564	**-6.89**	**0.000**
Availability of appliances:				
Kerosene and LPG	-0.2233	1.4989	-0.15	0.882
Electric power	-2.4538*	0.6123	**-4.01**	**0.000**
Affordability of appliances:				
Kerosene and LPG	0.0975	0.6860	0.14	0.887
Electric power	2.0498*	0.8272	**2.48**	**0.013**
3. HFCBs				
Dry and fry cereals:				
Kerosene and LPG	1.9511	1.9628	0.99	0.320
Electric power	-2.5880*	0.9404	**2.75**	**0.006**
The mix of two/more	-2.9412	2.0318	-1.45	0.148
Prepare cultural dishes:				
Kerosene and LPG	-2.5822***	1.5163	-1.70	0.089
Electric power	-1.2076**	0.5038	**-2.40**	**0.017**
The mix of two/more	-1.0771**	0.4913	**-2.19**	**0.028**
4. Other Factors				
Living area suitability: No	-1.2295*	0.3605	**-1.98**	**0.048**
Number of years lived: 4-6 years	-0.9930**	0.5024	**-3.44**	**0.001**
7-9 years	-1.9605*	0.5700	**-4.18**	**0.000**
Above 9 years	-2.5667*	0.6136	**-3.41**	**0.001**
Socio-cultural influences: No	0.7652**	0.3503	**2.18**	**0.029**
Personal feelings/life styles: No	2.1973*	0.7934	**2.77**	**0.006**
cons	5.1261	1.0548	**4.86**	**0.000**
Electric- users	**(Base outcome)**			

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

Source: Data developed by the author, April, 2021

2.5. Conclusions

This study has identified alternative energy sources for domestic use in informal settlements and the factors that affect households' electricity use status in Addis Ababa. However, owing to households' socio-economic and food consumption differences, all factors do not have equal importance in determining their energy choice and consumption levels. As a result, households that had access to electricity were found using more biomass and even consumed more charcoal than non-users of electricity.

Legality of land holding, proximity of the living area to electric line and its suitability to the urban plan had less influence on informal settlers' access to electricity. On the other hand, the number of years a household lived in the area, land size held the household; shelter condition/type and the number of rooms owned; the age, education level, family income and employment type of the household head; and number of dependent family members all played a significant role in influencing informal settlers' access to electricity.

The availability, reliability and affordability of electric supply were growing problems in informal settlements. High electricity connection fees and ever rising electricity tariffs had inhibited them from access to electricity. Associated with the increase in family size and increased energy consumption, availability and cost of biomass had also become a growing problem in informal settlements. Food consumption behaviors /cultural factors/ also play a significant influence on households' energy choice decisions.

2.6. Recommendations

It is noted that informal settlers occupied small and unauthorized land, earned irregular income, and were unable to pay connection charges and monthly electricity bills. These characteristics signify the need to take appropriate measures. Some of the recommendations that could increase households' access to electricity include three suggestions.

1) Segregate the criteria to provide electricity and formalize the informal settlers. Factors such as education of the household head, family size, number of years lived in the area, shelter size and condition. These conditions may encourage more people to involve in informal settlement and unplanned urban expansion. The government, therefore, has to formalize informal settlers' and the Ethiopian Electric Utility provide electricity services based on the suitability of the land held to the urban plan and the proximity of informal settlers' to the electricity facility. They should also balance households' socio-economic backgrounds and the availability and affordability of energy sources; and stabilize electricity prices by giving high priority to hydropower development.

2) Untargeted subsidies on the one hand and progressive electricity tariffs set indiscriminately for all households on the other should be thoroughly revised by considering the inadequate power supply and residents' paying capacity. To this end, subsidies should target the poor and discounts and encouragements given to those who use electricity power during off-peak hours. The initial connection fee should also take into account the residents' paying capacity and willingness to share cost among households in the surrounding areas.

3) Although the energy policy of Ethiopia underlines the need to transform from traditional to modern energy sources, due to the scarcity and the rising cost of electricity, most households (including electric-users) heavily use firewood and charcoal for various purposes (cooking/baking, roasting, boiling coffee, drying and frying cereals). This requires the need to change households' food consumption habits through conducting aggressive awareness creation campaigns and encourage them to use energy efficient stoves.

Chapter 3

Impacts of Access to and Use of Electricity on Households' Economic Status in Selected Informal Settlement Areas of *Woreda 12*, Yeka Sub City, Addis Ababa[12]

Abstract

At present, although electricity is essential for all human beings, it is not equally accessible to all people. This paper analyzed the impact of access and use of electricity on the economic status of informal settlements in Addis Ababa based on 450 households drawn from three sites of Woreda 12, Yeka Sub-City. The respondents were selected using proportional random sampling method and the data were analyzed using descriptive statistics and Endogenous Switching Regression (ESR) models. The study revealed that non-users of electricity shifted more family labor to domestic activities, backed Injera less frequently per week, owned small number of home-based businesses, and used less alternative fuels than electric-users. However, due to lack of reliable energy supply and households food consumption behaviors (FCB), households do not completely rely on a single energy source. These situations shall the attention of the government to provide reliable electric supply to non-users of electricity living sporadically mixed with electric-users and close to electric facilities and change households' energy consumption behaviors using alternative energy sources with the concept of energy stacking.

Keywords: *Electric-users; ESR; FCBs; energy stacking; home-based business; Informal settlement*

[12] *Paper accepted for publication by the ERJSSH, University of Gondar.*

3.1. Introduction

Access to adequate, reliable and affordable electricity is essential for basic human needs, improving family income, wealth creation, saving energy expenditures, improving the quality of life, and speed up households' energy transition in developing countries (WB, 2014; Torero, 2015; Stern, Burke, & Bruns, 2016; Beyene, 2018). It has the potential to simplify tasks, save family labor and time spent on food preparation, create home-based businesses, increase household income, and reduce environmental damages (Bhattacharjee & Reichard, 2011; Pickering, et al., 2017; Li, et al., 2019). Most importantly, it saves households' fuel expenditures and helps to enjoy a wider range of energy services to domestic activities (Lloyd, 2017; Hanania, Stenhouse, & Donev, 2018).

Many authors indicated energy increases gross domestic product, rises per capita income, reduces energy imports, solves current account deficits, and attracts foreign direct investments (Li, et al., 2021; Zhe, Yüksel, Dinçer, Mukhtarov, & Azizov, 2021). It also changes the consumption behavior of human beings, reduces the workloads of family members, influence food prices, improves healthcare services, nutrition level, water supply, and education service (Fantu, Abebe, & Tadele, 2015; FAO, 2015; Lloyd, 2017; Ateba, Prinsloo, & Fourie, 2018; Rahuta, Alib, Mottaleba, & Aryal, 2019). As a result, providing affordable, reliable, sustainable and clean energy for all in 2030 has become an agenda of sustainable development goals (UNDP, 2015; World Bank & IEA, 2017).

With the growth of the economy, people tend to use higher quality, cleaner, more productive and flexible energy source (Stern, Burke, & Bruns, 2016; Gyamf, Bein, & Bekun, 2020). The demand for this kind of energy grows due to continuing economic expansion and rising income levels (Adebayo, et al., 2021). As a result regulations that decrease the use of electricity have a negative impact on economic growth and obstruct economic growth at macro level.

The other issue that initiated this study is the reliability and affordability of energy consumed by households. Many people refer access to electricity only to availability. However, this concept incorporates adequacy, reliability, affordability, convenience to use, the length of time electricity is made available, amount of energy consumed per annum, legality and cleanness of energy sources (IEA, 2012; WB, 2015; Pueyo & Hanna, 2015; Padam, et al., 2018; UNESCAP, 2019). These concepts are crucial to properly analyze the impact of access to electricity on households' economic status in informal settlements.

Furthermore, residents found in different areas do not have equal access to electricity. The amount of energy consumed varies significantly among informal settlers. A study conducted by Njoroge, et al, (2020) identified the factors that influence households' fuel choices and the amount of energy consumed at the household level. These led households increasingly rely on biomass and expend more effort in cooking food on regular basis (Medina, Cámara, & Monrobel, 2016; Rahuta, Alib, Mottaleba, & Aryal, 2019).

Gaunt, et al., (2012), OnYekachi (2014) and Njoroge (2020) indicated informal settlements exist due to population growth associated with migration, the inability of the economy to supply housing for the low-income groups, and expansion of informal businesses. They are located in an area between the urban center and the cultivated edge of rural areas; occupied small, unauthorized and unplanned land that is not zoned for residential purpose; live relatively far from the city center and in dispersed settlements that makes them economically unattractive to electric suppliers (Subbiah, Mansoor, Misra, Jaffer, & Tiwary, 2016; Butera, Caputo, Adhikaria, & Facchini, 2016).

Residents lack basic services, live in a very poor living condition, dwellings vary from simple shacks to more permanent structures, found in different areas do not have equal access to electric power due to economic factors, population dynamics, the geographical location of residents, suppliers' limited capacity to provide electric power (Butera, Caputo, Adhikaria, & Facchini, 2016; Msimang, 2017; ESCAP, 2019). They are economically poor, earn irregular income, unable to pay connection charges, and even cannot use energy efficient technologies (Luhar, 2014; Dadzie, Runeson, Ding, & Bondinuba, 2018).

The provision of electricity to this area is constrained by capital investments and high costs of building infrastructures and transmission lines. Energy suppliers are not willing to make additional investments in informal settlements. This is mainly because of households lower electric consumption associated with their socio-economic backgrounds, electric tariffs that are not cost-reflective, and strategies that encourage households conserve energy consumption and minimize peak-time electric use (Karatasou, Laskari, & Santamouris, 2014; Arlet, Ereshchenko, & Rocha, 2019; Chowdhury, et al., 2019; Bayera, Kennedy, Yang, & Urpelainen, 2020). Those who already had access to electricity have faced with frequent power interruption, fluctuation, outages and sometimes over supply. These situations forced households in informal settlements rely on traditional energy sources.

The government, on the other hand, slowed dawn the expansion of electric supply in informal settlements. It gave less attention to energy kiosks, decentralized electrical services, off-grid electric expansion, private sector involvement in energy supply, and electric access programs like Universal Electricity Access Program (UEAP) that ignored the city of Addis Ababa (Subbiah, Mansoor, Misra, Jaffer, & Tiwary, 2016; Beyene, 2018). Increasing demand for energy, insufficient finance, and the need to subsidize electricity and energy-efficient devices are the major challenges to energy suppliers (Karatasou, Laskari, & Santamouris, 2014; Grueneich, 2015; Barnes, Golumbeanu, & Diaw, 2016; Blair, Pons, & Krumdieck, 2019). Together with lack of integrated urban planning, these factors influenced the power supply and enhance income differences among informal settlements. The number of people that have access to electricity is 44.98%, only 27% has grid connection and 92% of the energy produced is consumed for domestic use (WB, 2020).

Impact evaluations made on energy sector in Ethiopia have focused on rural electrification, improved cook stoves and environmental impacts of solar Photovoltaic systems (Torero, 2015; Raitzer, Blönda, & Sibal, 2019; Bayera, Kennedy, Yang, & Urpelainen, 2020; Wassie & Adaramola, 2021). Currently no study is found on the impacts access to and use of electricity on the economic status of households in informal settlements. Failure to properly understand the economic impacts of electric use and households' energy consumption habits in informal settlements could lead to incorrect policy decisions.

The objective of this paper, therefore, is to analyze the impact of access and use of electricity on the type of home-based business activities, income generated from these undertakings, number of times households bake per week, and the relationship between number of fuels utilized and monthly family income based on households' electric-use status. It assesses the impact of electric-use on informal settlers' family income, the share of each energy source on households' total energy expenditures and estimate the contribution of electric use on cost savings in informal settlements. It indicates the need to conduct measures to change households' energy consumption behaviors and revise policies related to the provision of basic services to households living in the outreach areas.

3.2. Method of Data Analysis and Model Specification

This study utilized descriptive statistics and regression models to analyze the data captured from sampled households. Descriptive methods are used to organize data on households FCB and energy sources; the number of times households bake *Injera* in a week; income generated from home-based businesses; and energy sources used for home-based businesses and domestic activities.

The study applied a regression model (i.e. ESR) to estimate the treatment effect of electric-use. It helped to evaluate the impacts access to electricity on informal settlers' economic situation and shows the relationship between the various explanatory variables and the dependent variable described by family income and households' monthly total energy expenditures. The guide to apply this method is to answer the question 'what would happen to households if they had access to electricity?'

Propensity Score Matching (PSM) Method

The propensity score is the conditional probability of assignment to a particular treatment given a vector of observed covariates (Rosenbaum & Rubin, 1983). The rationale for using the PSM model is that simple comparison of the outcomes before and after using electricity or between electric-users and non-users of electricity, and without establishing similar groundwork is considered as poor impact evaluation (Thoemmes, 2012; Torero, 2015). Rather this can be better done by using Difference in Difference model (DID).

The PSM model helps to balance the distribution of electric-users and non-users with respect to measured baseline covariates for a more objective analysis and excluding households who cannot be well matched. Bayera, et al., (2020) also explained failure to control confounding factors attributing to outcomes and nonrandom assignment of households to treatment groups brings differences across regimes and overestimates the impact of regressors. It helps to explain households' reasons for choosing electric power and any differences in outcomes are exclusively attributed to treatment differences.

Variables that are observable, measurable, directly relate to the outcome, help to minimize imbalances between electric-users and non-users of electricity, and treatment outcomes that are assumed to have no effect on baseline variables in the reverse order are used to estimate the propensity scores. Based on these criteria only five baseline covariates (sex, age, education, family size and number of years lived in the area) are considered. The probability of a household receiving treatment is calculated using the model as follows (Lane, et al., 2012):

$$Y_i = (T_i / Xi \text{ or } C_i / Xi) \quad \textbf{[1]}$$

Where, Y_i = Propensity score, T_i = Treatment group, C_i = Control group,
X_i = A set of baseline variables

Then, non-users of electricity are matched with electric-users using the PS calculated. The system matches non-users of electricity more than once with one electric-user governed by Nearest Neighbor Matching (NNM) technique. This method helps to maintain large sample sizes, ensures both groups have equal chance of receiving treatment, and guarantees the two are matched equally on all baseline covariates considered except in energy use status (Thavaneswaran & Lix, 2008; Staffa & Zurakowski, 2018). This process narrows the gap between electric-users and non-users of electricity and households in the two groups are relatively homogenous after matching. It helps to evaluate the changes in outcome variables (in this case family income and total energy expenditures by a household) by comparing electric-users with non-users of electricity based on the relevant covariates.

Endogenous Switching Regression (ESR) Model

The PSM model does not account unobservable variables and the outcome does not reveal precisely whether it is due to applying the preferred energy source or other unmeasured factors. When the outcomes of electric-users are different from non-users of electricity only on observable characteristics, the impact described by β is biased. Therefore, only the ESR model is applied to estimate the treatment effects by accounting both observable and non-observable variables such as the impact of the education of the household head and employment status on households electric use stats (Powers D. , 2007; Ifegbesana, Rampedia, & Annegarn, 2016). The dependent variables in the regression models are households' family income and total energy expenditures. It captures the latent benefit and the expected desirability of electric use by applying the model as follows (Pickering, et al., 2017; Wohlfarth, Eichhammer, Schlomann, & Worrell, 2018):

$$Z_i^* = X\gamma + \varepsilon \quad Z=1 \text{ if } Z_i^* > 0 \text{ and } Z=0, \text{Otherwise} \qquad \textbf{[2]}$$

Where, Z_i^*= the latent effect of electric use; γ= Parameters to be estimated; ε =error term; Z= endogenous benefits of electric-use.

ESR model is used to estimate treatment effects by comparing electric-users with non-users of electricity. The model that accounts exogenous variables affecting both treatment selection and the expected outcomes is provided as follows (Antonakis, Bendahan, Jacquart., & Lalive, 2014; Ifegbesana, Rampedia, & Annegarn, 2016; Bayera, Kennedy, Yang, & Urpelainen, 2020):

$$Y_1 = \beta_1 X_1 + \mu_1 \text{ (if Z=1) and } Y_0 = \beta_0 X_0 + \mu_0 \text{ (if Z=0)} \qquad \textbf{[3]}$$

Based on this model, only one outcome is observed at a time. If a household uses electricity, Y_1would be observed; if not, Y_0 would be observed. That is, when Y_1 is observed, Y_0 is missing and Z=1. When Y_0 is observed, Y_1 is missing and Z=0.

The model assumes that those households assigned to status 1 are identical to others assigned to status 0 and there is interchangeability across households' electric-use status. Thus, it is possible to ask what would be the outcome if a respondent in status 1 were assigned to status 0 and vice versa (Powers D. , 2007; Kanyamuka, 2017). To this end, four regimes describe households' energy user status.

Regime 1: $E(\,Y_1/X, Z = 1) = \beta_1 X_1 + \varepsilon_1$	Households using electricity
Regime 2:$E.\,(\,Y_0/\mathrm{X}, \mathrm{Z} = 0) = \beta_0 X_0 + \varepsilon_0$	Households not using electricity
Regime 3:$E(\,Y_0/X, Z = 1) = \beta_0 X_1 + \varepsilon_0$	Electric-users had they been non-users of electricity
Regime 4:$E\ (Y_1/X, Z = 0) = \beta_1 X_0 + \varepsilon_1$	Non-users of electricity had they been electric-users **[4]**

Where, Regime 1 and Regime 2 are observed from survey data; Regime 3 and Regime 4 are hypothetical switching effects to be calculated; ε_i = error terms

Average Treatment Effect (ATE) on family income and households total energy expenditure is determined by taking the difference between the conditional expected outcomes of electric-users and non-users of electricity (Powers D. A., 1993; Antonakis, Bendahan, Jacquart., & Lalive, 2014; Dehejia & Wahba, 2002). That is, had electric-users not been used electric power, the Average Treatment Effect on the Treated (ATET) is estimated by subtracting '*Regime 3 from Regime 1*'as follows:

$$\text{ATET} = E(\,Y_1/X, Z = 1) - E(\,Y_0/X, Z = 0) \qquad \textbf{[5]}$$

Similarly, the average switching effect on non-users of electricity had they been electric-users, i.e., the Average Treatment Effect on the Untreated (ATEU) is estimated by subtracting *'Regime 2 from Regime 4'* as provided under:

$$\text{ATEU} = E\,(Y_1/X, Z = 0) - E(\,Y_0/\text{X}, \text{Z} = 0) \qquad \textbf{[6]}$$

3.3. Results and Discussion

3.3.1. Socio-Economic Profiles of Households

Energy is vital for all human beings. Nowadays, it is used for everything such as baking, cooking, lighting, heating, refrigeration, and other home applications that people use in their day to day life. It improves the health and education services, water supply, the environment, and family income (Torero, 2015; Beyene, 2018; Guta, 2020). Understanding the socio-economic and demographic characteristics of households, therefore, is critical to determine their energy choice and consumption levels (Agizew, 2017; Ateba, Prinsloo, & Fourie, 2018; Ayele & Demel, 2018).

Table 4 in Chapter 2 presents the socio-economic and demographic profiles of informal settlers and their electric use status. The data shows that 63% are male headed households. From all households, 31% are male headed electric-users and 20% are female headed electric-users. Age wise, 58% are below 45 years of age and from this group, about 48% are electric-users. From those above age 45 years (42% of all households), 55% are electric-users. This implies that male and aged household heads are more likely to use electricity than traditional fuels.

Among households in informal settlements involved in domestic activities (baking, cooking, and washing activities), 95.11% are women, 3.11% are children and the rest are men. About 98% of electric-users and 92% of non-users of electricity are women (including servants) involved in domestic activities. The number of households who shifted family labor to domestic activities also varies based on their electric-use status. That is, 24 households from electric-users and 62 from non-users of electricity shifted family labor to domestic activities. This indicates non-users of electricity are forced to use more than 2.5 times more family labor than electric-users for domestic activities.

In terms of education, 40% have first degree and from this 76% are electric-users. About 56% of households are hired and out of these 69% are electric-users. From those who are already hired, 91% are permanent employees and 71% of them are electric-users. The number of years a household lived in the area, the condition and number of rooms owned as well as the size of land under his/her custody has close association with electric use status. For example, from households who lived more than 9 years (35% of all households), live in homes that are in a very good condition (6% of all households), owned more than 3 rooms (31 of all households), and held land above 240m² (12% of all households), 74%, 89%, 75% and 73% are electric-users respectively.

Mustefa & Lika (2016) have shown the nexus between energy and gender. Others such as (Danlami, Islam, & Applanaidu, 2015; Butera, Caputoa, Adhikaria, & Mele, 2019; Olugbire, et al., 2016) explained the influence of energy price, home type, size, and condition on energy choice and consumption levels. This study showed that all households do not have equal access to electricity. As Table 4 in chapter 2 indicates certain groups of households lack access to clean, reliable and affordable energy whilst providing affordable, reliable, sustainable and clean energy for all in 2030 is an agenda of sustainable development goals (UNDP, 2015; World Bank & IEA, 2017).

Generally, he study conducted by Butera, Caputo, Adhikaria, & Facchini (2016) indicated that informal settlers were about 18.3% of the population of Addis Ababa. In this study, the proportion of electric-users is 51% of informal settlers while the rest are non-users of electricity. At present the number of informal settlers is continuously swelling at a fast rate and this makes the provision of adequate, reliable and affordable electricity difficult. Such a study, therefore, helps to stabilize energy prices, increase the supply of alternative fuels, reduce the pressure on wood resources, and maintain appropriate energy mix (JICA, 2011; Nibretu, Degefa, & Tamirat, 2021).

Table 8 revealed households' most common food consumption behaviors (FCBs) that are linked to each energy source. Based on this data, households who want to add the taste and flavor of food staffs, roast and boil coffee, dry and fry cereals, and cook cultural dishes like *Doro Wot* and *Shiro Wot* use traditional energy sources. In other words, compared to electricity, biomass gives more taste and flavor to foods and households with lower family income are seen drying cereals and cooking foods using traditional energy sources. Contrary to this biomass has no substitute for cooking traditional foods and its scarcity and terrifically raising price over time urges households to consume few hot meals and adopt meals that can be cooked fast (Getachew, 2016).

On the other hand, although a large number of households are forced to use biomass, they need to bake *Injera* using electricity. This is because electricity saves time, relatively cheaper, clean, and healthy source. Behaviors such as the need to get a variety of foods /more nutrition/, fresh foods, frequently cook and take enough meals per day are often associated with using alternative energy sources with the concept of energy stacking.

Similar to these findings, prior studies revealed that all factors are not equally important in explaining households' fuel consumption behaviors. Danlami, Islam, & Applanaidu (2015) and Amoah (2019), for example, described that wealthy households headed by higher levels of education are less likely to use fire wood, kerosene and LPG. Instead, they consume more electricity and solar energy (Lay, Ondraczek, & Stoever, 2013; Baiyegunh & Hassan, 2014).

TABLE 8: Households' Food Consumption Behaviors Affecting Energy Choice

FCB	FWC	Electricity	Indifferent
▪ To get variety of foods /more nutrition/	46	12	389
▪ Frequently cook and get fresh foods	4	38	396
▪ Add flavor/taste to food staffs	267	5	174
▪ Help to get enough meals per day	29	26	392
▪ Roast and boil coffee	401	24	20
▪ Dry/fry cereals	421	20	3
▪ Cook cultural dishes	309	77	59
▪ Bake *Injera* and bread	115	271	59

FCB=Food consumption behavior, FWC=Firewood and charcoal;
Source: Data organized by the author, Oct., 2021

In an effort to study the factors affecting electric-use status of households, most electric-users and non-users of electricity agree that electricity helps them to generate more income, lowers indoor air pollution, clean and healthy, and reduces the workloads of family members (Table 9). However, due to lack of access to electricity, non-users of electricity (particularly low-income households) often consume biomass and this exposes them to indoor air pollution and associated health effects. According to Muller & Yanb (2018), this group of households heavily relies on plant and crop residues, animal dung, firewood and charcoal.

TABLE 9: Factors Influencing Households Electric Use Status

Factors affecting energy choice	EU		NUE	
	FWC	Electricity	FWC	Electricity
▪ Helps to generate more income	16	210	27	184
▪ Consumed by low income groups	105	123	197	24
▪ Lowers air pollution and clean/healthy	1	223	-	210
▪ Exposes to indoor air pollution	215	4	170	23
▪ Reduces workloads of family members	1	218	4	201

EU=Electric-users, NUE=Non-users of electricity, FWC=Firewood and charcoal
Source: Data organized by the author, Oct., 2021

The number of days that households bake *Injera* per week also varies based on their electric-use status (Fig. 7). For instance, electric-users baking once and more three times in a week are greater than the number of non-users of electricity. Those who bake only once are assumed to use electricity for personal consumption. The reason for larger number of households to choose electricity can be associated with its convenience, low air pollution effect, and saving cost and family labor. For business purposes, households baked more than three times per week using electricity. This in turn contributes to generate more income. Frequent power interruption and low power supply has also forced households to bake many times and use biomass for both business and domestic purpose.

As shown in Fig 7, 35% of non-users of electricity and 31% of electric-users bake twice in a week. Though the difference is small, due to their access to electricity, electric-users have relatively high chance of cooking more than two times in a week than non-users. The cost of cooking food frequently using biomass is very high for non-users of electricity.

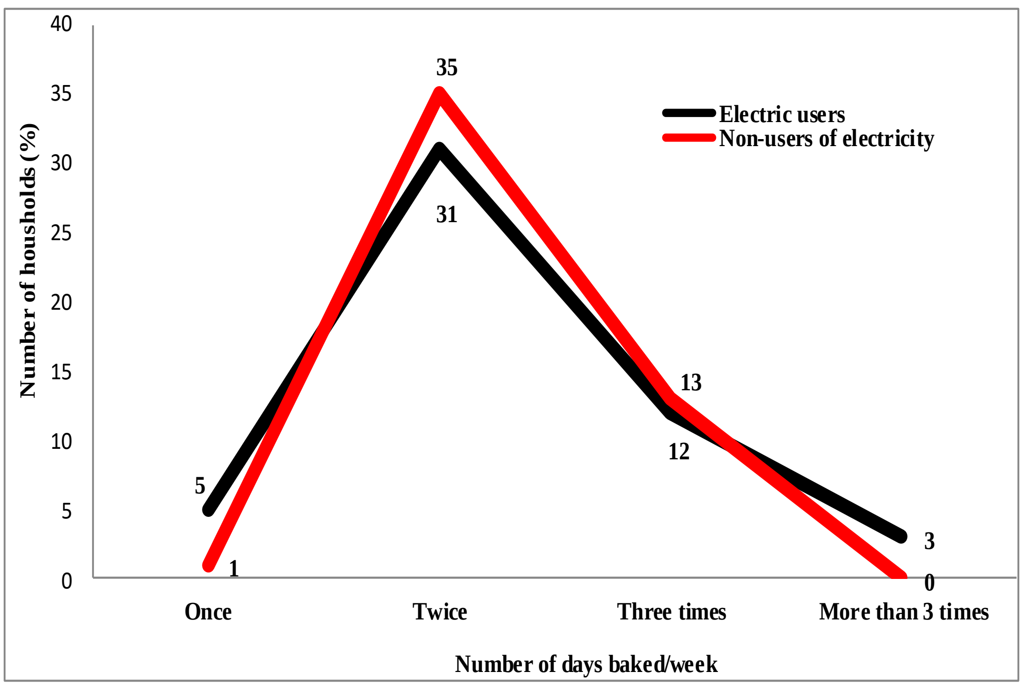

FIGURE 7: Number of Days Households Baked in a Week

Source: Data organized by the author, Oct., 2021

Table 10 presents the relationship between households' electric-use status and income generated from home-based business activities in informal settlements. The survey result indicated that from 450 households surveyed, 141 (31%) owned different kinds of home-based businesses and from these households, 63% are electric-users and 37% are non-users of electricity.

The types of home-based business activities carried by households in informal settlements include baking *Injera* (57%); roasting and boiling coffee, preparing potato chips and drying cereals (14%); retail trade and fruit selling (16%); and renting a house, selling firewood and charcoal and a mix of activities (13%). From households baking *Injera*, 82% use electric power and from those roasting and boiling coffee, drying and frying potato chips and cereals, 68% use electricity. From home-based business activities that require little or no energy (such as retail trade and fruit selling, renting a house and selling charcoal and firewood), 76% are non-users of electricity.

Households used different energy sources for their home-based businesses. These energy sources differ based on households' electric use status. The data in Table 5 below showed that 56% use electricity, 36% biomass, and 8% low electric consuming activities or businesses that do not require energy at all. Among electric-users, 88% use electricity and the rest use biomass or business activities that do not require energy. On the other hand, 81% of non-users used biomass for their businesses and the rest used little energy or activities that do not require energy at all.

From households generating business income above 2,000 *Birr* per month, more than 63% are electric-users and from those earning more than 4,000 *Birr* per month, this group reaches to 92%. This shows electric-users generally earn greater family income per month and carried more business activities than non-users of electricity. This corroborates households' electric use status has a significant impact on the number of home-based businesses owned and amount of income generated that in turn influence access to electricity.

TABLE 10: Type of Home Business Activities, Energy Sources and Households Income from these Activities based on Electric Use Status

Type of home-based business activities	EU	NUE	Total*
Baking *Injera*	66	15	81 (57)
Roasting and boiling coffee, potato chips and cereals	13	6	19 (14)
Retail trade and fruit selling	5	18	23 (16)
Renting a house, selling firewood and charcoal	2	4	6 (4)
A mix of activities	3	9	12 (9)
Total	89	52	141 (100)
Sources of energy			
Firewood and charcoal	9	42	51 (36)
Electricity	78	1	79 (56)
Not using energy at all	2	9	11 (8)
Total	89	52	141 (100)
Income from home-based business (*birr*)			
< 2,000	49	29	78 (56)
2,001-4,000	29	22	51 (36)
Above 4,000	11	1	12 (8)
Total	89	52	141 (100)

Note: *Numbers in the parenthesis are percentages

EU=Electric-users, NUE=Non-users of electricity

Source: Survey data, Oct., 2021

3.3.2. Households' Energy Consumption Levels in Informal Settlements

Based on Table 6, households' average monthly expenditure for firewood is 402 *Birr,* non-users of electricity expend 542 *Birr* and electric-users 252 *Birr* per month. For charcoal, households' average monthly expenditure is 248 *Birr,* non-users of electricity 322 *Birr* and electric-users spend 175 *Birr* per month. The data shows households in informal settlements mainly use firewood and charcoal due lack of adequate and reliable electricity supply and compared to electric-users, non-users of electricity heavily rely on traditional energy sources. According to Getachew, Abera, Edwards, & Troncoso (2018), the gap between supply and demand for biomass is growing and the proportion of income spent on energy is increasing.

Electricity is the second most important energy source (following firewood) for households in the study area. On average, they expend 300 *Birr*, non-users of electricity 109 *Birr* and electric-users 438 *Birr* per month. These indicate electric-users expend more for electricity and this energy significantly affects their total energy consumption.

The overall average monthly energy expenditures of non-users of electricity (995 *Birr*) is greater than that of electric-users (882 *Birr*). This could be non-users' large amount of biomass consumption and inefficient use of resources and this result shows the positive contribution of electric use in saving households' monthly energy expenditure.

TABLE 11: Households' Monthly Energy Expenditures *(Birr)*

Energy expenditures*	EU	NUE	Total
Firewood: Mean	252	542	402
Maximum	620	1200	1200
Minimum	100	60	60
Charcoal: Mean	175	322	248
Maximum	600	800	800
Minimum	50	50	50
Kerosene: Mean	110	160	132
Maximum	210	400	400
Minimum	50	20	20
Electricity: Mean	438	109	300
Maximum	1200	300	1200
Minimum	45	25	25
Total: Mean	882	995	938
Maximum	1580	2100	2100
Minimum	360	200	200

EU=Electric-users, NUE=Non-users of electricity
**The energy expenditures in a month cover for both domestic use and home-based business activities*
Source: Data organized by the author, Oct., 2021

A relationship between households' monthly income and the number of fuels consumed by households is established (Fig. 8). The survey data indicated that about

12% of households use two, 57% use three and 31% use four kinds of energy sources. Income wise, 73% of households earn a family income more than 6,000 *Birr* and 27% below 6,000 *Birr* per month. Among households earning more than 6,000 *Birr* per month, 197 households (60%) are electric users. Further, from households earning more than 6,000 *Birr* per month, the proportion of electric-users consuming two or more energy sources are greater than that of non-users of electricity.

When we try to look the relationship between the number of fuels used by a household and family income from different perspective, as the number of fuels consumed by a household increases, the gap between households earning an income below 6,000 *Birr* and above 6,000 *Birr* per month widens. This means as households' income increases, they tend to use two or more energy sources with the concept of energy staking and no one relies on a single energy source. Similar to this finding Alemu & Köhlin (2008), Fantu, Abebe, & Tadele (2015) and Agizew (2017) indicated that expenditures for energy and the number of fuels used increases with higher levels of income.

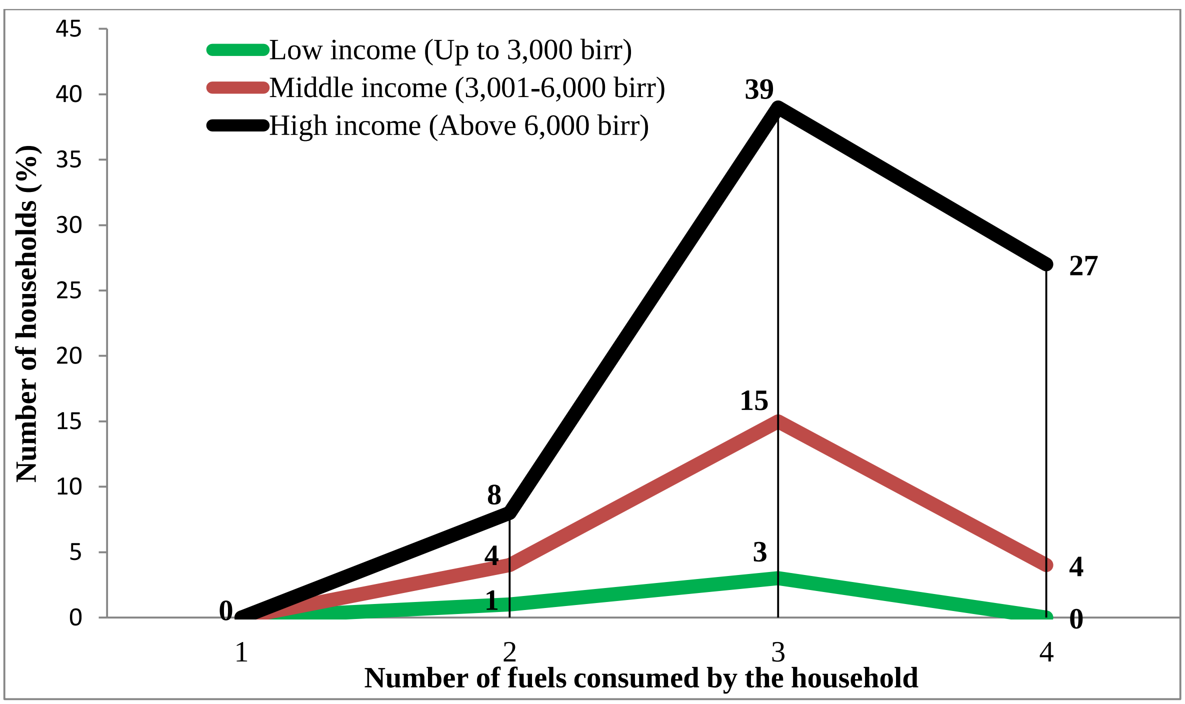

FIGURE 8: Households' Monthly Income and Number of Fuels Used
Source: Data organized by the author, Oct., 2021

3.3.3. Impact of Electric Use on Family Income: The ESR Model

For simplifying our discussion, the dependent variable (that is, family income) is classified into two groups: those earning up to 6,000 *birr* and above 6,000 *birr.* The first group constitutes 27% of the total sampled households (7% electric users and 20% non-users of electricity) while the second group includes 73% (44%. electric users and 29% non-users of electricity).

The ESR model introduces exogenous variables affecting family income. It helps to avoid errors in estimating ATE simply by introducing instrumental variables as presented in Table 12 (Ifegbesana, Rampedia, & Annegarn, 2016; Pickering, et al., 2017; Wohlfarth, Eichhammer, Schlomann, & Worrell, 2018). The reverse effect of family income on the independent variables in turn induces changes in the explanatory variables and the final outcome of the model.

The p-value and the strength of the model are statistically significant indicating the strong correlation between households' family income and various independent variables. High R^2 values for both electric users and non-users of electricity indicate the explanatory power of the model and the variables considered in estimating the impact of electric-use on family income. The equivalency of the endogenous variable (employment status) and the instrumental variable (education level) portrays the model is just and defined correctly.

After a long iterative process, the regression results indicated that employment status of the household head, energy that add the taste and flavor of food staffs, and sources that are appropriate to dry and fry cereals but expose households to indoor air pollution have negative impact on family income of electric-users whilst the type of home-based business owned, energy source appropriate to prepare a variety of food staffs, and land size held have significant positive effect on the family income of electric-users. However, demographic factors (such as sex, age and family size), shelter type, land holding status, availability, reliability and price of energy sources have no significant impact on family income in informal settlements.

The survey data indicated that among households who held a relatively large plot of land (above $180m^2$), 63.57% are electric-users, the appropriate source for carrying out home-based business activities and cook a variety of food staffs is electricity or a mix of alternative energy sources. To this end as electric-users' land size held increases, the number of households' earning a family income increases.

Similarly, the amount of income generated from home-based business activities, energy sources that add the taste and flavor of food staffs, and those that are used to bake *Injera* have significant positive influence on family income of non-users' of electricity. On the contrary, biomass (firewood and charcoal) that are mainly used to cook cultural dishes (like *Doro Wot* and *Shiro Wot*) have negative influence on the family income of non-users of electricity. This might be because of the health effects, inefficient use of biomass and the shifting of family labor from other income generating activities.

TABLE 12: Factors Affecting Family Income: The ESR Model

Family income	Coef.	Std. Err.	Z	Coef.	Std. Err.	Z
Electric users				**Non users of electricity**		
Employment status	-0.4410	0.2650***	-1.66	-0.6011	0.4747	-1.27
Income from home businesses	0.0382	0.0454	0.84	0.3792	0.1209*	**3.14**
Type of home business owned	0.0621	0.0347***	**1.79**	-0.0431	0.0595	-0.72
Sex	0.0818	0.0900	0.91	-0.0127	0.2792	-0.05
Age	0.0731	0.0880	0.83	-0.0134	0.1310	0.10
Family size	0.0558	0.0727	0.77	-0.1608	0.1279	-1.26
Energy to take food variety	0.2910	0.0728*	**4.12**	-0.1538	0.0983	-1.56
Energy that adds food flavor/taste	-0.0355	0.0408	0.87	0.1747	0.0652*	**2.68**
Energy used to dry and fry cereals	-0.1610	0.0905***	**-1.78**	-0.1375	0.0991	-1.39
Energy to cook cultural dishes	-0.0382	0.0406	-0.94	-0.2603	0.0698*	**-3.73**
Energy for baking *Injera*	0.0432	0.0637	0.68	0.1901	0.0753*	**2.53**
Shelter type	0.0586	0.1072	0.55	0.3389	0.2736	1.24
Land size	0.0684	0.0344**	**1.99**	-0.1181	0.0944	-1.25
Land holding status	-0.0115	0.0407	-0.28	-0.0545	0.1553	-0.35
Air pollution effect $^{\Theta}$	-0.2803	0.1461**	**-1.92**	-0.0431	0.2080	-0.21
Available and reliable energy	-0.0342	0.0573	-0.60	-0.2569	0.1718	-1.50
Affordability of energy source	0.0277	0.0797	0.35	-0.1179	0.1298	-0.91
_cons	-0.1219	0.4104	-0.30	2.1274	0.9001	2.36

, ** and * statistically significant at p<1%, p<5% and P<10% respectively.*
Θ Pollution effect is measured based on the energy source that has more indoor air pollution effect /cause headache and burning of eyes/.
EU=Electric-users, NUE=Non-users of electricity
Source: Data developed by the author, Oct., 2021

The regression result presented in Table 13 shows the impact of expenditures made for each source on electric-users' total energy expenditure. The result revealed that the use of electric power and firewood positively affect monthly total energy expenditures of households. On the other hand, expenditures made for kerosene and charcoal have no significant impact on total energy expenditures of electric-users. That is, keeping all other variables in the model constant, as expenditure for electricity increases by one unit, the total energy expense of the household increases by 0.4254 whilst per unit increase in firewood expenditure increases the total energy expenditure of the same household by 0.2548. This implies that electric use has more significant impact on increasing households total energy expenditure than firewood use. Hence, any measure taken to save electric power could contribute to the total energy saving efforts of households.

The family income is also influenced by households' electric use status. For example, under citreous paribus assumption, as the income of electric users increases by one unit, their family income increases by 0.6184 while other sources of energy have no significant impact on households' family income.

TABLE 13: The Impact of Energy Sources on Electric-users' Energy Expenditure and Family Income: The ESR Model

	Coef.	Std. Err.	z	p>/z/
Total expenditure				
Electricity	0.4254***	0.2550	1.67	0.09
Firewood	0.2548**	0.1133	2.25	0.02
Charcoal	0.0597	0.0920	0.65	0.52
Kerosene	0.0923	0.0657	1.41	0.16
_cons	0.4015	0.5661	0.71	0.48
Family income				
Electricity	0.6184*	0.2477	2.50	0.01
Firewood	0.0777	0.1101	0.71	0.48
Charcoal	0.0571	0.0894	0.64	0.52
Kerosene	-0.0545	0.0638	-0.85	0.39
_cons	-0.3488	0.5501	-0.63	0.53

*** and *** statistically significant at p<5% and p<10% respectively.*

Source: Data developed by the author, Oct., 2021

Finally, estimating the average effect of electric-use is crucially important and Table 14 portrays the treatment impact of the variables identified in Table 12 above. The estimates of the average treatment effect on the treated (ATET) and average treatment effect on the untreated (ATEU) showed households' family income differences due to their electric use status. That is, ATET and ATEU are both *positive* and the mean values of the independent variables are significantly higher for electric-users than had they been non-users of electricity. The mean treatment effects are statistically significant indicating the considerable impact of electric use on family income. This is clearly seen when electric-users had been non-users of electricity and non-users of electricity had been shifted to electric-users. That is, as a result of electric use, ATET has increased from 0.7609 to 0.7703, representing 2.02% increase in family income, ATEU has increased from 0.5163 to 0.5803, representing a 12.40% increase in family income, and ATE has increased by 25.85%.

The test for heterogeneity effect (HE) indicates 1) the difference between the impact of electric use on family income of electric-users and non-users of electricity had they been electric-users and 2) the difference between the impact of electric use on family income of electric-users had they been non-users of electricity and non-users of electricity on family income. In both cases, the HE test showed that electric use has high potential impact on family income and its impact on non-users of electricity is higher than that of electric-users. These could be associated with non-users' limited and less frequent use of biomass and electric-users' high electric consumption experience relative to their family income.

TABLE 14: Impact of Electric Use on Family Income: The ESR Model

Electric use status	EU	NUE	TE
Electric-users (n=229)	0.7763	0.7609	0.0154*(ATET)
Non-users of electricity (n=221)	0.5803	0.5163	0.0640*(ATEU)
Heterogeneity effect (HE)	0.1960	0.2446	-
All households (n=450)	-	-	0.2585*(ATE)

** Statistically significant at p<1%*
EU=Electric-users, NUE=Non-users of electricity, TE= Treatment effect
Source: Data developed by the author, Oct., 2021

3.4. Conclusions

Transition to modern energy sources facilitates the socio-economic growth in informal settlements. However, complete dependence on a single energy source (that is, electricity) does not ensure improvements in the quality of life of households and may not help to meet their FCBs. The study revealed that about 31% of households in informal settlements owned different kinds of home-based businesses and from these households 63% are electric-users. The number of family labor shifted to domestic activities, frequency of baking per week, type of home-based business activities carried, the amount of income generated from these businesses and energy expenditures made by electric-users indicate the significance of access to electricity and its positive effect on improving households' economic status in informal settlements. The results of the treatment effects of electric use also indicated the positive impact of electric-use on family income.

However, lack of access to electricity does not totally prohibit non-users of electricity from carrying out home-based business activities and one has to pay attention that households will continue to use biomass due to lack of access to reliable and affordable electric supply and in relation to their FCBs. Besides these informal settlers have low paying capacity to electric service and living for longer periods in the area does not ensure legal entitlement to own land get formal access to electricity

3.5. Recommendations

Policy prescriptions shall focus on improving electric supply to households with power shortages, frequent interruption and fluctuation. Subsidizing electricity or making it affordable to low income groups for primary functions like illumination and charging of batteries, encouraging households using electricity during slack periods and power saving devices, and changing their FCBs are very critical policy measures. The government shall also consider the possibilities of *"formalizing the informal settlers"* based on the number of years they lived in the area and the suitability of their living area to the urban plan as short-term strategy. Furthermore, special attention shall be given to non-users of electricity living sporadically mixed with electric-users and close to electric lines in the provision of electricity.

Chapter 4

Households' Challenges to Access Electricity and their Coping Strategies: A Reference to Informal Settlements in *Woreda 12*, Yeka Sub City, Addis Ababa[13]

Abstract

Lack of access to adequate, reliable, sustainable and affordable electric power presents numerous economic, social, and environmental challenges to households in informal settlements. The data for this study was captured from households in Addis Ababa (Yeka Sub-city, Woreda 12) and analyzed using descriptive statistics and binary logit model. The study showed that households have very low and unstable income, live in unauthorized and scattered settlements, lack access to adequate electric supply, and required to pay unaffordable connection fees and electric bills. These challenges forced them to take energy conservation and coping strategies, change food consumption behaviors, and proposed policy options. The logistic regression result showed that households are willing to share the cost of improving electric supply with the increase in their family size, if they can get the electric service within shorter time period, if it increases the number of meals taken per day, high chance of getting a legal land title and electric counters, and if households are currently non-users of energy efficient stoves and power saving lamps. In order to solve the challenges to get access to electricity and high connection fees required, 93% of non-users of electricity are willing to use temporary and less power consuming electric services and 73% share electric meters in groups.

Keywords: *Access; Challenge; Coping strategy; Informal settlement; Addis Ababa*

---

13 *Paper accepted for publication in the Ethiopian Journal of Development Research, Addis Ababa University.*

4.1. Introduction

Access to electricity is essential for basic human needs and improves the socio-economic life of households in developing countries. It improves the health and education services, water supply, the environment, family income, saves energy expenditures, and speeds up households' energy transition (Sanaeepur, Sanaeepur, Kargari, & Habibi, 2014; Torero, 2015; Beyene, 2018; Guta, 2020). As described by FAO, (2015), it plays a key role in achieving food security, better nutrition and influence food prices. As a result, providing affordable, reliable, sustainable and clean energy for all in 2030 has become an agenda of sustainable development goals (SDGs) (UNDP, 2015; World Bank & IEA, 2017).

However, many people refer access only to availability and this concept does not capture the adequacy, reliability and affordability of electric service. Pueyo and Hanna, (2015) and Padam, et al., (2018) described energy access as availability, adequacy, reliability, affordability and convenience to use. It includes the number of people connected to electricity, the length of time electricity is available, amount of energy consumed per annum, legality and cleanness of energy sources (IEA, 2012; WB, 2015; UNESCAP, 2019). These concepts are crucial to understand households' challenges to access electricity and their coping strategies.

In Sub Saharan Africa, a large group of population lacks access to electricity, a quarter of those without electricity live in urban areas (where the majority are informal settlers) and a person on average consumes as little as 200 kWh per year against 1,442 kWh in North Africa in 2016 (Hafner, Tagliapietra, & Strasser, 2018; Arlet, Ereshchenko, & Rocha, 2019). In the region, the share of electricity from the total energy consumption is as low as 4%, the rate of electrification in 2017 was not higher than 43% and the average annual electric consumption is 521 kWh (IEA, 2012; Hafner, Tagliapietra, & Strasser, 2018). This is due to absence of technologies, unstable income, cultural acceptance of alternative cook stoves, households limited capacity, lack of sufficient credit facilities for energy saving stoves in informal settlements and inability of energy suppliers to recover operating costs with the existing electric tariffs (REEEP Secretariat, 2012; UNDESA, 2014; Middlemiss & Gillard, 2015).

In Ethiopia, although the country has high potential to produce electricity (over 60,000 MW, 86% from hydropower, 8% from wind and solar energy, and 6% from geothermal), it generates only 4,284 MW from all sources (7.14% of the potential) to serve over 117 million people (Power Africa, 2016; EEP, 2016; World Population Review, 2021; MWIE, 2017). Access to electricity is only 45% of its population and the per capita electric consumption is about 85-100 kWh/year while the standard set in rural areas is at least 250 kWh and in urban areas is 500 kWh (IEA, 2012; MoWIE, 2015; Hafner, Tagliapietra, & Strasser, 2018).

Since informal settlers are found in an area between the urban center and the cultivated edge of rural areas and occupied small, unauthorized and unplanned land that is not zoned for residential purpose, they lose energy providers trust and those who had access to electricity are faced with frequent power interruption, fluctuation, outages and sometimes oversupply (Majale, 2002; Subbiah, Mansoor, Misra, Jaffer, & Tiwary, 2016; Butera, Caputo, Adhikaria, & Facchini, 2016). They are economically poor, earn irregular income, unable to pay connection charges and electric bills, not using energy efficient and expensive technologies, live in poor housing and created by the inability of the economy to supply housing for the low income groups, high population growth associated with rural to urban migration, expansion of informal businesses and continuously swelling condition (Gaunt, et al., 2012; Onyekachi, 2014; Luhar, 2014; Dadzie, Runeson, Ding, & Bondinuba, 2018). These situations forced them to rely on traditional energy sources emitting high carbon monoxide and smoke, produce less fire and use inefficient stoves (Yu, Yaoqiu, Ningsheng, Zhifeng, & Lianzhong, 2008; Karatasou, Laskari, & Santamouris, 2014).

Energy suppliers are not willing to make additional investments in informal settlements. Insufficient finance and lack of small-scale technologies on the one hand and high demand for subsidized electricity, energy-efficient devices and the requirements to integrate the energy supply with carbon reduction frameworks on the other are the major challenges to energy suppliers (Karatasou, Laskari, & Santamouris, 2014; Grueneich, 2015; Barnes, Golumbeanu, & Diaw, 2016; Blair, Pons, & Krumdieck, 2019).

Households have low socio-economic backgrounds, limited electric consumption and unreliable demand patterns, electric tariffs are not cost-reflective, encourage households take energy conservation strategies, and minimize peak-time electric consumption (Millsa & Schleich, 2012; Karatasou, Laskari, & Santamouris, 2014; Figueroa, 2016; Lia & Just, 2018; Arlet, Ereshchenko, & Rocha, 2019; Chowdhury, et al., 2019; Bayera, Kennedy, Yang, & Urpelainen, 2020). The Ethiopian Government slowed expansion of electric supply in informal settlements, gave little attention to off-grid electric expansion, failed to involve the private sector in energy supply, and electric access programs such as Rural Electrification Program-REP and Universal Electricity Access Program-UEAP do not cover Addis Ababa (Beyene, 2018). All these together with lack of integrated urban planning influence the power supply in informal settlements and enhance income inequalities among citizens.

To deal with such problems Zarnikau, Zhu, Russell, Holloway, & Dittmer (2015) and Kuhn, Huber, Dorfner, & Hamacher (2016) proposed the need to decentralize electric generation, storage and supply systems at local levels, reach individual homes through rooftop solar energy systems, and large-scale generation and grid distribution systems. But these systems require a thorough analysis of the financial viability of energy sources to the energy supplier, the socio-economic backgrounds and settlement patterns of households in informal settlements.

Woreda 12 of Yeka sub-city is one of those areas in Addis Ababa where large numbers of informal settlers suffer from limited access to electricity. The objective of this paper, therefore, is to assess households' challenges to access electricity, the socio-economic backgrounds affecting energy consumption levels and their coping strategies in informal settlements. It captured the reasons for households' lack of access to electricity, the length of time households require to adapt new energy sources and energy efficient stoves, willingness to pay (WTP) for improved energy service based on current electric use status, and criteria to set electric tariffs using descriptive statistics and logistic regression model. It identified households various coping strategies that are largely associated with reducing the challenges to use electricity.

4.2. Method of Data Analysis

Households were asked to describe their challenges to get access to and use of electric power and their coping strategies to the energy problem by classifying them into current electric-users and non-users of electricity. The explanatory factors are the various challenges to get access to electricity and their coping strategies based on the data captured from informal settlers. Then, demographic variables influencing electric use, informal settlers' challenge to access electric power, and their coping strategies were analyzed using descriptive methods and binary logit models. The later in particular was applied to identify factors affecting households' willingness to pay (WTP) for improved electric supply, groups of households more influenced due to lack of access to electricity and criteria to be considered in setting electric tariffs.

4.3. Results and Discussion

4.3.1. Demographic Profiles of Informal Settlers

Knowledge of the demographic and socio-economic backgrounds of households in informal settlements is important to understand their problems, energy consumption behaviors, the choice of energy sources and the reasons for their choice, the challenges to access electricity and establish correlation between those factors and their coping strategies. The survey data in the study area shows (Table 4 in Chapter 2), 63% of the household heads are males, 87% are from 30-60 years of age, 78% married while the rest are either single or separated, and 54% have 3-4 families. Education wise, 40% have first degree and above and 94% are either hired or self-employed[14]. From those who are hired, 91% are employed on permanent basis and the rest are working on contract, daily or hourly basis and 73% earn family income above 6,000 *birr* per month (this is the sum of money earned by all family members currently working).

Although all households considered in this study are informal settlers, for different reasons 51% have legal access to electricity from the Ethiopian Electric Utility (EEU) and immediate neighbors that exposed them to pay higher electric bills than the official rate. The rest (49%) do not use electricity except for illumination and charging mobile phones. Furthermore, regardless of their electric use status, 58% lived more than 6 years in the area, 70% lives in homes made from wood and cement and rated as "*good*" by the households, only 31% owned more than 3 rooms, and 12% occupied a dwelling space more than 240 m^2.

---

[14]. Self-employment includes both working in own business (often home-based) and for someone else on contract basis.

4.3.2. Challenges to Use Electricity in Informal Settlements

Access to electricity provides numerous benefits to households in informal settlements. The survey result showed that electricity enables large number of households to take more meals in a day, brings socio-economic and business development to the residents, facilitates domestic activities, relieves family members from the risk of smoke and generally improves the quality of life of the residents.

However, households are required to pay up to 10,000 birr for connection fee by the EEU and in the absence of credit facilities, non-users of electricity cannot afford to pay this charge. Following kerosene and LPG, electricity is the second most expensive energy source for households and 31% of the current electric-users contend electric bill is a financial burden to them. Electric-users unanimously agree that the power supply is not reliable (frequently interrupt and fluctuate). As a backup solution, most electric-users are using firewood and charcoal for cooking and baking, rechargeable batteries and candles for lighting during electric blackouts and about 73% of electric users are forced to use the three-stone traditional stoves. On the other hand, more than 79% of households believe the price of biomass (fire wood and charcoal) is increasing over time and 58% of non-users of electricity are questioned its availability. Households have very little knowledge on the availability of energy saving technologies for electricity and more than 85% of households attribute the concept of energy efficient technology to biomass use.

As presented in Table 15, 32% of informal settlers associate the reasons for lack of access to electricity to households' low income (about 27% earn below 6,000 birr or 133 USD per month) that varies on monthly basis. This forced them to consume low energy and the EEU to be unwilling to provide electric service in informal settlements. About 22% of households linked the denial to access electricity to their illegal land occupancy and scattered settlement. However, although households' lack of permanent address contributes the EEU loose trust on informal settlers, illegality by itself cannot be a sole criterion to deny them from access to electricity. Similarly, even if residents' scattered settlement can make connection fees high and unaffordable, the study indicated that non-users of electricity are found mixed with electric-users and scattered settlement cannot be considered as reason to deter them from access to electricity.

As explained by 21% of households, ever growing demand for electric service, power supply shortages, and frequent electric interruption are key challenges to access electricity. These challenges mainly affected non-users of electricity and forced them to use biomass. The other 24% of households described that high and progressive electric tariff and EEUs' lack of responsiveness and mismanagement to provide the required service have also prohibited them from getting access to electricity. A similar study conducted by Blair, Pons, and Krumdieck (2019), indicated that high electric tariffs deterred households from getting electric connection and exposed them to unaffordable electric bills. These problems left the energy needs of households in informal settlements remain unmet and deepened energy shortages.

However, electric-users, unlike non-users of electricity, perceive that EEU is reluctant to provide electric service in informal settlements for different reasons. For example, 28% of electric-users and 4% of non-users believe that households' low and irregular income; 7% of electric-users and 15% of non-users believe due to their illegal and scattered settlement; and 23% of electric-users and 1% of non-users due to high electric tariffs and bureaucratic red tapes. This implies that non-users' low and unstable income, high electric tariff and long bureaucracy are basic constraint to get access to electricity. Supply shortage and their limited energy consumption might also inhibit them from access to electricity.

TABLE 15: Households' Challenges for Lack of Access to Electricity (%)

Challenges	Electric-Users	Non-Users	Total
1. Low and unstable income	28	4	32
2. Illegal and scattered settlement	7	15	22
3. Supply shortage and high energy demand	2	19	21
4. High electric tariff	13	1	14
5. Long bureaucracy of the electric supplier	10	0	10

Source: Survey data, Oct., 2021

On the other hand, if non-users of electricity are given the chance to get access to electricity, 61% do not want to either shift to new energy sources and use energy efficient technologies or change through long time while 39% wants to shift automatically (Table 16). Among those households who decided to shift to modern energy sources, decide to use energy efficient stoves and consume more energy with lapse of time, 45% require more than one year to fully adopt those technologies. The reason for failure to shift or slow transition to new energy sources and adopt ICS is lack trust on the reliability of the new energy sources, limited knowledge on the new technologies, prior psychological influences and energy consumption habits, and the desire to use the limited money they have elsewhere (Table 16). Arlet, Ereshchenko, & Rocha (2019) also confirmed that households facing frequent power outages and fluctuations lack trust on the reliability of the energy supply and discouraged to use this energy source. However, among households who decided to take instantaneous measures to shift to new energy sources and ICS, 58% are better educated (completed grade 9 and above) and 66% earn relatively higher family income (more than 6,000 *birr* per month).

TABLE 16: Non-users Speed of Adoption of Modern Energy Sources, ICS and Reasons for Switching Failure

Speed of adopting modern sources and energy efficient stoves	Number of households	%
1. Never change	53	24
2. With lapse of time	82	37
3. Instantaneously	86	39
Reasons for switching failure		
1. Imperfect knowledge on the new technology	40	30
2. Lack of trust on the new sources	70	52
3. Past consumption habits and psychological influences	16	12
4. To use the money elsewhere	8	6

Source: Survey data, Oct., 2021

4.3.3. Households' Coping Strategies to the Challenges of Electricity

I. Applying Energy Stacking and Energy Ladder Concepts: One of the most widely used coping strategies for households faced with lack of access to electricity, inadequate and fluctuating power supply, and unaffordable price is conducting a portfolio analysis of alternative energy sources. Since informal settlers in the study area do not use animal dung, plant residues, biogas, and solar energy (except for lighting), these sources are excluded from the options provided to respondents.

In addition to this, the possibility of using three or more sources of energy is also deliberately left out on the premise that informal settlers with low and unstable income cannot afford to use more than two sources of energy at the same time. Then, by considering biomass, kerosene, liquefied petroleum gas (LPG) and electric power and by mixing only two sources, households can have six options to choose from. As a result, 72% used electric power and LPG, 15% electric power and biomass, and 11% electric power and kerosene and all these combinations indicate electric power is inescapable and vital energy source for domestic use in informal settlements (Table

17). Similar to this, about 86% of households in Niger stack 2-5 low level energy sources while kerosene being the most easily mixed cooking energy with biomass (Ohadugha, Sanusi, Morenikeji, & Zubairu, 2016).

TABLE 17: Households' Alternative Energy Sources

Alternative mixes	Freq.	Percent
1. Biomass and Kerosene	2	1
2. LPG and Kerosene	6	1
3. Electricity and Kerosene	51	11
4. Electricity and LPG	323	72
5. Electricity and Biomass	68	15

Source: Survey data, Oct.., 2021

Table 18 below provides households' economic, social, behavioral and environmental reasons for mixing two energy sources. Based on this data, 45% of households used two energy sources due to absence of one reliable energy source, 30% due to different functions of each energy source and the other 25% for reasons such as the need to save family labor and time, the relative affordability of some energy sources and appliances than others. Of all these, the study shows low income households used two energy sources to cope up the rising energy prices while high-income households take similar coping strategy due to their prior food consumption behaviors and as a cushion to unreliable electric supply.

TABLE 18: Households' Reasons for Using Alternative Energy Sources based on their Electric Use Status (%)

Major Reasons	Electric-Users	Non-Users	Total
1. To get secured and reliable energy source	23	22	45
2. Different uses/purposes of each source	14	16	30
3. Save family labor and time	12	6	18
4. Some sources are relatively affordable	2	4	6
5. Some energy sources have low cost appliances	-	1	1

Source: Survey data, Oct. 2021

Households also substitute one renewable energy source by another and transit to higher level sources prompted to reduce excessive reliance on traditional energy sources, declining biomass and rising prices, and when there is frequent power interruption, fluctuation and outages (Jalalimajidi, Seyedhosseini, Makui, & Babakhani, 2018). In this study, about 56% of households substituted one source (like biomass) by another (like electricity) due to lack of access and scarcity of energy sources. Such measures, however, require subsidies to electric power and minimizing or avoiding encouragements (if any) provided to households consuming poor energy sources such as fire wood, charcoal and kerosene. About 28% of households took substitution measures due to high labor and time required to use lower level energy sources while the rest 16% shifted to energy sources due to high cost of energy which is not affordable to the poor, the need to get clean and healthy energy sources and a combination of reasons (Table 19). However, the scarcity of energy sources and the reliability of electric supply are given much weight by electric-users indicating power shortages and lack of reliable electric supply threatens not only non-users of electricity but also it strikes the electric-users.

TABLE 19: Households' Reasons for Substituting Existing Energy Sources (%)

Major Reason	Electric-Users	Non-Users	Total
1. Scarce and not reliable source	31	25	56
2. Require more labour and time to use	13	15	28
3. Unaffordable/expensive energy source	4	4	8
4. Not safe and unclean source	3	4	7
5. Other reasons	0	1	1

Source: Survey data, Oct., 2021

II. Changing Households' Food Consumption Behaviors (FCB): According to Hernández (2016), improving FCB helps to cope, improvise and counteract the impacts of energy insecurity on environmental and economic benefits and reduce health and safety risks. Fig. 8 presents households best coping strategy to the electric problem in relation with their FCBs. Based on this data, among the five measures taken, 58% of households consumed foods cooked easily and stay longer once cooked, 46% reduced the number and adequacy of meals consumed per day, 40% minimized the variety of food staffs /nutrition level/ consumed, 37% reduced the frequency of cooking per day or week and used refrigerators, 24% consumed non fresh foods and lack the required level of taste and flavor. The data also shows, except for households consuming foods that can be easily cooked and stay longer, in all other strategies, the proportion of non-users of electricity are greater than the number of electric-users implying the need to change households' FCBs and developing their awareness level on the negative effects of existing energy consumption habits accompanied by reliable electric supply.

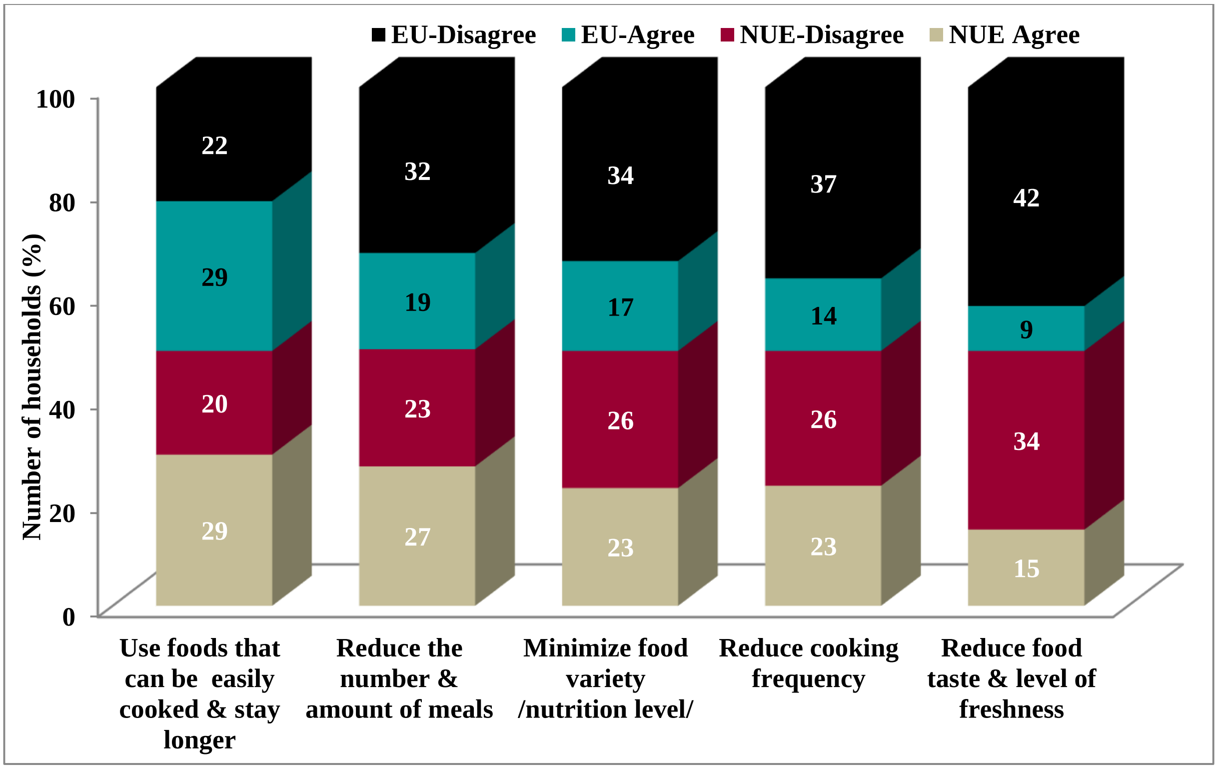

FIGURE 9: Strategies to Change Households' FCB based on Electric Use Status

Note: EU=Electric user; NEU=Non-users of electricity

Source: Data developed by the author, Oct., 2021

III. Households' Energy Conservation Strategies (ECS): Households in informal settlements tried to save energy using energy efficient cooking stoves, power saving light bulbs and compact florescent lights to lower electric bills and reduce environmental damages. They turn off devices and light bulbs when not in use with the aim of avoiding wasted energy, reduce peak time electric use, and change households' energy consumption behaviors.

Based on Fig. 9, since electric-users do not have access to reliable power and required to pay high and progressive electric tariffs, the number of electric-users are greater than non-users of electricity. For example, 50% of electric-users and 15% of non-users of electricity want to switch off everything when not using electricity and 46% of electric-users and 15% of non-users want reduce or do not want to use electric power during peak hours. However, the application of ECS requires huge investments, lowering thermostat settings and better maintenance of electric facilities and electric costs can be minimized by using lights, heating equipment and other appliances sparingly and reducing heat loss (Sovacool, 2014; Hernández, 2016).

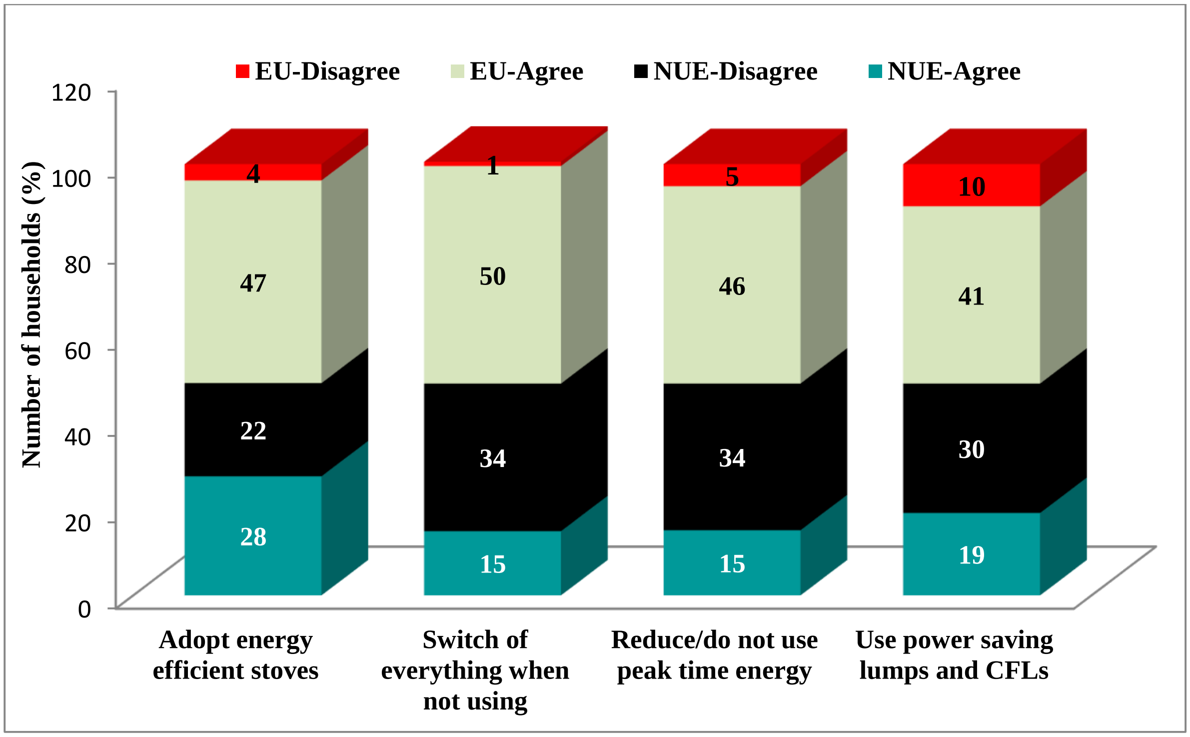

FIGURE 10: Households Energy Conservation Strategies Based on Electric Use Status

Note: EU=Electric user households and NEU=Non-users of electricity
Source: Data developed by the author, Oct., 2021

IV. Households' Coping Strategies (HCS): These strategies are prompted by lack of alternative energy sources and require the support of others, short-term solutions, reactive in solving the problem and degrade households' resource base. Because of these, households in informal settlements responded to the challenges of electricity (inadequacy, unaffordabllity and unreliability of electric supply) in various ways. As indicated in Table 20, 33% of households shifted to use cheap energy sources, 24% energy efficient technologies (such as *Mirt, Lakech* and improved electric stoves), 22% preferred existing low cost appliances, 11% reduced basic expenses like food and consumed their personal asset for energy, 7% reduced or cut their energy consumption at all, and others shifted family labor to do cooking and baking activities together with other domestic jobs.

Except for the inability to use low cost cooking appliances and measures to reduce the overall energy consumption level that are more practiced by electric users, non-users of electricity widely practiced all other coping strategies. This might be because of non-users' low level of income and electric-users' prior energy consumption behaviors that forced them to use traditional cooking appliances. In line with this Dlamini (2015) indicated that low income households resorted to traditional energy sources and suppress their demand through foregoing cooked meals.

TABLE 20: Households Coping Strategies to the Challenges of Electricity (%)

Households' Coping Strategies	Electric-Users	Non-Users	Total
▪ Shift to cheaper energy sources	16	17	33
▪ Use energy efficient technologies	12	12	24
▪ Use energy sources requiring low cost appliances	14	8	22
▪ Reduce other expenses and use assets for energy	5	6	11
▪ Reduce the overall energy consumption level	4	3	7
▪ Require subsidies and credit for connection fees	-	2	2
▪ Shift some family members to cook food	-	1	1

Source: Survey data, Oct. 2021

As a supplement to HCS strategy, households proposed alternative electric pricing strategies. To this end, 29% of electric-users preferred constant rate for any level of power consumption (flat metering), 28% chose decreasing tariff with increasing use, 27% opted progressive tariff /volume pricing/, and the rest 16% chose income or wealth-based electric pricing system accompanied by using prepaid cards. However, in an area where there is energy shortage, both flat metering and decreasing tariffs might not be good billing systems. Similarly when there are large numbers of low income households, both income-based and progressive billing systems may inhibit households from access to electricity.

To deal with the high cost of connection fees required, 73% of non-users of electricity are willing to share electric meters with their immediate neighbors and 93% are willing to accept temporary and less power consuming primary electric functions (such as illumination, charging batteries and mobile phones, listening radios and watching televisions) at market price. However, Barnes, Golumbeanu, & Diaw (2016) these measures do not typically lead to improvements in households' income, education and health levels whilst subsidizing connection charges based on the purpose of electricity needed, billing periods and using energy-efficient lights are critically important to households.

V. Policy Options: In addition to the above strategies, households suggested various policy options to solve the electric challenges of poor people in informal settlements. These options include the following (Table 21).

1. Simply legalizing all informal settlers further exacerbates illegal land grabbing. Instead, allotting land to urban dwellers and electric meters based on the number of years households lived in the area and suitability of the land held to the urban plan could increase access to electricity as confirmed by 97.33% of households. However, the data in the table 24 shows this measure still favors more the current electric-users than non-users implying the existence of some other criteria to provide access to households in informal settlements.

2. Since the Ethiopian Electric Utility (EEU) is the only electric supplier in Ethiopia, 94.65% of households in the study area explained that there is lack of adequate and reliable power supply, unaffordable price, and poor customer service. However, only

51% of households believe that involving a broad range of private electric suppliers improves the electric service and lower existing electric tariff, 21% believe this action does not change the overall electric service and 28% expect it worsens the electric problem in informal settlements. However, this policy favors more electric-users than non-users.

3. As suggested by 96.44% of households, providing solar panels freely or at low cost could help to reach indigent households in the outreach areas. In addition to subsidizing solar energy, setting affordable and flexible electric pricing systems, and removing subsidies on imported fuels could also improve the electric use status of informal settlers. Such measures are similar to Free Basic Electricity (FBE) program implemented in South Africa with the objective of mitigating energy poverty and facilitating households to cope up with escalating energy costs (Dlamini, 2015). However, FBE is costly and failed when large family sizes energy consumption goes beyond the threshold of 450kWh/month and households consuming subsidized energy sources do not take appropriate energy saving measures (Rouhier, 2010; Lloyd P. , 2014; Danlami, Islam, & Applanaidu, 2015; Figueroa, 2016).

4. Technically, measures such as lowering thermostat settings, servicing and repairing cooking appliances, recharging batteries and storing electric power when there is adequate power supply (as contended by 91.31% of households) could contribute for the efficient use of scarce resources and help to deal with households' challenges to access electricity. To this end Ampower (2019) indicated that every heating and cooling device in the home can be on and off based on pre-set schedule and appliance chargers can be timed to control how long devices have to be charged for. In this study, households indicated that such measures are highly beneficial to them and help to use the scarce resources optimally.

5. A study conducted by Laicane, Blumberga, Blumberga, & Rosa (2015) revealed that transferring the load of a washing machine and dishwasher to off-peak hours can reduce load by 24% and 13.5% respectively. Similarly, households in this study area indicated that marketing and financial measures such as effectively managing electric demand through discouraging peak time electric use, setting high electric prices to push households use ICS, managing demand for individual households through load limiting, and providing credit facilities for households using energy efficient cooking stoves improves electric use. These measures, however, are very complex and their effectiveness must be further studied under highly controlled conditions.

Although the policy options identified so far helps to deal with the challenges of all households, it specifically improves the electric supply of the current electric-users in informal settlements. Further applying a policy measure randomly may bring undesirable results or executing all policy options at the same time may contradict each other. It is, therefore, necessary to evaluate the interactive effect of alternative policy options on households' electric use status and their willingness to involve in cost sharing programs designed to improve power supply, which is the focus of the next section.

TABLE 21: Households Perspectives on Policy Options to Access Electricity

Policy options	Electric-users			Non-users		
	AG	ID	DG	AG	ID	DG
1. Legalize land and provide electric meters	225	3	0	212	5	4
2. Involve private suppliers	224	2	2	201	8	12
3. Provide solar panels	221	4	3	212	6	3
4. Provide subsidies and tailored electric tariffs	215	1	13	201	8	12
5. Lower thermostat settings and servicing appliances	212	6	10	198	16	7
6. Urge households use energy efficient devices	21	29	179	61	37	123
7. Reduce peak electric demand	209	3	16	191	15	15
8. Provide credit to energy efficient users	187	5	37	157	10	54
9. Managing demand	158	14	55	127	31	63

Note: AG=Agree; ID=Indifferent; DG=Disagree

Source: Survey data, Oct., 2021

4.3.4. Households Coping Strategies to the Challenges of Electricity: Binary Logit Model

Table 22 presents some of the demographic factors influencing the WTP for improved electric supply and their coping strategies to the challenges to use electricity in informal settlements. Based on this data, demographic factors such as sex, age, marital status education of the household head and family income have no effect on households' WTP for improved electric service. But family size and the number of years a household lived in the area with informal status have significant effect on households' WTP for improved electric service. Specifically, holding all other factors in the model constant, as family size increases by one unit, households' WTP for improved electric service decrease by 0.76. This means large families are more willing to participate in cost sharing programs designed to improve electric supply than small families. Similarly, as the number of years households lived in the area increases by one unit, their WTP for improved electric service increase by 0.3043 indicating those who lived longer periods in the area (more than 7 years) are more willing to involve in cost sharing programs designed to improve the electric supply than those who lived for shorter periods (below 7 years). This could be mainly because of power shortage, unreliable electric supply and lack of access to electricity for extended periods for some. However, it should be noted that as the number of years non-users of electricity lived in the area increases by one unit, their number decreases by 1.1255 units.

In terms of food consumption behaviors, among the various factors considered in the model, only reducing the number of meals taken per day is a significant factor that affects households' WTP for improved electric service. For example, under citreous paribus assumption, as the number of meals reduced per day increases by one unit, the number of households who are not WTP for the improved electric supply decreases by 0.4889 units. That is, households who reduced the number of meals in a day due to lack of access to reliable electric supply are more WTP for the improved electric service. On the other hand, as the frequency of cooking increases and the taste and freshness level of the food improves by one unit associated with access to electricity, the number of non-users of electricity decrease significantly (by 1.0750 and 1.1054 units respectively).

Among ECS, adopting ICS and using power saving lamps and CFLs significantly affect households' WTP for improved electric supply. That is holding all other variables constant, as households' ICS and power saving lamps and CFL use increases by one unit, their WTP for improved electric service increases by 0.743 and 0.8416 units respectively. This implies that energy efficient use encourages households to consume more and further participate in cost-sharing programs designed to improve the electric supply. In terms of electric use status, as non-users of electricity adopting ICS, switching-off everything when not using, and reducing or not using energy at peak time increases by one unit, their number increases by 2.8989, 6.4787 and 1.9028 respectively. This might be because non-users of electricity understand the financial burden of inefficient energy use and leaving light bulbs on when not in use.

Among alternative policy options considered, only legalizing land titles and technical measures have a significant influence on households' role in cost sharing programs and deal with the challenges of electric shortage. In lieu of this, holding all other variables in the model constant, as households who generally agree on legalizing informal settlers' land titles and disagree on taking technical measures such as lowering thermostat settings, servicing and repairing appliances by one level, their WTP for improved electric service increases by 0.596 and 0.339 units respectively. This means legalizing informal settlers contributes more involve households in development endeavors and when less technical services provided they will be more pushed to share the investment cost of improving electric supply. In terms of electric status, as one improves the reliability electric supply by a certain level, the number of non-users of electricity increases 1.0681 relative to electric users. This implies that the reliability of electric supply worries more non users of electricity than electric users.

Generally because of the inaccessibility of electric supply and high connection fees required by the EEU, 63% of households are willing to involve in a cost-sharing program designed to improve the current electric supply (availability, reliability and timing of energy service). Among these households, 63% are willing to add less than 33%, 29% from 33-66% and the rest 8% from 66-110% of the current electric bill. On the other hand, households who are not willing to share the cost of improving electric supply explained that the existing electric bill is unaffordable and set based on market principles (37.50%), getting electric service at subsidized price is their right and governments responsibility (35.71%) and others believe electricity is unreliable source and household need to have alternative source (23.81%).

Table 22: Factors Influencing Households Willingness To Pay (WTP) for Improved Electric Service and Electric Use Status: The Binary Logit Model

	WTP		Electric Use Status	
Number of obs	=	430	=	430
LR chi2(27)	=	87.32	=	418.70
Prob > chi2	=	0.0000	=	0.0000
Pseudo R2	=	0.1535	=	0.7024
	Coef.	**Std. Err.**	**Coef.**	**Std. Err.**
1. Demographic Factors			**Non-users of electricity**	
Sex: Females	0.1015	0.2482	-1.1471	0.5112**
Age	0.1506	0.1940	0.4717	0.3432
Marital status	-0.0572	0.2716	-0.8015	0.5028
Education	0.0495	0.1522	-0.3424	0.2770
Family income	-0.3245	0.3199	-0.5070	0.6323
Family size	-0.7600	0.2014*	0.0610	0.3514
Years lived in the area	0.3043	0.1453**	-1.1255	0.2569*
2. Food Consumption Behaviors				
Use foods easily cooked and stay long: No	0.3745	0.2548	-0.8231	0.5137
Reduce meals: No	-0.4889	0.2665***	-0.0282	0.4992
Minimize food variety: No	-0.1134	0.2586	0.2220	0.4918
Reduce the frequency of cooking: No	0.0435	0.2980	-1.0750	0.5434**
Reduce the taste and level of freshness: No	-0.2342	0.2817	-1.1054	0.4951**
3. Energy Conservation Strategies				
Adopt ICS: No	0.7430	0.3082**	2.8989	0.6674*
Switch-off everything when not using: No	-0.5252	0.3724	6.4787	1.2751*
Reduce /do not use/ energy at peak time: No	-0.2880	0.3238	1.9028	0.5256*
Use power saving lumps and CFLs: No	0.8416	0.2904*	-0.0018	0.5105
4. Households' Adaptive Strategies✞	0.0954	0.0759	0.5085	0.1545*
5. Policy Options				
Legalize land and provide electric meters	0.5960	0.2140*	0.4164	0.4506
Provide reliable electric power	-0.2934	0.2544	1.0681	0.5006**
Subsidize and set tailored electric tariffs	-0.1689	0.1570	0.0992	0.2507
Set high prices to urge HHs' save energy	-0.0164	0.1234	-0.4367	0.2419***
Provide credit to energy efficient users	-0.1136	0.1191	-0.3059	0.2189
Provide rooftop solar panels	-0.1057	0.2127	-0.2808	0.4547
Technical measures	0.3390	0.1695**	-0.4343	0.3375
Reduce peak demand and storing energy	-0.1627	0.1564	0.0966	0.2766
Load limiting	-0.0926	0.1094	-0.2441	0.2010
Involve private electric suppliers	0.1744	0.1910	0.6653	0.4179
-cons	-0.6081	1.5056	-1.5839	2.6389
Base outcome			**Electric users**	

- **, ** and *** are statistically significant at p< 1%, p<5% and P<10% respectively.*
- *✞ includes shift to cheaper energy sources, use energy efficient technologies and energy sources requiring low cost appliances, reduce other expenses and use it for energy, and reduce the overall energy consumption.*
  Source: Data developed by the author, Oct., 2021

Table 23 provides major criteria that prompt households' WTP for improved electric service: Source from which energy is generated (such as biomass, kerosene, LPG, solar, wind or water), residence place of a household and settlement patterns (such as proximity to transmission line, electric pole and a transformer), season in the year electric power is required (such as dry or cold season), *hours in a day* electric power is needed (such as day or night time), and households' *ability to pay* the bills required (income brackets or wealth levels).

Pursuant to these criteria, the result showed that households in informal settlements responded positively and significantly to electric tariffs varied based on energy source, households' residence place (far or close to electric line), and seasonal variations in power supply (low tariff in summer and high in winter). That is, compared to households who are WTP for improved electric supply, as electric tariffs revised based on the sources of energy increases by one unit, households who are not WTP for the tariff increases by 0.6416. Similarly, though less significant, as tariffs revised based on the place where households live and seasonal variations in energy supply increases by one unit, households who are not WTP for the new tariff structure increases by 0.369 and 0.3576 respectively. All these reveal households are not willing to pay more for electric tariffs revised based on the source of energy, residence place differences, and seasonal variations in energy supply. These criteria are also used to determine households' electric-use status. For example, non-users of electricity responding to tariffs set by the type of energy source is greater than electric-users whilst non-users responding to tariffs set based on season of the year are less than electric-users.

Since most households in informal settlements (about 77%) earn family income below 9,000 *birr* per month, wealth-based billing system is not applicable for such households. It could be feasible when there is adequate and reliable electric supply as confirmed by 73% of electric-users and adequate electric supply is not possible in situations where there is sole electric supplier and EEU applied progressive tariff structure (volume pricing) for its services while more than 57% of electric-users still contend either flat metering or decreasing rate. Similarly, households are not willing to adjust their electric consumption levels if the tariff varies within a day (i.e., low in the evenings, high at day time and peak from late afternoon to mid night). This could be associated with the work culture where almost all Ethiopians carry their activities (including cooking and baking) at day time.

TABLE 23: Criteria to Set Electric Tariffs and Households' WTP for Improved Service based on Electric Use Status

Criteria	Coef.	Std. Err.	Z	P>/Z/	Coef.	Std. Err.	Z	P>/Z/
WTP: No					**Electric use status: Non-users**			
Source of energy	0.6416	0.2194*	2.92	0.003	-0.7990	0.2265*	-3.53	0.000
Residence place	0.3690	0.2093***	1.76	0.078	-0.0374	0.2109	-0.18	0.859
Season/year	0.3576	0.2011***	1,78	0.075	0.8451	0.2025*	4.17	0.000
Time in a day	-0.0585	0.2118	-0.28	0.783	0.6812	0.2105*	3.24	0.001
Income/wealth	0.0831	0.4039	0.21	0.837	0.0320	0.4053	0.08	0.937
_cons	-2.4468	0.7058	-3.47	0.001	-1.1329	0.6869	-1.65	0.099
Base outcome	**Yes**				**Electric-users**			

, ** and * and are statistically significant at p< 1%, p<5% and p<10% respectively*

Source: Data developed by the author, Oct., 2021

It is also necessary to investigate the relationship between households' energy consumption levels (measured by energy expenditure made to each source) and improvements in income per month. According to Fig. 10, compared to the previous month, if family income per month increases by 100%, 77% of firewood users, 75% of charcoal users and 82% of kerosene users either decrease their energy use by more than 25% or do not change at all while 84% of LPG users and 97% of electric-users are willing to increase their current energy expenditure by more than 25% for clean energy sources. In other words, as family income increases, most of households would like to shift to clean energy sources and their energy consumption increases significantly (even beyond 100% of their current LPG and electric expenditures). In line with, as the incomes of households increase in South Africa, the increasing share of income goes to cover escalating energy costs (Dlamini, 2015).

The increase in firewood use by 23% and charcoal by 25% might be associated with households prior FCB and lack of adequate and reliable electric supply in informal settlements.

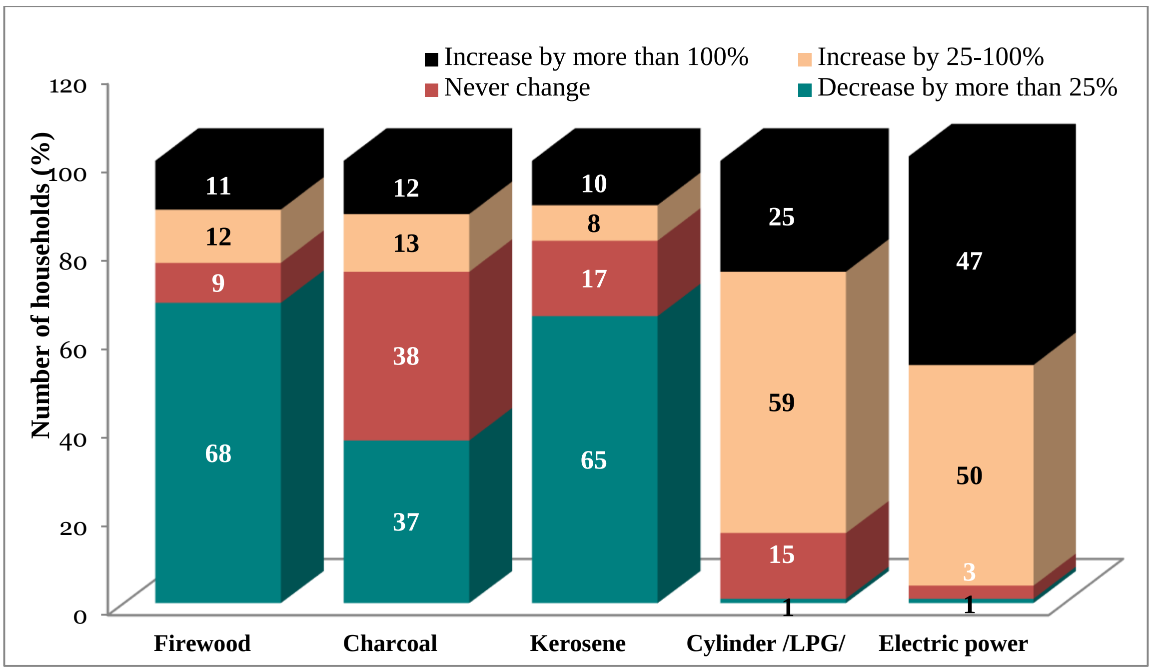

FIGURE 11: Households Energy Consumption Levels if Income Doubles

Source: Data developed by the author, Oct., 2021

4.4. Conclusions and Recommendations

Households in different locations of Addis Ababa do not have equal access to electricity. Informal settlers in particular lack access to electricity and those who already had access to electricity are faced with inadequate power supply, frequent interruption, fluctuation, and outages. Illegal and scattered settlement, low and unstable income, lack access to credit service has contributed much to the inability to pay unaffordable connection fees and electric tariffs required. Informal settlers also faced long bureaucracy and mistreatment by the EEU to get the electric supply and 61% either do not want to shift to new energy sources and use energy efficient stoves or require relatively long period to adopt new technologies. These challenges forced informal settlers in general and non-users of electricity in particular design numerous coping strategies. The data showed that non-users of electricity are resorting to get electricity from their immediate neighbors at a higher rate than the official tariff set by EEU, about 73% have shown interest to share electric meters and pay connection charges in groups, and 93% are willing to accept temporary and low power consuming electric services. Depending on each households'' socio-economic condition, they also applied various energy mix and substitution strategies, changing FCBs, ECS and HCS.

The results of the binary logistic regression model indicated that households with large family sizes and lived in the area for short period of time (below 7 years) are more willing to participate in cost sharing programs designed to improve electric supply. In terms of FCBs, reducing the number of meals in a day and amount of food consumed helped to cope up the electric challenges of households and force them to involve in cost sharing programs designed to improve electric supply. In this regard, electric-users are found cooking frequently to get fresh food and get the desired taste than non-users of electricity. Similarly, households in informal settlements tried to conserve energy using energy efficient stove, power saving lamps and CFLs.

Among alternative policy options that can be considered at national level, formalizing the informal dwellers, providing individual electric meters to households, lowering thermostat settings, servicing and repairing cooking appliances positively influence households' willingness to involve in cost sharing programs designed to improve electric service.

To speed up households' transition to new energy sources and the use of improved technologies in informal settlements, energy suppliers shall focus on providing reliable electric supply, increase awareness level on the benefits of new energy sources and power saving devices, and change consumption habits. Involving a wide range of private suppliers in the energy sector by avoiding a sole source problem is also sought as the viable policy option to decision makers. Finally, to set a fair electric tariffs, billing systems shall consider the type of energy source, households' residence place (proximity to electric lines), and season of the year electricity is supplied, instead of setting tariff structures based on the income/wealth of the household and time in a day electric is consumed.

Chapter 5

Adoption of Improved Cook Stoves by Households in Informal Settlements in *Woreda 12,* Yeka Sub City, Addis Ababa[15]

Abstract

This study analyzed the factors affecting the use of Improved Cook Stoves (ICS)) in informal settlements of Addis Ababa based on the data generated from 450 households drawn from Woreda 12 of Yeka Sub-city. It examined the interactive effect of households' socio-economic backgrounds and energy sources on the adoption of ICS. The data was analyzed using descriptive methods and the multinomial logit model. Demographic and economic factors such as sex of the household head, family size and family income have no relationships with households' ICS use while education level, number of years lived in the area, type of home owned, and stove operating costs have a significant influence on the choice of ICS. Households who live in a good home (made from wood and cement) used more Mirt[16]and Lakech[17] stoves than the traditional three-stone stoves. On the other hand, household heads with higher education and lived more than 7 years in the area in a better home owned more ICS than the traditional three-stone stoves. The availability, affordability, durability and simplicity to operate stoves, and subsidies affect the choice of ICS. Energy sources that are commonly used by households in informal settlements have also strong influence on the choice of energy efficient stoves. Compared to ICS, heavy use of traditional three-stone stoves by households who have already access to electricity directs the government to focus on providing reliable electric service and subsidize households using ICS.

Keywords: *Informal settlement; ICS, Lakech stove; Mirt stove; Three-stone stove*

---

[15]. *Paper accepted for publication in the Journal of Energy, Sustainability and Society, Springer International Publishing.*

[16]. *Mirt is improved firewood stove mainly used to bake Injera and bread.*

[17]. *Lakech also called Tikikil is an improved charcoal stove used to cook different kinds of dishes (non-Injera).*

5.1. Background

Energy efficient cooking technologies or simply ICS increase energy efficiency (Reyna & Chester, 2017), reduce heavy reliance on fuel wood, energy consumption levels, and save cooking time (Bhattacharjee & Reichard, 2011; Chagunda, Kamunda, Mlatho, Mikeka, & Palamuleni, 2017). They add the taste and flavor of food staffs and improve the quality of life (Sohagab, Beguma, Abdullaha, & MokhtarJaafar, 2015; Parka, Xingb, Hanaokab, Kanamorib, & Masuib, 2017; Flores, Benjamin, Pino, Al-Sumaiti, & Rivera, 2020), help to manage demand and save energy by replacing conventional energy technologies (Mfundis & Commeh, 2019), efficiently convert biomass into energy, emit very little smoke associated with complete combustion, and contribute to the sustainable use of scarce resources (Cai, Grant, & Pandey, 2018; Olugbire, et al., 2016; Sanaeepur, Sanaeepur, Kargari, & Habibi, 2014). Switching to modern fuels and using ICS with better technological designs transforms lives, improves health, helps to protect climate and environment, lowers households' expenses on medicines, reduces the workloads of women and children; and make free women's labor, time and money (Kammen, 2011; EIA, 2019; CCA, 2022).

Projections for 2030 indicated that aggressive energy efficiency measures can significantly save the demand for energy. For instance, a study conducted by Reyna and Chester (2017) indicated that the adoption of light-emitting diodes (LEDs) reduce residential electricity consumption for lighting by 53%, upgrading electrical appliances could lower by 28%, replacing light bulbs and incandescent lamps with more efficient compact fluorescent lamps by 75%, ICS save firewood consumption by 40-60% and charcoal use by 30-40% compared to traditional stoves (Kammen, 2011; Shellenberger & Nordhaus, 2014; Feldmann & Otremba, 2015). Such ICS can produce the same amount of light with less energy and expense and firewood and traditional stoves are likely to break easily when moved from place to place (Herring & Roy, 2007; Flores, Benjamin, Pino, Al-Sumaiti, & Rivera, 2020). High storage capacity batteries and solar panels are also useful, resilient and clean energy sources used over geographical areas (Feldmann & Otremba, 2015; Ifegbesana, Rampedia, & Annegarn, 2016).

The Multi-Tier Framework (MTF) developed by the World Bank provided a compressive guide to analyze the factors affecting households' choice of energy saving stoves. These factors are availability of energy sources, uninterrupted power supply, durability and affordability of the stove, price of fuel, the capacity to load big appliances, the health and safety of using the stove, and the formality of the service provided (Padam, et al., 2018). In line with this, Yonas, Abebe, Köhlin, & Alem (2016) found that as income increases, households are more likely to buy ICS that lower energy price and use clean energy sources. Medina, Cámara, & Monrobel (2016) and Amoah (2019) also suggested that substituting declining biomass, adopting ICS and changing households' energy consumption behaviors are effective tools to get economic outcomes and lower environmental pollution.

However, studies indicated that limited supply and high cost of ICS at local levels, shortages of electric meters, unavailability and high cost of spare parts, lack of access to credit facilities, and spending priorities for other basic needs affect the use of energy-efficient technologies (Triannia, Cagnob, & ErnstWorrellc, 2013; Grueneich, 2015; Barnes, Golumbeanu, & Diaw, 2016; Kanyamuka, 2017; Zeng, Dong, Shi, & Li, 2018; Bayera, Kennedy, Yang, & Urpelainen, 2020). The cost of fulfilling ICS and appliances is capital intensive and unaffordable. Padam, et al, (2018) underlined the importance of providing incentives and arranging flexible payment systems or credit facilities. A study made by Mfundis & Commeh (2019) indicated socio-cultural, behavioral and competence-related barriers made the adoption of ICS difficult at household level. For example, youths in Botswana have made collecting fuel wood and making fire part of their culture. Some even do not identify the indoor air pollution effects of traditional stoves, the savings for firewood and the health benefits of using ICS (Nepal, Nepal, & Grimsrude, 2010; Mobarak, Dwivedi, Bailis, Hildemann, & Miller, 2012). Feldmann & Otremba, (2015) and Chagunda, Kamunda, Mlatho, Mikeka, & Palamuleni (2017) described that households prefer to use traditional three-stone stoves more than power saving technologies whilst food such as *Injera*[18] baked on ICS does not smell smoke, with good taste, and the edges are smooth (World Vision, 2016).

Access to electricity in Ethiopia 48.27% of the total population, currently producing 4,284MW, domestic energy consumption accounts 92% of the energy supply, waste and biomass are the primary sources of energy accounting 92.4% of Ethiopia's energy supply, 84% of urban households used biomass, and 63.3% use traditional three-stone stoves as their primary stove (World Vision, 2016; energypedia, 2019; MWIE, 2017; Padam, et al., 2018; Tiruye, Besha, Mekonnen, & Benti, 2021). The use of these stoves (such as flat *Mitad*[19] *and Fermelo*[20]) require low initial cost, highly consistent with consumers' preferences, ease of use and relatively widely available (Zeng, Dong, Shi, & Li, 2018). The cost of cooking appliances like kittles, flat *Mitad* and pots are cheaper and the technology is easily adaptable than electrical items such as electric oven, toasters and water boilers. Culturally, people like to see open fire and be around it, smoke makes food smell nice, and women like to go out collecting fuel wood as it gives them a space to socially interact (Mfundis & Commeh, 2019). Traditional three-stone stoves can be easily set up, fit all pot sizes, the heat from the fire provides warmth, light, a sense of comfort and the use of biomass is often the only available, accessible and affordable fuel for most households (Feldmann & Otremba, 2015). On the other hand, traditional open fire cook stoves are not fixed at

18 *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.*

19. *Mitad is a three-stone traditional stove used to bake Injera (staple food in Ethiopia) using fuel wood, plant residues and animal dung.*

20**.** *Fermelo is a stove used to cook dishes using charcoal in an open fire.*

one place and when these stoves move from place to place, the risk of breakage is high.

However, heavy reliance and inefficient utilization of biomass in open fire burning wastes resources and overconsumption of biomass causes many harmful impacts that impede economic and social development in developing countries (Abebe & Koch, 2013; Sheng, He, & Guo, 2017; CCA, 2022). According to WHO, inefficient combustion of solid fuels in low-quality open fire and outdated stoves, operated in poorly ventilated kitchens and excessive exposure to smoke impacts the health of women and children (EIA, 2019; Padam, et al., 2018). It causes 4 million deaths and produces 1 gigaton CO2 emissions every year from burning wood fuels (CCA, 2022). Globally, it resulted in severe respiratory disease responsible for up to 12% deaths in Ethiopia, makes clothes dirty and smells like smoke, irritates eyes and creates a sense of discomfort (World Vision, 2013; World Vision, 2016). Burning biomass in such stoves has undesirable consequences on the environment such as the decline in the availability of biomass resources, deforestation, and greenhouse gas emissions contributing to climate change. Most studies indicated that households will continue to depend on these fuels for decades to come (World Vision, 2016).

Whilst ensuring access to affordable, reliable, sustainable, clean, safe, healthy and modern energy for all by 2030 is one of the 17 Sustainable Development Goals of the UN, only 4.1% of households in Ethiopia use electricity as a primary cooking fuel (Padam, et al., 2018). Energy sources such as biogas and Liquefied Petroleum Gas (LPG) are rare accounting less than 1% of households and unaffordable (Padam, et al., 2018). Similarly, although solar energy is easily available, clean, and very effective to prepare staple foods, generating electricity using these sources is a recent practice in Ethiopia. Beyond this, not all traditional dishes can be prepared with solar energy and solar cookers are expensive to use. As a result, the government has prioritized the use of ICS and efficient lighting as the most important areas to guide investments, expand energy supply, and ensure environmental sustainability (Mondal, Bryan, Ringle, Mekonnen, & Rosegrant, 2018).

Classification of ICS based on fuel use, portability in the kitchen and different sizes are also essential in the choice of stoves (Abebe & Koch, 2013; Feldmann & Otremba, 2015). For example, Mirt stoves use firewood to bake *Injera*, and designed to reduce environmental degradation whereas *Lakech* stoves use charcoals. Though the performance of these stoves are evaluated mainly by how much of the energy generated is absorbed by the cooking pot (heat-transfer efficiency) and the amount of energy converted to heat and carbon dioxide (combustion efficiency) (Ekouevi, Freeman, & Soni, 2014), households use them for preparing different kinds of food staffs.

Lack of access to legal land entailment forces households to construct houses below the standard and become the major impediment to get access to electricity. This in turn forces many households to use open fire traditional three-stone stoves while wealthy and educated households are likely to adopt energy-efficient stoves. Literatures focused on alternative energy sources, the available technologies and the deteriorating living condition of households in rural and urban areas of Ethiopia (Chen, 2016; Yonas, Abebe, Köhlin, & Alemu, 2016; Howell, 2011; Gebreegziabher, Mekonnen, Kassie, & Köhlin, 2012). However, in Ethiopia little has been done on the adoption of ICS in informal settlements.

This study addressed the question, 1) What stoves households owned in informal settlements? 2) What factors attributed to the adoption of ICS? 3) What is the effect of energy sources and households' socio-economic backgrounds on the adoption of ICS? The study considered households' socio-economic and demographic characteristics, financing options such as credit facilities and subsidies affecting the choice of energy efficient stoves.

The study is set in four sections: The first section provides the background of the study followed by a section that explains the data and methods used. The second section begins with description of the study area, how the sample is designed, and then data collection and analysis methods employed. The third part is devoted to present the results of the study and discuss the findings. The final section provides conclusions, implications and future research direction in the area.

5.2. Data Analysis Methods

In this study, description of the study area, study approach and sample design are provided in the general introduction chapter. Here only data analysis and specification of the model is provided. To this effect descriptive statistics such as frequency tables, percentages, bar graphs and figures were used to present and analyze the influence of demographic variables affecting ICS use, explain the relationship between the duration of ICS adopted by households and fuel consumption trends, discuss alternative methods of financing ICS and factors affecting the adoption of ICS, explain the conditions to use solar and electric stoves, present the rationale for using ICS and the major problems that households in informal settlements encountered.

The *multinomial logit model* is used to analyze the adoption of ICS in informal settlements. It combined a set of factors affecting the choice of energy efficient stoves. To analyze the determinants of ICS use, the dependent variable is households' alternative cook stoves (the traditional three-stone stove, *Mirt*, *Lakech* and electric stoves) and the explanatory variables are developed based on the theoretical frameworks and factors expected to influence households' ICS. The structural model that integrates these variables and help to interpret the effects of a set of explanatory variables listed in Table 27 on the adoption of ICS is provided as follows:

$$Y_i = \delta_i + \beta_1 X_1 + \beta_2 X_2 + \cdots + \varepsilon_i$$

Where, Y_i= The outcome variable for a household adopting energy efficient technologies (such as power saving electric stoves and ICS like Lackech and *Mirt*); X_i are explanatory variables that includes demographic, economic and stove related factors; δ_i *and* β_i= parameter estimates; ε_i =error terms.

5.3. Results and Discussion

5.3.1. Factors Affecting Energy Efficient Stove Use: Descriptive Analysis

Table 24 provides the stoves owned by households based on their socio-economic profiles. The order of these stoves is presented based on their energy efficiency level. As provided by Yonas and et al., (2016) and Zenebe, et al., (2018), this order spans from the traditional three-stone stoves with the lowest technology through improved biomass stoves (*Mirt*) and charcoal stoves *(Lakech)* to electrical stoves with advanced technology.

The survey result indicated that 20% of households in informal settlements used open fire traditional three-stone stoves, 42% *Mirt/Lakech* stoves and 38% electric stoves as their primary cooking stove. Male and female headed households considered in this study are 63% and 37% respectively. About 13% of male headed households and 7% of female headed households used traditional three-stone stoves; 29% males and 13% females used *Mirt/Lakech* stoves; and 21% males and 17% females used electric stoves. However, although males are greater than females in all cases, it is difficult to exhibit a clear relationship between sex of the household head and the adoption of ICS.

In terms of family size, the number of households using traditional three-stone stoves has increased from 3% (below 3 families) to 9% (above four families) whilst the number of households using ICS *(Mirt/Lakech* and electric stoves) varies considerably with an increase in family size. This indicates that family size does not affect the households efficient stove use. However, studies conducted by Bekere and Megerssa (2020), Geddafa, Melka, & Sime (2021) and Woubishet (2008) indicated that sex of household head and family size are important determinants in adopting *Mirt* stoves and biogas technology. In fact, the findings of Bekere and Megerssa (2020), Geddafa, Melka, & Sime (2021) in particular are based on the adoption of biogass technology and *Mirt* stoves in rural areas, not in informal settlements.

Among married households that constitute 78% of all households, 35% used electric stoves and 28% Mirt/Lakech stoves. This shows that married people are more likely to use ICS than singles. Likewise, higher levels of education of the household head and living longer periods in the area have a positive influence on the adoption of ICSs. Income wise, from households earning below 6,000 birr/month, 7% use traditional three-stone stoves and 20% ICS. From those earning above 6,000 birr/month, 13% use traditional three-stone stoves and 60% ICS. In both cases, a significant number of households preferred to use ICS indicating the relationship between family income and stove choice is not clearly described while Sheng, He, & Guo (2017) and Woubishet (2008) concluded that wealth and income are important determinants to adopt ICS.

Informal settles that had already access to electricity were expected to use electric stoves. But only 73% are found using electric stoves and the rest used three-stone and ICS. From electric-users, 72% found using *Mirt or Lakech* stoves mainly due to lack of adequate and reliable electric supply.

TABLE 24: Households' Demographic and Socio-Economic Backgrounds and Stoves Owned (%)

		3-stone stove	*Mirt/Lakech* stove	Electric stove	Total
Sex	▪ Male	13	29	21	63
	▪ Female	7	13	17	37
	Total	20	42	38	100
Family size	▪ Below 3 families	3	4	5	12
	▪ 3-4 families	8	22	24	54
	▪ More than 4	9	15	10	34
	Total	20	41	39	100
Marital status					18
	▪ Not married	4	11	3	78
	▪ Married	15	28	35	4
	▪ Separated	1	2	1	100
	Total	20	41	39	
Education	▪ Below grade 4	3	6	0	10
	▪ Grade 4-8	6	11	4	21
	▪ Grade 9-Diploma	8	14	8	30
	▪ Degree and above	2	10	27	40
	Total	20	41	39	100
Family income per month	▪ Up to 6000 *Birr*	7	16	4	27
	▪ Above 6000 *Birr*	13	25	35	73
	Total	20	41	39	100
Years lived in the area	▪ Up to 3 years	5	9	2	16
	▪ 4-6 years	6	11	8	26
	▪ 7-9 years	3	11	9	23
	▪ Above 9 years	5	10	20	35
	Total	20	41	39	100
Home type /condition/	▪ Poor (wood and mud)	9	11	4	24
	▪ Good (wood and cement)	10	30	30	70
	▪ Very good (steel & blocket)	0	1	5	6
	Total	19	42	39	100
Number of dwellings	▪ 1-2 rooms	12	18	7	37
	▪ Three rooms	4	15	13	31
	▪ More than 3 rooms	3	10	18	31
	Total	20	42	38	100

Source: Survey data, March 2022

The relationship between home condition (described by the type of home owned) and number of dwellings owned and energy saving stoves adopted by the households is also clearly depicted in Table 27. Among households living in a good house (made of mud and cement), only 10% used traditional three-stone stoves while 60% used *Mirt/Lakech* and electric stoves. From households living in very good houses (made of steel and blockets), households used the traditional three-stone stoves is literally nil while those using ICS are 6%. Similarly, among households who live in 1-2 rooms, 12% used the traditional three-stone stoves and 25% used ICS. From those who owned more than 2 rooms, only 7% used traditional three-stone stoves while 55% used *Mirt/Lakech* and electric stoves. These results suggest home condition and number of rooms in a home determine households ICS use and as the number of rooms and the condition of houses owned by households improves, the tendency of that household using ICS increases. This finding is similar to that of (Woubishet, 2008).

Fig. 11 presents the typical *Mirt stove* used by households in Ethiopia to bake *Injera* and bread. Compared to the traditional three-stone stove tripod, it saves fuel wood from 22-31% (Howell, 2011).

FIGURE 12: Typical *Mirt* Stove Owned by Households in Informal Settlements

Source: Photograph taken by the author, April, 2020

In Ethiopia, ICS were primarily designed to solve deforestation problems and pollution effects. They are keys to safe, reliable, affordable and sustainable energy in the future and balance energy scarcity (Ouedraogo, 2017; Shove, 2018). However, in this study, 50% of households used these stoves to reduce the operational cost of energy by efficiently utilizing biomass and reducing wastages, 31% to save time and reduce workloads of family members involved in cooking activities, and 18% to protect forests and sustainably utilize scarce resources. This is in line with the research findings of Abebe and Koch (2013) and Dawit (2020) who emphasized households' economic reasons to own energy efficient cooking stoves and use renewable energy sources.

Households were required to rate the salient factors that affect their choice of stove based on the most pressing reasons provided to them. Table 25 presents the five most important factors that influenced households' decision to own a specific stove. Based on this data, 82% households use traditional three-stone stoves influenced by the availability and price of the stove, 79% prefer to use Mirt stoves due to the availability of subsidies, credit facilities, quality/durability and efficiency reasons; and 69% owned Lakech due to its capacity to lower energy cost, durability of the stove, the availability of subsidies and credit facilities. The choice of electric stoves depends mainly on the cleanness, contribution to minimize indoor air pollution, capacity to save family labor and time, and simplicity and convenience to use the stove technology as confirmed by 68% of households. In relation to this, Feldmann & Otremba (2015) concluded that availability, affordability and reliability of fuels and the contribution of stoves to clean burning, the purchasing price of the stove and simplicity to use determines the choice of ICS.

TABLE 25: Key Factors Affecting Households' Choice of Stove

Stove type	Factors affecting stove choice	Percent
Three-stone stove	1. Cheap technology to buy	43
	2. Widely available stove	39
	3. Well-known stove	8
	4. Lowers the cost of energy	6
	5. Simple/easy to use	4
Mirt stove	1. Most subsidized and easy to obtain credit	33
	2. Quality and durability of stove	25
	3. Lowers the cost of energy	21
	4. Well-known stove	11
	5. Widely available stove	10
Lakech stove	1. Lowers the cost of energy	25
	2. Quality and durability of stove	25
	3. Most subsidized and easy to get credit	19
	4. Widely available stove	16
	5. Cheap technology to buy	16
Electric stove	1. Clean and health source	24
	2. Saves family labor and time	23
	3. Convenient and easy to use	21
	4. Well-known stove	18
	5. Quality and durability of stove	14

Source: Survey data, April, 2020

5.3.2. Duration of ICS Adopted by Households and Fuel Consumption Trends

To better understand the adoption rate of ICS in informal settlements, data is captured from 390 households (excluding the 60 households who did not provide a response for this particular question). Based on this data, 55% are electric-users and 45% are non-users of electricity. Depending on the source of energy about 87% of households owned only one type of stove and others owned two or more kinds of cooking stoves. Fig. 12 presents the time when households owned energy saving stoves (that is, 8% owned before 10 years, 40% before 5-10 years, and 51% in the past 5 years). Based on this data the adoption of ICS increased greatly in recent periods and the rate of adoption of electric-users is greater than that of non-users. As corroborated by Abebe & Koch (2013) the adoption speed of ICS also increased with the increased income and varies across regions.

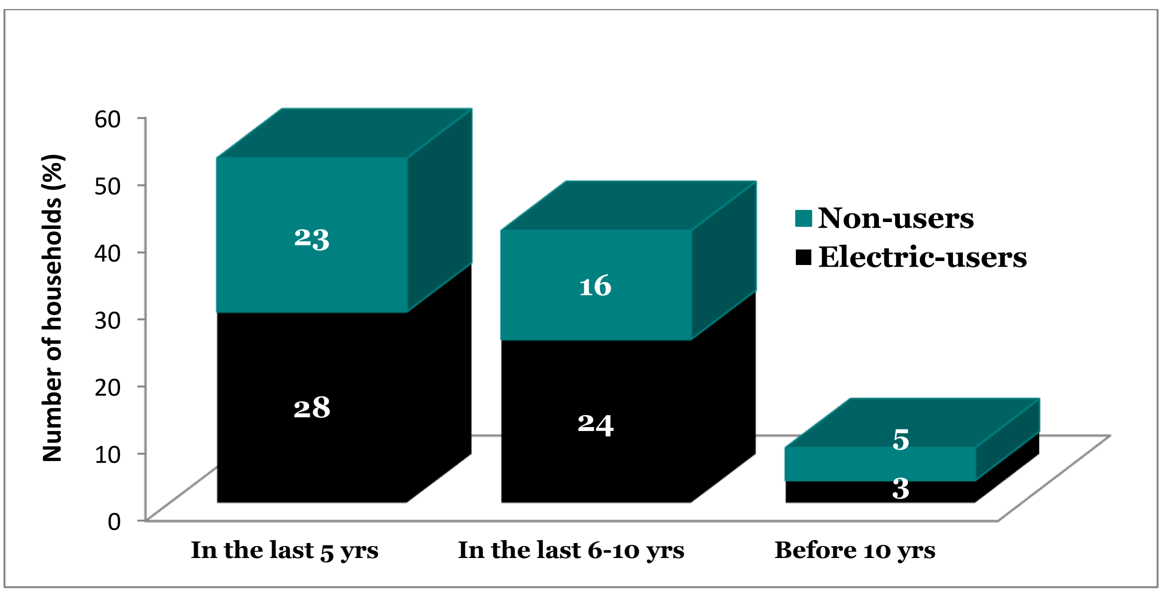

Figure 13: Period Improved Cook Stoves Owned by Households

Source: Data developed by the author, March, 2022

It is also essential to understand the perception of households on fuel consumption trends and the forces that drive them to adopt ICS. The result showed that both electricity and biomass users contend that their consumption levels either remained the same as before or increased over time. Specifically, 22% of biomass users and 42% of electric-users perceive that energy consumption has grown significantly whilst 21% of biomass users and 9% of electric-users contend there is no change in energy use over time. In both cases, households are either forced to expend extra cost for energy sources or use ICS with the intent of reducing operation costs. Biomass users in particular should adopt ICS use and focus on shifting to modern energy sources.

5.3.3. Financing Sources and Challenges to Use Energy Efficient Stoves

Households have alternative financing methods to own energy efficient stoves. In the study area, about 47% of stoves are owned from own source through upfront payment, 33% obtained through subsidies and discounted sales, 15% through suppliers' credit and loans from creditors, and 6% freely and a mix of financing options (Fig. 13). The sources of finance also vary based on households electric use status. For example, 27% of electric users obtained from own source and 6% through installment basis while this figure is 20% and 9% respectively for non-users of electricity. This indicates that unless special arrangements such as subsidies, discounts, incentives and credit facilities are arranged to the low income households, they cannot afford to pay the upfront cost of ICS like cylinders, electric stoves and expensive electrical appliances.

Many households believe that subsidies and credit facilities help them to install ICS and enjoy the economic and health benefits of switching to clean energy sources. They also contend that the risk of unreliable electric supply urges them to own more than one kind of stoves and adopt energy stacking approach. On the contrary, not very little number of households (about 30%) believed that the removal of subsidies, making the price of energy high, and urging polluters pay for their pollution effects encourage households use energy efficient cooking stoves and discourage the consumption of traditional energy sources. The risk of unreliable electric supply also urges households own more than one kind of stoves and adopt energy stacking approach.

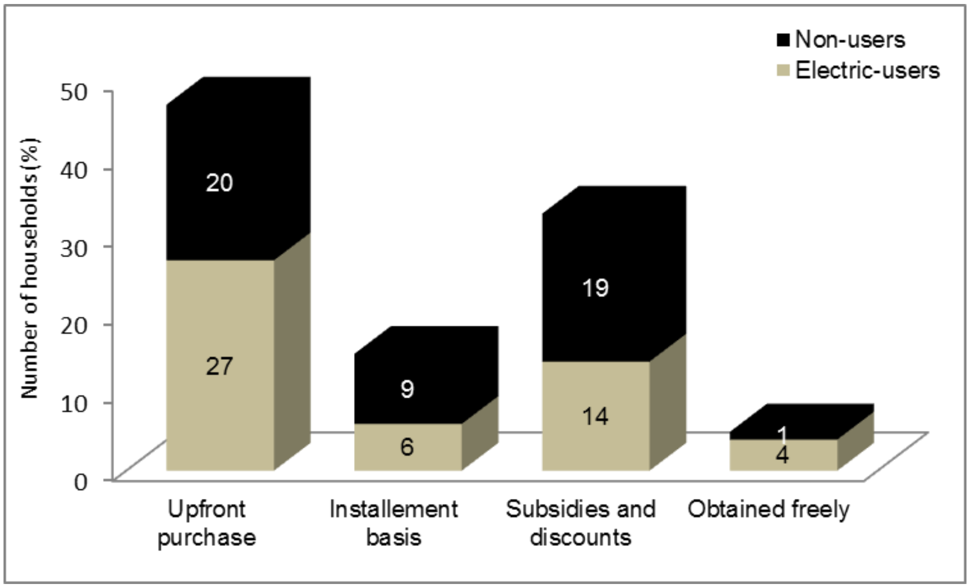

Figure 14: Sources of Financing Energy Saving Stoves

Source: Data developed by the author, March, 2022

However, although 38% of households described that they had no problems in using ICS, 62% described that they faced different challenges (Table 26). Specifically, about 22% faced with high cost of obtaining ICS, 12% encountered lack of maintenance service, 12% described that the stoves are poor in quality, do not last long and poor in workmanship, and 6% explained the stoves cannot power large appliances. These problems shall require the attention of ICS suppliers, creditors, donors and government bodies. According to Wassie & Adaramola (2021) the provision of poor quality, high cost of solar PV systems, lack of after-sales service, and limited access to credit facilities are critical problems to use ICS.

TABLE 26: Households' Problems to Use ICS

Problems encountered to use ICS	Freq.	%
1. No problem encountered till now	172	38
2. Expensive to buy	96	22
3. Absence of maintenance service	55	12
4. Not durable /poor in quality/	53	12
5. Cannot power large appliances	27	6
6. Other reasons	47	10
Total	450	100

Source: Survey data, Feb., 2022

5.3.4. The Use of Solar Energy and Electrical Appliances

In urban Ethiopia, the use of solar energy for domestic use is a recent practice and the least utilized resource. According to Hailu and Kumsa (2020), the country uses off-grid solar photovoltaic (PVs) technologies such as distance-education through radios and vaccine fridges in remote areas. Where other fuels are not easily available, it is a useful source of energy for lighting and preparing staple foods. However, the current energy mix in Ethiopia is dominated by hydropower. Projections indicate this mix will shifts to solar and wind energy towards the end of 2050 as a least-cost energy supply option (Boke, Moges, & Dejen, 2022). In rural Ethiopia, electricity has reduced kerosene use, health damages, CO_2 emissions and helped micro enterprises to generate more business income (Wassie & Adaramola, 2021).

In this study, 60% of households used solar energy for lighting and charging batteries while solar cookers are too expensive, unavailable, and not utilized at all influenced by cultural factors. On the other hand, traditionally, all dishes cannot be prepared with it. That is, solar energy does not completely replace traditional fuels and stoves (Feldmann & Otremba, 2015). All these forced households in informal settlements to prioritize electrical appliances according to their income level and importance of appliances for a household (Fig.14). In view of this, 60% want to own baking and cooking devices, 21% entertaining devices (such as television and radios), 8% refrigerators, and 4% power saving lumps and chargers as their priority choice. Households mainly need baking and cooking stoves to fulfill their basic needs, reduce cost of energy associated with increasing biomass price, and the cleanness or healthy nature of electricity and solar energy.

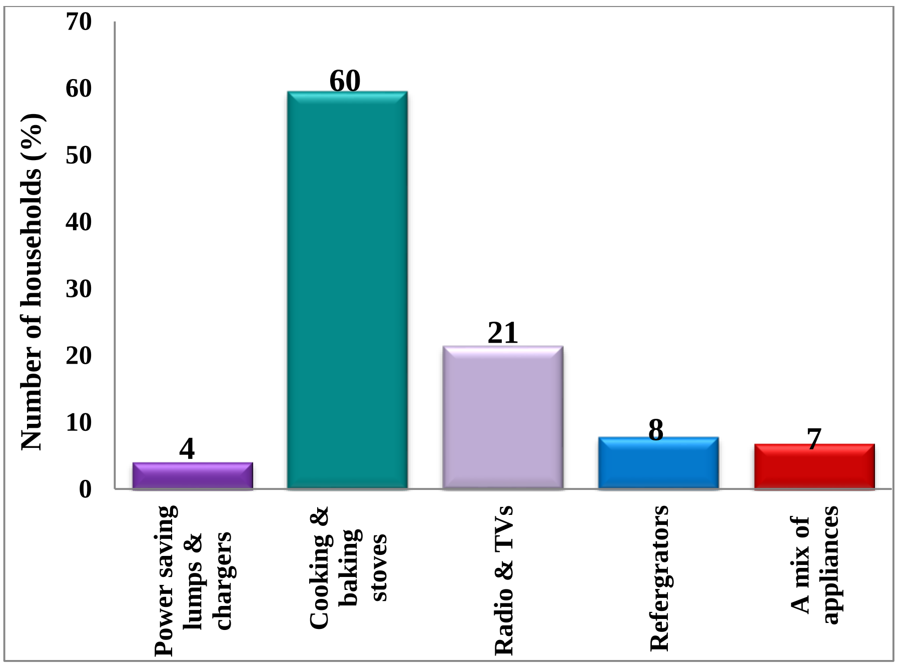

Figure 15: Electric-Users' Reasons for Choosing Electrical Appliances

Source: Data developed by the author, Feb., 2022

In terms of the frequency of stove use, 37% of electric users used electric stoves regularly while 21% used sometimes. The latter group used electric stoves sometimes due to lack of adequate, reliable and affordable electric supply and shortage and high price of stove technologies. To cope up with these problems and cushion sudden electric interruption, 28% found using traditional three-stone stoves always and 14% sometimes. Absence of reliable supply and the use of biomass by households who have already access to electricity, however, exacerbate increased deforestation and indoor air pollution.

5.3.5. The Use of ICS in Informal Settlements: The Multinomial Logit Approach

This section presents various factors that have a potential impact on the choice of ICS in informal settlements. These factors were considered separately in the descriptive analysis. However, the multinomial logit is used to evaluate the impact of those factors on households' ICS use. It helps to estimate the direction and strength of relationship between the various factors and the types of stoves households owned. Before presenting the results of the MLR, it is essential to describe the key variables considered in the model.

1. Sex: The gender of the household head selected for study is labeled as male or female.
2. Marital status: The marital status of the household head is labeled as single, married or separated (widowed and divorced).
3. Education level of the head of a household is categorized in four groups: Below grade 4, Grade 4-Grade 8, Grade 9-Diploma and Degree and above.
4. Family income: This is the monthly income generated by all family members and categorized into two groups: those earning up to 6,000 **B***irr* and above 6,000 *Birr.*
5. Family size: This refers to the number of family members living in one home and grouped into up to 2, 3-4 and more than 4 families.
6. Years lived: Since the first time a household held the land, the number of years he/she lived in the area is categorized as those who lived up to 3, 4-6, 7-9, and more than 9 years.

7. Shelter type and condition: This is the material from which the house is made and its current condition labeled as poor (made from wood and mud), good (made from wood and cement) and very good (made from steel and blockets).
8. Shelter size: This is described by the number of bed rooms in a home and labeled as 1 room, 2 rooms, 3 rooms, and more than 3 rooms.
9. Land title: This is how land is owned by households and classified as purchased land, informally held land, and inherited land.
10. Factors affecting the choice of stoves: These include lowering cost of energy, saving family labor and time, availability, durability/quality, affordability, simplicity to use, safe and clean, subsidized and easy to obtain credit facilities, and well-known stove. The stoves are labeled as open fire three-stone stoves, *Mirt* stoves, *Lakech* stoves, and electric stoves.

Table 27 presents the parametric estimates used to determine households' ICS choice and estimated p-values. Then, households' choice of ICS is measured by comparing each group of stove *(Mirt* stoves, *Lakech* stoves and electric stoves) against the reference category (the three-stone traditional stove) along a spectrum of variables. The reference category is used as a relative measure. Then, each group of stove is compared to the base category based on the relevant variables considered.

Valid households considered for this analysis are 423 (94%) and the chi-square test indicates the model with those factors considered significantly affect the choice of ICS with $\chi^2(54)=388.51$ and $p<0.0000$. Although a higher value of Pseudo R2 closer to one indicates the best fit of the model, the outcomes of this study are still valid.

The analysis indicated that keeping all other relevant variables in the model held constant, relative to the traditional three-stone stove, as households shelter condition improves by one unit (i.e., from poor to good or from good to very good condition), the number of households using *Mirt* stoves increases by 0.7678 units; as the stove operating cost increases by a unit, its demand decreases by 0.2942 units compared to prior periods; if its availability decreases in the market or when the level of shortage increases by a unit, its demand decreases by 0.3447 units; as the simplicity to use the stove increases by one level, households demand increases by 0.2853;.as households lack of awareness/recognition level increases by a unit, the demand for *mirt stoves* decreases by 0.3183 units.

The choice of *Lakech* stoves depends on shelter type and land title held by a household. Like *Mirt* stoves, under citreous paribus assumption, as the shelter condition owned by a household improves by one level, the number of *Lakech* users' increases by 1.1119 units relative to the three-stone traditional stove users. That is, households who lived in a relatively good shelter use more *Lakech* stoves than the open fire traditional three-stone stoves. However when informal settlers' land insecurity increases by one unit and if there is high possibility of eviction by a single letter, the number of *Lakech* users decreases by 0.4505 units while those using the traditional three-stone stoves increases.

The choice of electrical stoves is influenced by various factors. The data shows that household heads with higher levels of education, live in relatively better home (such as those who live in good and very good shelter) and stayed for longer periods in the area are found using more electrical stoves than the traditional three-stone stoves. For instance, holding all other relevant variables constant, as household heads education increase by one level, the number of electric stove users increase by 1.0173 units; as the length of time a household lived in the area increase by one year, electric stove users increase by 0.6742 units; and as the condition of shelter owned by residents improves by one stage, the demand for electrical stoves increases by 1.2905 units relative to the traditional three stone users.

Households also choose electrical stoves that lower the operating cost of energy (save family labor and time), long lasting, affordable, and simple to use. For example, under citreous paribus assumption and relative to the three stone stoves, as electrical stoves save operating cost and this saving increases by one unit, the demand for this stoves increases by 1.4825; as the quality of electrical stoves increases by one unit (become more durable), their demand increases by 0.7756; when the purchase price of these stoves increases by one unit, their demand decreases by 0.7326; as the simplicity to use electrical stoves improves by a unit, their demand increases by 0.8286.

TABLE 27: Factors Affecting the Choice of Energy Efficient Stoves: The Multinomial Logit Model

Number of obs		=		423
LR $chi^2(54)$		=		388.51
Prob > chi^2		=		0.0000
Pseudo R^2		=		0.3491

	Coef.	**Std. Err.**	**Z**	**P>/Z/**
3- stone stove	**(base outcome)**			
***Mirt* stove**				
Sex	0.0178	0.3567	0.05	0.090
Marital status	-0.0382	0.3196	-0.12	0.905
Education	0.2913	0.1786	1.63	0.105
Family income	-0.4817	0.4002	-1.20	0.229
Family size	-0.1061	0.2696	-0.39	0.694
Years lived	0.1674	0.1932	0.87	0.386
Shelter type	0.7682**	0.3508	**2.19**	0.029
Shelter size	0.2308	0.2215	1.04	0.297
Land title	0.0344	0.1944	0.18	0.859
Stove operating cost	-0.2942**	0.1548	**-1.90**	0.057
Save labor and time	-0.0721	0.1917	-0.38	0.707
Availability of stove	-0.3447***	0.1870	**-1.84**	0.065
Quality of stove	-0.2285	0.1664	-1.37	0.170
Cost of stove	-0.1489	0.2324	-0.64	0.522
Simple to use	0.2853***	0.1661	**1.72**	0.086
Clean and safe stove	-0.3426	0.2527	-1.36	0.175
Subsidized stove	-0.2064	0.1613	-1.28	0.201
Widely known stove	-0.3183**	0.1487	**-2.14**	0.032
_cons	2.1665	1.6167	1.34	0.180
***Lakech* stove**				
Sex	-0.3091	0.4240	-0.73	0.466
Marital status	-0.0348	0.3733	-0.09	0.926
Education	0.0455	0.2058	0.22	0.825
Family income	-0.6546	0.4644	-1.41	0.159
Family size	-0.1019	0.3128	-0.33	0.744
Years lived	0.0915	0.2164	0.42	0.672
Shelter type	1.1119*	0.4074	**2.73**	0.006
Shelter size	0.0951	0.2529	0.38	0.707
Land title	-0.4505***	0.2540	**-1.77**	0.076
Stove operating cost	0.0348	0.1823	0.19	0.848
Save labor and time	-0.1512	0.2312	-0.65	0.513
Availability of stove	0.0348	0.1933	0.18	0.857
Quality of stove	-0.0394	0.1964	-0.20	0.841
Cost of stove	0.1643	0.2418	0.68	0.497
Simple to use	0.0740	0.1894	0.39	0.697
Clean and safe stove	0.0242	0.3177	0.08	0.939
Subsidized stove	-0.1756	0.1828	-0.96	0.337
Widely known stove	0.0476	0.1787	0.27	0.790
_cons	-0.7658	1.8939	-0.40	0.686

Electric stove				
Sex	0.3383	0.4269	0.79	0.428
Marital status	0.5568	0.4766	1.19	0.234
Education	1.0173*	0.2694	**3.78**	0.000
Family income	0.2463	0.5561	-0.44	0.658
Family size	-0.2987	0.3284	-0.91	0.363
Years lived	0.6742*	0.2380	**2.83**	0.005
Shelter type	1.2905*	0.4482	**2.88**	0.004
Shelter size	0.3646	0.2768	1.32	0.188
Land title	0.2652	0.2401	1.10	0.269
Stove operating cost	1.4825*	0.2684	**5.52**	0.000
Save labor and time	0.7222	0.4486	1.61	0.107
Availability of stove	-0.2224	0.2045	-1.09	0.277
Quality of stove	0.7756*	0.2235	3.47	0.001
Cost of stove	-0.7326*	0.2940	**-2.49**	0.013
Simple to use	0.8286*	0.2988	**2.77**	0.006
Clean and safe stove	-0.3461	0.4797	-0.72	0.471
Subsidized stove	-0.3315	0.2000	-1.66	0.097
Widely known stove	0.2396	0.2054	1.17	0.243
_cons	-19.5514	3.2376	-6.04	0.000

, ** and * are statistically significant at p< 1%, p<5% and p<10% respectively*

Source: Data developed by the author, Feb., 2022

Similarly, household heads with higher levels of education and lived in relatively better home for longer periods in the area are found using more electrical stoves than the traditional three-stone stoves. The empirical data shows that, holding all other relevant variables constant, as household heads education increase by one level, the number of electric stove users increase by 1.0173; as the condition of shelter owned by residents improves by a unit, the demand for electrical stoves increases by 1.2905; and as the length of time a household lived in the area increase by one year, electric stove users increase by 0.6742 relative to the traditional three-stone users.

Households also choose electrical stoves that are quality /long lasting/, affordable, and simple to use. Such stoves are found lowering the operating cost of energy and save family labor and time. For example, under citreous paribus assumption, as the quality or durability of electrical stoves increases by one unit, the number of households using it increases by 0.7756. As the purchasing cost of the stove increases by one unit (i.e., if the price becomes more expensive), its demand decreases by 0.7326 units; and an increase in electric tariffs by one unit leads to an increase in electrical stove use by 1.4825 units relative to the use of traditional three stone stoves. The latter result could signify, in addition to other benefits of using electricity, electricity is more convenient to use, clean and the tariff is still lower than the cost of using biomass. However, these stoves are less affordable and less subsidized than the traditional three-stone stoves.

The findings from the descriptive analysis and the MLR model yielded similar results in many of the variables considered. In both cases, the factors affecting the choice of stove vary based on the type of stove considered. However, the descriptive analysis shows the positive contribution of shelter size to own ICS while this is not a significant factor in the logistic regression. This is because the descriptive analysis treated the factors affecting the choice of stoves independently while the MLR estimated the interactive effect of all variables on households' energy efficient stove choice.

5.4. Conclusions and Implications

Conclusions

ICS burn fuels cleanly, save time, cost, workloads of family members involved in cooking activities, and contribute to the sustainable utilization of scarce resources. The choice of these stoves and appliances, however, depend on households' socio-economic backgrounds and availability and affordability of alternative energy sources.

The findings of both MLR and descriptive statistics showed that sex, family size and family income have no relationship with the utilization of energy efficient stoves. However, education level of the household head, the number of years lived in the area, shelter type and size owned, energy price /operating cost/, availability, affordability and quality of the stove have significant influence on ICS use in informal settlements. These technologies help to meet ever-increasing energy needs of households and save expenditures for energy while protecting the environment.

At present, due to shortage of fuel wood and lack of access to reliable electric supply in Ethiopia, households using ICS are growing significantly in number (8% before ten years to 51% in the last five years).

Implications

Since the prices of ICS are roaring up, arranging loan facilities, flexible payment systems, subsidies and incentives to households are critical policy issues. On the other hand, such schemes should discourage the use of open fire traditional stoves and the consumption of high polluting energy sources through requiring payments in the form of taxes and penalties. Solar energy should also be utilized beyond lighting and charging batteries. Integrating households' socio economic backgrounds with their energy sources and promoting the utilization of energy efficient cooking stoves could be seen as major policy issue in informal settlements.

Future Research Directions

This study analyzed factors that determine the adoption of ICS in informal settlements from the perspectives of households using cross-sectional data. Future research, however, could focus on ICS suppliers' problems, government policies and energy consumption behaviors of households using panel data and optimize the needs of different stakeholders.

Chapter 6

Synthesis, Conclusion and the Ways Forward

6.1. Synthesis

Energy is vital for all human beings. It is used for various purposes ranging from domestic use to income generation. Nowadays, it is connected to everything. However, a number of factors affect households' energy choice and consumption behaviors among informal settlers.

This section brings together the four papers with the objective of analyzing domestic energy consumption by households in informal settlements in one of the pre-urban areas of Addis Ababa. The papers are presented thematically, discussed topical issues, and synthesized in a logical order in order to achieve the objectives set in the study. The study provided insightful findings that are vital to address economic, social and environmental challenges of households. However, it is was found quite difficult to show the similarity and differences between this study and the previous studies due to the absence prior studies on the same topic that considers similar variables (i.e. on informal settlements, access to electricity, challenges and copping strategies).

6.1.1. Determinants of Households' Energy Choice

The study showed numerous factors that affect households' energy choice in informal settlements. The five capitals developed in the conceptual framework (economic, finance, social, environmental and physical) streamlined our analysis. The study identified four groups of variables that determine households' energy choice: Demographic and household characteristics, energy source related factors, food consumption behaviors, and others such as size and condition of shelter owned. It revealed that socio-economic factors (such as age and education of the household head, family income, and type of employment) and availability and reliability of energy sources determine households' access to electricity. Specifically, traditional energy sources are relatively available, reliable, and lower in price than modern energy sources while electricity saves family labor, time, clean and convenient to use. While the need to bake *Injera* quickly and get variety of food staffs are associated with electricity, the desire to add the taste and flavor of food staffs, prepare cultural dishes, and roasting and boiling coffee are associated with traditional energy sources. Large number of households also uses alternative energy sources to backup emergencies and cushion sudden power interruptions. For this, electric-users are found consuming more biomass than non-users of electricity. Shelter type and condition, land size, and number of years a household lived in the area affect households' access to electricity while land title, suitability of the dwelling place to the urban plan, and proximity to electric facility have little or no influence on it.

6.1.2. The Impact of Access to Electricity on Households' Economic Status

After clearly identifying the principal variables affecting energy choice, this dissertation analyzed the impact of electric use on economic status of households in informal settlements using Endogenous Switching Regression (ESR) and Average Treatment Effects (ATE) models. The findings indicated that electric-use has no significant impact on households' frequency of cooking and number of meals taken per day. However, electric-users carried more business activities than non-users of electricity, earn greater family income per month, expended less for energy per month and used alternative fuels than that of non-users of electricity. On the other hand, non-users of electricity have shifted family labors to carryout domestic activities.

6.1.3. Challenges to Access Electricity and Informal settlers' Coping Strategies

A notable advance made in this study is assessing the various challenges that households faced in getting access to electricity and tracking dawn their coping strategies to the electric problem. Households in informal settlements earn low and unstable income, lack access to credit service, required to pay high connection fees and electric bills. Non-users of electricity associate lack of access to electricity to their illegal land occupancy and scattered settlement. The current electric-users also contend that the power supply is inadequate and unreliable.

These challenges forced 73% of electric-users use three-stone traditional stoves and use rechargeable batteries and candles for lighting purpose. Households' with large family sizes and those who lived shorter periods in the area become more willing to participate in cost sharing programs designed to improve the electric supply than those who have small family sizes and those who lived longer periods. They opt to use alternative energy sources, consume foods cooked easily and stay longer once cooked, reduce the number of meals and variety of food staffs consumed per day and the frequency of cooking, use food preserving methods, and consume foods that lack the required level of taste and flavor to cop up the electric challenge. Households considered adopting energy efficient cooking stoves and power saving light bulbs and turning off devices when not in use as critical measures.

6.1.4. Households' Adoption of Improved Cook Stoves

ICS burn fuels cleanly, save time, cost and reduce workloads of family members involved in cooking activities. This study assessed households' adoption level of ICS governed by the five capitals identified in the conceptual framework. It showed education level of the household head, the number of years they lived in the area, type of home owned, operating cost of stove, and durability or quality of stove have significant influence on ICS use whilst sex, marital status, and family size have no relationships with ICS use.

It also noted that, households' demand for ICS has increased overtime with scarcity of traditional energy sources and absence of adequate, reliability, affordable electricity. However, the prices of ICS are unaffordable for the informal settlers and the urban poor requiring the need to subsidize, arrange loans, installment payments and even provide them through donations.

6.2. Conclusions

The electric problem of informal settlers is much worse and deeper than the urban counterparts in Ethiopia. About 49% of this group of population does not have access to electricity at all and those who have already access to electricity are faced with inadequate power supply, frequent interruption and outages for long hours and even days. Besides all these, the problem is worsened due to households' illegal and scattered settlement, low in socio-economic background, and situated long distance from the electric facility.

The study shows energy choice in informal settlements is influenced by availability of reliable electric supply and households' food consumption behaviors. They prefer to use traditional energy sources (firewood and charcoal) to add the taste and flavor of food staffs. These sources of energy are relatively cheaper and more available than electricity and used with other sources of energy to get a variety of foods with the concept of multiple sourcing.

Using firewood and charcoal, however, create indoor air pollution and threatens the health of households. The price of these sources of energy is increasing over time associated with growing demand, increased energy consumption levels, and limited electric supply in the area. Households who had already access to electricity are also found using biomass and consume even higher amount of charcoal than non-users of electricity.

On the other hand, access to electricity improves households' socio-economic status, creates opportunities to own home-based business activities and generates more income from these activities. Lack of access to electricity forced households to shift family labor to domestic activities (cooking, baking and washing). All these show each source of energy has different purposes and all factors do not have equal importance in determining households' energy choice and consumption levels.

Households' adoption rate of ICS is expanding in informal settlements. These stoves save time, cost and reduce workloads of family members involved in cooking activities. They burn fuels cleanly and contribute to the sustainable utilization of scarce resources (firewood and charcoal). However, demographic characteristics and socio-economic backgrounds of households and the availability and affordability of alternative energy sources have significant effect on the adoption of these stoves and electrical appliances.

To sum up, households in informal settlements have numerous challenges: Low and unstable income, live in unauthorized areas as illegal settlers, lack access to adequate and reliable electric supply. There is shortage of electric meters, unaffordable connection fees, high and progressive electric bills, and absence of credit facilities. To cope up with these challenges, households used temporary and less power consuming electric services, shared electric meters with their neighbors and bought power from private dealers. They are willing to pay for improved electric supply if tariffs are revised on the basis of the source of energy, distance to the electric line, and hourly and daily differences in electric use.

6.3. The Ways Forward

From the empirical findings and discussion made so far, the following recommendations are expected to improve households' access to electricity in informal settlements.

1) The provision of electric service to informal settlers on the basis of the number of years a household lived in the area; shelter type, condition, and number of rooms owned; and the age and education level of the household head simply encourages them to continue on land grabbing, unplanned urban expansion and undesirable land use. Therefore, EEU shall provide electricity to households based on the suitability of the land held to the urban plan, proximity to electric facility, and the investment cost it requires. In line with this, the government should provide urban land to inhabitants; give attention to the housing sector; legalizing informal settlers based on the suitability of the land held to the urban plan; and take corrective measures before the expansion of squatter settlement. In lieu of this, it is quite necessary to segregate the criteria to legalize informal settlement and the provision of electricity to citizens. The inhabitants should also recognize the multifaceted nature creating access to electricity and play a key role in solving the problem.

2) Progressive electric tariffs set indiscriminately for all households and untargeted subsidies should be revised thoroughly. Residents indicated that the monthly electric bill is unaffordable and continuously rising. The tariff does not consider electric demand on hourly basis, geographical location of households, and the source of energy. The initial connection fee shall also consider the residents paying capacity, wealth and their willingness to share the cost in groups. To this end, subsidies should target the poor and marginalized sections of the society /informal settlers/. It must encourage households using electricity for primary functions, during off-peak hours (such as at night time and rainy seasons when power supply is relatively

abundant), and solar home system users. The EEU can shift electric load by setting variable electric tariffs, payment schemes and avoiding progressive tariff applied equally for all.

Since energy efficient cooking stoves are expensive to buy, arranging loan facilities, flexible payment systems and providing incentives to households using these stoves are also highly critical. Schemes such as setting high prices and requiring payments in the form of taxes and penalties on households using high polluting fuels and inefficient traditional stoves could discourage their consumption. In this regard, deploying solar energy beyond lighting and using energy saving electrical appliances for domestic use could be a major policy issue in informal settlements.

3) Most households including electric-users preferred to use firewood and charcoal for cooking cultural foods, roasting and boiling coffee, and drying and frying cereals. They believe that these sources of energy add the taste and flavor of food staffs. On the other hand, these sources of energy have health hazards and affect the environment. These situations engender the government and other stakeholders to enforce households to use clean energy sources and take aggressive awareness creation campaigns to change their food consumption habits. In fact, such actions shall be superseded by improving the electric supply, its reliability and affordability (lowering power interruption, fluctuation and sudden outages), and adoption of ICS. Other actors (such as the private sector, non-profit foundations, and households) can also much role in solving the energy problem of informal settlements and provide support in the outreach areas.

4) Per the urban land policy of Ethiopia, although inheritance is one of the legal means of transferring land to others, only 59% of households inherited land from their parents and relatives has access to electricity. Also 26% of households who lived more than 9 years in the area are still treated as non-users of electricity. This could be

due to administrative red tapes and indecisiveness in the local administration. Ignoring such kinds of households from access to basic services like electricity is purely injustice and unfair treatment of citizens.

5) In the short run, due to lack of access to electricity, non-users of electricity shall be encouraged to take energy conservation measures, share connection fees in groups, use electricity for primary functions and low power consuming activities. In the long run, however, the government should thoroughly understand citizens' challenges to get access to electricity and involve a broad range of private suppliers; avoid administrative red tapes; and indecisiveness at local level**.**

6.4. Contribution of the Study and Future Research Direction

Empirically, the study provides data that directs government policy to scale-up energy sources, encourage the use of ICS, design subsidies, and support informal settlers. Since availability, reliability and affordable of energy sources have transcending effect across a wide range of economic, social and environmental activities, this study is vital to improve the livelihoods of informal settlers ignored from urban services. It helps to execute the energy policy.

Methodologically, the study assessed a wide range of secondary sources and relied mainly on firsthand information. The analysis considered the key variables that determine households' access to electricity, the impact of energy use on households' economic performance and the adoption of ICS. It shows the complex relationship that exists between households' income levels, employment condition, land tenure, housing condition, physical location, number of years they lived in the area and access to electricity. It shows the *interactive effect* of various factors on energy choice and ICS using descriptive statistics and regression models. To this end, the findings present a notable advance in implementing energy policy and provide intervention mechanisms to policy makers.

Theoretically, this research adheres to the energy stacking or multiple energy sourcing approach associated with absence of one best and reliable energy source. It adds to the development of existing literatures and contributes to the scientific progress required in the area. Furthermore, all the findings of this study converge to the applicability of this theory in informal settlements.

Finally, the study sheds some light on the highly contentious issues among researchers and contributes in building a body of knowledge related to the complex realities of informal settlers' access to electricity; understand the impact access to electricity; adoption of ICS; and coping strategies to the energy crunch in informal settlements. It serves as a springboard for further studies that could focus on how to integrate households' socio-economic backgrounds, FCBs, the legal and regulatory environment in which the energy sector operates, and the availability and affordability of the energy source. It should also balance the problems of energy and ICS suppliers', development partners, creditors and government concerns; and systematize households coping strategies developed so far.

References

Abebe, D. B., & Koch, S. F. (2013). Clean fuel-saving technology adoption in urban Ethiopia. *Energy Economics*, 605-613 (36).

Adebayo, T. S., Agboola, M. O., Rjoub, H., Adeshola, I., Agyekum, E. B., & Kumar, N. M. (2021). Linking Economic Growth, Urbanization, and Environmental Degradation in China: What Is the Role of Hydroelectricity Consumption? *Int. J. Environ. Res. and Public Health, 18*(6975), 2-14.

Adom, D., Hussein, E. K., & Agyem, J. A. (2018). Theoritical and Conceptual Framework: Mandatory Ingedients of A Quality Research. *International Journal of Scientific Research, 7*(1), 438-441.

Agizew, A. W. (2017). Determinants of Household Energy Consumption in Urban Areas of Ethiopia. Cape Town, South Africa: IUSSP International Population Conference.

Akintoye, A. (2015). Developing Theoretical and Conceptual Frameworks. Jedm.oauife.edu.ng>uploads.

Alahdad, Z. (2014). *A Case for More Integrated and Coordinated Planning and Policymaking.* Wilson Center, Asia Program.

Alem, Y., Beyene, B., Köhlin, G., & Mekonnen, M. (2013). Household Fuel Choice in Urban Ethiopia: A Random Effects Multinomial Logit Analysis. Environment for Development.

Alemu, M., & Köhlin, G. (2008). Enviroment for Development: Determinants of Household Fuel Choice in Major Cities in Ethiopia, Working Papers in Economics No 399. Sweden: University of Gothenburg.

Alemu, M., & Köhlin, G. (2009). Determinants of Household Fuel Choice in Major Cities in Ethiopia, Working Papers in Economics. Sweden: University of Gothenburg.

Ali, A. M., & Megento, T. L. (2017). The energy-poverty Nexus: Vulnerability of the urban and peri-urban households to energy poverty in Arba-Minch town, Southern Ethiopia. *AUC Geographica*, 116-127.

Amoah, l. T. (2019). Determinants of household's choice of cooking energy in a global south city. *Energy and Buildings, 196*, 103-111.

Ampower. (2019). Top 7 New Energy Saving Technology For Your Home. Retrieved Oct. 10, 2020

Antonakis, J., Bendahan, S., Jacquart., P., & Lalive, R. (2014). Causality and endogeneity: Problems and solutions. In D. Day (Ed.), *The Oxford Handbook of Leadership and Organizations* (pp. 93-117). New York: Oxford University Press.

Arlet, J., Ereshchenko, V., & Rocha, S. L. (2019). Barriers to urban electrification in Sub-Saharan Africa from the perspective of end-users. World Bank Group.

Ateba, B. B., Prinsloo, J. J., & Fourie, E. (2018). The impact of energy fuel choice determinants on sustainable energy consumption of selected South African households. *Journal of Energy in South Africa, 29*(3), 51-65.

Ayele, B. (2019). Urban Informal Dwellers Access to Urban Land for Housing and Regularization of Informal Settlements: The case of Nifas Silk-Lafto Sub-city.

Ayele, S. T., & Demel, T. (2018). Supply and Consumption of Household Energy in Central Ethiopia: The Case of Debre Berhan Town. *Journal of Fundamentals of Renewable Energy and Applications, 8(5)*, 1-11.

Baiyegunh, L., & Hassan, M. (2014). Rural household fuel energy transition: evidence from Giwa LGA Kaduna State, Nigeria. *Energy Sustain. Dev., 20*, 30-35.

Barja, G., & Urquiola, M. (2001). Capitalization, Regulation, and the Poor: Access to Basic Services in Bolivia. UNU/WIDER.

Barnes, D. F., Golumbeanu, R., & Diaw, I. (2016). *Beyond Electricity Access: Output-Based Aid and Rural Electrification in Ethiopia.* Washington, DC: World Bank.

Bauer, M., Gaskell, G., & Allum, N. (2000). Quality, Quantity and Knowledge Interest: Avoiding Confusions. In M. &. Bauer (Ed.), *Qualitative Researching with Text, Image and Sound: A Practical Handbook* (pp. 3-17). London & Thousand Oaks: Sage.

Bayera, P., Kennedy, R., Yang, J., & Urpelainen, J. (2020). The need for impact evaluation in electricity access research. *Energy Policy, 137*.

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., . . . Yumkella, K. (2011). Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy, 39*(789).

Bekere, Y. B., & Megerssa, G. R. (2020). Role of biogas technology adoption in forest conservations: evidence from Ethiopia. *7*(2).

Belay, Z., & Aberham, B. (2015). Biofuel Energy for Mitigation of Climate Change in Ethiopia. *Journal of Energy and Natural Resources, 4*(6), 62-72.

Beyene, G. (2018). The Challenges and Prospects of Electricity Access in Ethiopia, masters thesis. Addis Ababa, Ethiopia.

Bhattacharjee, S., & Reichard, G. (2011). Socio-Economic Factors Affecting Individual Household Energy Consumption: A Systematic Review, Proceedings of the ASME 2011 5th International Conference on Energy Sustainability. Washington: https://www.researchgate.net/publication/267646836.

Bisu, D. Y., Kuhe, A., & Iortyer, H. A. (2016). Urban household cooking energy choice: an example of Bauchi metropolis, Nigeria. *Energy, Sustainability and Society, 6*(15).

Blair, N., Pons, D., & Krumdieck, S. (2019). Electrification in Remote Communities: Assessing the Value of Electricity Using a Community Action Research Approach in Kabakaburi, Guyana. *Sustainability*, 1-31.

Boke, M. T., Moges, S. A., & Dejen, Z. A. (2022). Optimizing renewable-based energy supply options for power generation in Ethiopia .

Bosena, A. (2019). Urban Informal Dwellers Access to Urban Land for Housing and Regularization of Informal Settlements: The case of Nifas Silk-Lafto Sub-city. *https://www.researchgate.net/publication/330846664*.

Bouzarovsk, S., & Herrero, S. T. (2017). The energy divide: Integrating energy transitions, regional inequalities and poverty trends in the European Union. *European Urban and Regional Studies, 24*(1), 69–86.

Butera, F. M., Caputo, P., Adhikaria, R. S., & Facchini, A. (2016). Analysis of Energy Consumption and Energy Efficiency in Informal Settlements of Developing Countries, The challenge of Energy in Informal Settlements. A review of the Literature for Latin America and Africa. *Procedia Engineering, 161*, 2093–2099.

Butera, F. M., Caputoa, P., Adhikaria, R. S., & Mele, R. (2019). Energy access in informal settlements. Results of a wide on site survey in Rio De Janeiro. *Energy policy, 134(110943)*.

Cai, W., Grant, H., & Pandey, M. (2018). Vintage Capital, Technology Adoption and Electricity Demand-Side Management. *The Energy Journal*, 39(2).

Carnaghan, I. (2018). Creswell, J. W., 2012, Qualitative inquiry and research design: Choosing among five approaches, In: Philosophical Assumptions for Qualitative Research. Thousand Oaks, CA: Sage.

CCA. (2022, April 30). *https://cleancooking.org/*. Retrieved from Clean Cooking Alliance (CCA).

Chagunda, M. F., Kamunda, C., Mlatho, J., Mikeka, C., & Palamuleni, L. (2017). Performance assessment of an improved cook stove (Esperanza) in a typical domestic setting: implications for energy saving. *7*(19).

Chance, T. (2009). Towards Sustainable Residential Communities; The Beddington Zero Energy Development (BedZED) and Beyound. *Journal of Environment and Urbanization, 21*(2), 527-544.

Chen, B. (2016). Energy, ecology and environment: a nexus perspective. *Joint Center on Global Change and Earth System Science of the University of Maryland and Beijing Normal University, 1*, 1–2.

Chowdhury, P. K., Weaver, J. E., Weber, E. M., Lunga, D., LeDoux, S. T., Rose, A. N., & Bhaduri, B. L. (2019). Electricity consumption patterns within cities: application of a data-driven settlement characterization method. *International Journal of Digital Earth*, 119-135.

Clancy, J. (2006). Urban poor livelihoods: Understanding the role of energy services. The Netherlands.

Corburn, J., & Karanja, I. (2014). Informal settlements and a relational view of health in Nairobi, Kenya: sanitation, gender and dignity. *Health Promotion International, 31*, 258-269.

Coyle, E. D., Grimson, W., Basu, B., & Murphy, M. (2014). Reflections on Energy, Greenhouse Gases,and Carbonaceous Fuels. In R. A. Eugene D. Coyle (Ed.), *Understanding the Global Energy Crisis* (pp. 11-26). Indiana: Purdue University Press.

Creswell, J. (2012). *Qualitative inquiry and research design: choosing among five approaches.* C.A: Thousand Oaks, Sage.

Dadzie, J., Runeson, G., Ding, G., & Bondinuba, F. K. (2018). Barriers to Adoption of Sustainable Technologies for Energy-Efficient Building Upgrade Semi-Structured Interviews. *Buildings, Vol. 8(57)*, 1-15.

Damte, A., Koch, S., & Alamu, M. (2011). Coping With Fuel Wood Scarcity: Household Responses in Rural Ethiopia: 2011-25. Addis Ababa: University of Pretoria.

Danlami, A. H., Islam, R., & Applanaidu, S. D. (2015). An Analysis of the Determinants of Households' Energy Choice: A Search for Conceptual Framework. *International Journal of Energy Economics and Policy, 5*(1), 197-205.

Dawit, D. (2014). Bio-Based Energy, Rural Livelihoods and Energy Security in Ethiopia. Universität Bonn.

Dehejia, R. H., & Wahba, S. (2002). Propensity Score-Matching Methods for Nonexperimental Causal Studies. *The Review of Economics and Statistics, 84*(1), 151–161.

Denzin, N., & Lincoln, Y. (1994). Introduction: Entering the field of qualitative research. In N. Denzin, & Y. Lincoln (Eds.), *Handbook of Qualitative Research* (pp. 1-17). CA: Thousand Oaks.

Dlamini, K. T. (2015). Coping mechanisms of low-income urban households to escalating energy costs in South Africa, University of Witwatersrand. Johannesburg.

Domnikov, A., Khomenko, P., Chebotareva, G., & Khodorovsky, M. (2017). Risk and Profitability Optimization of Investments in the Oil and Gas Industry. *Energy Production and Management, 2*(3), 263-276.

Ed, H. (2018). Theoretical orientation of qualitative research: Demystifing higher education. Demystifing higher education.

EEP. (2016). Ethiopia - Energy. Addis Ababa: Ethiopia Electric Power.

EIA. (2019). *https://www.eia.gov/energyexplained/use-of-energy/efficiency-and-conservation.php.*

Ekouevi, K., Freeman, K. K., & Soni, R. (2014). *Livewire; Understanding the Differences Between Cookstoves.*

energypedia. (2019). *Ethiopia Energy Situation.*

ESCAP. (2019). Electricity Access for Social Change. Bankok, Asia Pacific: Economic and Social Commission for Ascia and Pacific (ESCAP), UN.

Fantu, G., Abebe, D., & Tadele, F. (2015). The Residential Demand for Electricity in Ethiopia. Addis Ababa: Ethiopian Development Research Institute (EDRI/AAU).

FAO. (2015). *FAO and the 17 Sustainable Development Goals.* Food and Agricultural Organization of the United Nations.

FDRE. (2011, Septmber). Ethiopia's Climate-Resilient Green Economy Strategy. Addis Ababa.

Feldmann, L., & Otremba, D. (2015). *Efficient cookstoves & cooking energy for a healthier living.* Frakfurt, Germany: Internationale Zusammenarbeit (GIZ).

Figueroa, A. R. (2016). Efficient lighting uptake among the urban poor: evidence from a Kenyan informal settlement. *Environment & Urbanization, 28*(2), 535–552.

Flores, W. C., Benjamin, B., Pino, H. N., Al-Sumaiti, A., & Rivera, S. (2020). A National Strategy Proposal for Improved Cooking Stove Adoption in Honduras: Energy Consumption and Cost-Benefit Analysis. *Energies; doi:10.3390/en13040921, 13*(921), 1-18.

Gaunt, T., Salida, M., Macfarlane, R., Maboda, S., Reddy, Y., & Borchers, M. (2012). Informal Electrification in South Africa: Experience, Opportunities and Challenges. *Sustainable Energy Africa*.

Gebreegziabher, Z., Mekonnen, A., Kassie, M., & Köhlin, G. (2012). Urban energy transition and technology adoption: the case of Tigrai, northern Ethiopia. *Energy Econ., 34*(2), 410–418.

Geddafa, T., Melka, Y., & Sime, G. (2021). Determinants of Biogas Technology Adoption in Rural Households of Aleta Wondo District, Sidama Zone, Southern Ethiopia.

Getachew, B., Abera, K., Edwards, R., & Troncoso, K. (2018). *Opportunities for transition to clean household energy in Ethiopia: Application of the WHO Household Energy Assessment Rapid Tool (HEART).* Geneva: WHO.

Getachew, M. M. (2016). Biogas Technology Adoption and Its Contributions to Rural Livelihood and Environment in Northern Ethiopia, the Case of Ofla and Mecha Woredas. Addis Ababa.

Getie, E. M. (2020). Poverty of Energy and Its Impact on Living Standards in Ethiopia. *Journal of Electrical and Computer Engineering, https://doi.org/10.1155/2020/7502583* .

Grant, C., & Osanloo, A. (2014). Understanding, Selecting, and Integrating a Theoretical Framework in Dissert ation Research: Connecting Education, Practice and Research. *Administrative Issues Journal*, 12-22.

Greene, J., Caracelli, V., & Graham, W. (1989). Toward the conceptual framework of mixed-method evaluation designs. *Educational Evaluation and Policy Analysis, 11*, 255–274.

Grueneich, D. M. (2015). The Next Level of Energy Efficiency: The Five Challenges Ahead. *The Electricity Journal, 28*(7), 44-56.

Guta, D. D. (2020). Determinants of household use of energy-efficient and renewable energy technologies in rural Ethiopia. *Technology in Society, 61*, 1-8.

Gyamf, B. A., Bein, M. A., & Bekun, F. V. (2020). Investigating the nexus between hydroelectricity energy, renewable energy, nonrenewable energy consumption on output: evidence from E7 countries . *Environmental Science and Pollution Research, 27*, 25327–25339.

Hafner, M., Tagliapietra, S., & Strasser, L. d. (2018). The Challenge of Energy Access in Africa. *Energy in Africa*, 1-21.

Hailu, A. D., & Kumsa, D. K. (2020). Ethiopia renewable energy potentials and current state. *9*(1).

Hailu, D. M. (2010). Ethiopian Energy Systems- Potentials, Opportunities and Sustainable Utilization. Swden: Uppsala University.

Hanania, J., Stenhouse, K., & Donev, J. (2018). Access to electricity. https://energyeducation.ca/wiki/index.php?

Heltberg, R. (2004). Fuel Switching: Evidence from Eight Developing Countries. *Energy Economics, 26*, 869-887.

Hernández, D. (2016). Understanding 'energy insecurity' and why it matters to health. *doi: 10.1016/j.socscimed.2016.08.029, 167*, 1-10.

Herring, H., & Roy, R. (2007). Technological innovation, energy efficient design and the rebound effect. *Technovation, 27*(4), 194-203.

Howell, J. (2011). *Environmental Policy Review: Rural Electrification & Renewable Energy in Ethiopia.* Maine: Environmental Policy Group.

IEA. (2012). *World Energy Outlook 2012.* Paris, France: OECD/International Energy Agency.

IEA. (2014). Ethiopia Energy Situation. Addis Ababa.

Ifegbesana, A. P., Rampedia, I. T., & Annegarn, H. J. (2016). Nigerian households' cooking energy use, determinants of choice, and some implications for human health and environmental sustainability. *Habitat International, https://doi.org/10.1016/j.habitatint.2016.02.001, 55*, 17-24.

Jalalimajidi, M., Seyedhosseini, S., Makui, A., & Babakhani, M. (2018). Developing a comprehensive model for new energy replacement in the country's development program using a robust optimization approach. *Energy & Environment, 29*(6), 868–890.

Jarrett, M. B. (2017). *Lights out: poor governance and Africa's energy crisis.* Lagos, Nigeria: The African Report.

JICA. (2011). Energy Policy of Ethiopia. Tokyo International Center: Japan International Coperation Agency.

Jones, P. (2017). Formalizing the Informal: Understanding the Position of Informal Settlements and Slums in Sustainable Urbanization Policies and Strategies in Bandung, Indonesia. *Sustainability, 9*, 1-27.

Kammen, D. M. (2011). *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem.* World Bank.

Kanyamuka, J. S. (2017). Adoption of Integrated Soil Fertility Management Technologies and its effect on Maize Productivity: A Case of the Legume Bets Bets Project in Mkanakhoti Extension Planning Area of Kasungu District in

Central Malawi, Thesis in Agri. & applied economics. Lilongwe University of Agriculture and Natural Resources.

Karatasou, S., Laskari, M., & Santamouris, M. (2014). Models of behavior change and residential energy use: a review of research directions and findings for behavior-based energy efficiency. *Advances in Building Energy Research, 8*(2), 137–147.

Kothari, C. (2004). *Research Methodology: Methods and Techniques* (Second revised edition ed.). New Delhi, India: New Age International (p) Ltd., Publishers.

Kovacic, Z., Smit, S., Musango, J. K., Brent, A. C., & Giampietro, M. (2016). Probing uncertainty levels of electrification in informal urban settlements: A case from South Africa. *Habitat International, 56*, 212-221.

Kuhn, P., Huber, M., Dorfner, J., & Hamacher, T. (2016). Challenges and opportunities of power systems from smart homes to super-grids. *doi: 10.1007/s13280-015-0733-x, 45*(1), 50–62.

Laicane, I., Blumberga, D., Blumberga, A., & Rosa, M. (2015). Reducing household electricity consumption through demand side management: the role of home appliance scheduling and peak load reduction. *International Scientific Conference "Environmental and Climate Technologies – CONECT 2014"* (pp. 222-230). Riga Technical University: Institute of Energy Systems and Environment.

Lane, F. C., To, Y. M., Shelley, K., & Henson, R. K. (2012). An Illustrative Example of Propensity Score Matching with Education Research. *Career and Technical Education Research, 37*(3), 187-212.

Latham, J. (2017). Research-methods-framework: Conceptual Framework. http://johnlatham.me/frameworks/.

Lawana, N., & Booysen, F. (2018). Decomposing socioeconomic inequalities in alcohol use by men living in South African urban informal settlements. *BMC Public Health, 18*(993), 1-9.

Lay, J., Ondraczek, J., & Stoever, J. (2013). Renewables in the energy transition: evidence on solar home systems and lighting fuel choice in Kenya. *Energy Econ. , 40*, 350–359.

Lemaire, X. (2015). *Informal settlements: to electrify or not?* Cape Town: UrbanAfrica.Net.

Lewis, O. (2000). A Study of Sum Culture: Backgrounds for La Vada (1968). In J. R. Hite (Ed.), *From Modernization to Globalization: Perspectives on Development and Social Change* (pp. 110-118). Blackwell Publishers Inc.

Li, C., Wang, N., Zhang, H., Liu, Q., Chai, Y., Shen, X., . . . Yang, Y. (2019). Environmental Impact Evaluation of Distributed Renewable Energy System Based on Life Cycle Assessment and Fuzzy Rough Sets. *Energies, Switzerland, 12*(21).

Li, K., Zu, J., Musah, M., Mensah, I. A., Kong, Y., Owusu-Akomeah, M., . . . Agyemang, J. K. (2021). The link between urbanization, energy consumption, foreign direct investments and CO2 emanations: An empirical evidence from the emerging seven (E7) countries. *Energy Exploration & Exploitatio, 0*(0), 1-24.

Lia, J., & Just, R. E. (2018). Modeling household energy consumption and adoption of energy efficient technology. *Energy Economics*, 404-415.

Lisahunter, Emerald, E., & Martin, G. (2013). Where Do You Stand: Philosophical Orientations. Participatory Activist Research in the Globalised World. *Explorations of Educational Purpose, 26*(Springer), 45-58.

Lloyd, P. (2014). Challenges in household energisation and the poor. *Journal of Energy in Southern Africa*, 25(2), Cape Town, South Africa.

Lloyd, P. (2017). The role of energy in development. *Journal of Energy in Southern Africa, 28*(1).

Lowe, L., & Schilderman, L. (2001). The Impact of policies, institutions and processes in urban upgrading; Paper presented at the International Workshop on Regulatory Guidelines for Urban Upgrading, May 17-18, 2001. Bourton-on-Dunsmore.

Luhar, H. (2014). Causes for the creation and expansion of slum Sai Om. *Journal of Commerce & Management, 1*(10), 56-58.

Majale, M. (2002). Towards Pro-poor Regulatory Guidlines for Urban upgrading, A Review of Papers presented at the International Workshop held at Bourton-On-Dunsmore, May 17-18, 2001. United Kingdom: Intermediate Technology Development Group .

Makonese, T., Ifegbesan, A. P., & Rampedi, I. T. (2018). Household cooking fuel use patterns and determinants across southern Africa: Evidence from the demographic and health survey data. *Energy & Environment, 29*(1), 29-48.

Medina, A., Cámara, Á., & Monrobel, J.-R. (2016). Measuring the Socioeconomic and Environmental Effects of Energy Efficiency Investments for a More Sustainable Spanish Economy. *Sustainability, 8*(1039), 1-21.

Melchorjr, A. (1981). *The three facts of the energy crisis.* Asian Development Bank.

Mele, R. (2014). *The Challenge of Energy in Informal Settlements: Sustainable Energy for All Forum.* Enel Foundation energy for knowledge.

Mfundis, K. B., & Commeh, M. K. (2019). Clean Cookstove Technology Use for Energy Efficiency in the School System. *Journal of Natural resources and development, DOI 10.5027/jnrd.v9i0.04, 9*, 34-41.

Middlemiss, L., & Gillard, R. (2015). Fuel poverty from the bottom-up: Characterising household energy vulnerability through the lived experience of the fuel poor. *Energy Research & Social Science, 6*, 146-154.

Millsa, B., & Schleich, J. (2012). Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: An analysis of European countries. *Energy Policy, https://doi.org/10.1016/j.enpol.2012.07.008, Volume 49*, 616-628.

Mobarak, A., Dwivedi, P., Bailis, R., Hildemann, L., & Miller, G. (2012). Low demand for nontraditional cookstove technologies. *Proc. Natl. Acad. Sci., 109*, 10815–10820.

Mondal, M. A., Bryan, E., Ringle, C., Mekonnen, r., & Rosegrant, M. (2018). Ethiopian energy status and demand scenarios: Prospects to improve energy efficiency and mitigate GHG emissions. *Energies, 149*, 161-172.

MoWIE. (2015). *Energy balance & statistics report for year 2002/6-2013/14.* Addis Ababa, Ethiopia: Ministry of Water, Irregation and Electricity.

Msimang, Z. (2017). A study of the negative impacts of informal settlement on the environment : a case study of Jika Joe, Pietermaritzburg. *https://researchspace.ukzn.ac.za/handle/10413/16293*.

Muller, C., & Yanb, H. (2018). Household fuel use in developing countries: Review of theory and evidence. *Energy Economics, 70*, 429–439.

Mustefa, A., & Lika, T. (2016). The Energy-Gender Nexus: A Case Study among Urban and Peri-urban Female Headed Households in Arba-Minch Town, Southern Ethiopia. *EJOSSAH, Vol. XII (1)*, 1-38.

MWIE. (2017). *The Ethiopian Power Sector: The Renewable Future.* Berlin: Ministry of Water, Irrigation and Electricity (MWIE), Federal Democratic of Ethiopia.

Nepal, M., Nepal, A., & Grimsrude, K. (2010). Unbelievable but improved cookstoves are not helpful in reducing firewood demand in Nepal. *Environ. Dev. Econ. , 16*, 1–23.

Nibretu, K., Degefa, T., & Tamirat, T. (2021). Determinants of Energy Choice for Domestic Use in Informal Settlements of Addis Ababa. *Journal of Science & Sustainable Development, ISSN: 2070-1748 Vol. 8; https://dx.doi.org/10.4314/jssd.v8i1.3*, 33 - 44.

Njoroge, P., Ambole, A., Githira, D., & Outa, G. (2020). Steering Energy Transitions through Landscape Governance: Case of Mathare Informal Settlement, Nairobi, Kenya. *Land, 9*(206), 1-19.

Ohadugha, C. B., Sanusi, Y., Morenikeji, O., & Zubairu, M. (2016). Analysis of households domestic cooking energy poverty coping strategies in Minna, Niger state.

Olaniyi, O. (2017). *Research: Tackling the energy crisis in Nigeria – a case for solar.* Legos: Nanyoung Technological University.

Oliveira, D. (2017). Joburg pilots scheme to improve energy access in informal settlements. Johannesburg: Creamer Media.

Olugbire, O., F.J., A., O.H., O., C.A., O., O.O, O., & A., A. (2016). Determinants of Household Cooking Energy Choice In Oyo State, Nigeria. *DOI http://dx.doi.org/10.18551/rjoas.2016-04.04, 4*(52), 28-36.

Onyekachi, A. F. (2014). Prospects and Challenges of Informal Settlements and Urban Upgrading in Abuja. *International Journal of Innovation and Scientific Research, 11*(2), 420-426.

Ouedraogo, N. S. (2017). Africa energy future: Alternative scenarios and their implications for sustainable development strategies. *Energy Policy, http://dx.doi.org/10.1016/j.enpol.2017.03.021, 106*, 457-471.

Padam, G., Rysankova, D., Portale, E., Koo, B. B., Keller, S., & Fleurantin, G. (2018). *Ethiopia-Beyound Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework.* Washington DC: World Bank Group.

Parka, C., Xingb, R., Hanaokab, T., Kanamorib, Y., & Masuib, T. (2017). Impact of Energy Efficient Technologies on Residential CO2 Emissions: A Comparison of Korea and China. *Energy Procedia, 111*, 689 – 698.

Pearce, D., & Ozdemiroglu, E. (2002). *Economic Valuation with Stated Preference Techniques: Summary Guide.* London: Department for Transport, Local Government and the Regions.

Perera, N., Boyd, E., Wilkins, G., & Itty, R. P. (2015). *Literature Review on Energy Access and Adaptation to Climate Change.* UK: Department for International Development (DFID).

Pickering, E. M., Hossain, M. A., Mousseau, J. P., Swanson, R. A., French, R. H., & Abramson, A. R. (2017). A cross-sectional study of the temporal evolution of electricity consumption of six commercial buildings. *12*(10, https://doi.org/10.1371/journal.pone.0187129).

PIERG. (2017). *The Climate Change and Energy Debate in Ethiopia, Pegasys Institute and Ethio Resources Group (PIERG).* Brussels: Cities Aliance.

Power Africa. (2016). Ethiopia's Energy Sector Overview. www.usaid.gov.

Powers, D. (2007). Censored Regression, Sample Selection, Endogenous Switching, and Treatment-Effect Regression Models. Soc385K.

Powers, D. A. (1993). Endogenous Switching Regression Models with Limited dependent Variables. *Sociological Methods & Research, Sage Publications, Inc., 22*(2), 248-273.

Prasad, B. G. (2010). Energy Efficiency, Sources and Sustainability. *Journal of Energy Resources Technology, 132*(2).

Pueyo, A., & Hanna, R. (2015). *What level of electricity access is required to enable and sustain poverty reduction?* UK.

Rahuta, D. B., Alib, A., Mottaleba, K. A., & Aryal, J. P. (2019). Wealth, education and cooking-fuel choices among rural households in Pakistan. *Energy Strategy Reviews, https://doi.org/10.1016/j.esr.2019.03.005, 24*, 236-243.

Raitzer, D. A., Blönda, N., & Sibal, J. (2019). *Impact Evaluation of Energy Interventions: A review of the evidence.* Manila, Philippines: Asian Development Bank.

Ravitch, S. M., & Carl, N. M. (2016). Qualitative Research: Bridging the Conceptual, Theoretical and Methodological. Los Angeles, U.S.A: SAGE Publications, Inc.

REEEP Secretariat. (2012). *Renewable Energy and Energy Efficiency Partnership (REEEP).* Vienna: Clean Energy Information Portal.

Regoniel, P. A. (2015). *Conceptual Framework: A Step by Step Guide on how to make one.* https://simplyeducate.me/2015/01/05/conceptual-framework-guide/.

Reyna, J. L., & Chester, M. V. (2017). Energy efficiency to reduce residential electricity and natural gas use under climate change. *Nature Communications, 8*(14916).

Rosenbaum, P. R., & Rubin, D. B. (1983). The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika, 70*(1), 41-55.

Rouhier, S. (2010). Environmental Impacts of Rising Energy Use in China: Solutions for a Sustainable Development. Paris: International Association for Energy Economics.

Sanaeepur, S., Sanaeepur, H., Kargari, A., & Habibi, M. H. (2014). Renewable energies: climate-change mitigation and international climate policy. *International Journal of Sustainable Energy, 33*(1), 203–212.

Shellenberger, M., & Nordhaus, T. (2014). The Problem With Energy Efficiency. New York: The New York Times.

Sheng, P., He, Y., & Guo, X. (2017). The impact of urbanization on energy consumption and efficiency. *Energy & Environment, 28*(7), 673–686.

Shove, E. (2018). What is wrong with energy efficiency? *Building Research & Information, 46(7)*.

Smith, J. (1983). Quantitative versus qualitative research: An attempt to clarify the issue. *Educational Research, 12*, 6-13.

Sohagab, K., Beguma, R. A., Abdullaha, S. M., & MokhtarJaafar. (2015). Dynamics of energy use, technological innovation, economic growth and trade openness in Malaysia. *Energy, 90(2)*, 1497-1507.

Soltani, M., Rahmani, O., Pour, A. B., Ghaderpour, Y., Ngah, I., & Misnan, S. H. (2019). Determinants of Variation in Household Energy Choice and Consumption: Case from Mahabad City, Iran. *Sustainability, 11*(4775), 1-20.

Sovacool, B. K. (2014). *Environmental Issues, Climate Changes and Energy Security in Developing Asia.* Manila, Philippines: ADB Economics Working Paper Series, No. 399.

Staffa, S. J., & Zurakowski, D. (2018). Five Steps to Successfully Implement and Evaluate Propensity Score Matching in Clinical Research Studies. *Anesthesia & Analgesia (Special Article), www.anesthesia-analgesia.org, XXX*(XXX).

Stern, D. I., Burke, P. J., & Bruns, S. B. (2016). The Impact of Electricity on Economic Development: A Macroeconomic Perspective. *Energy and Economic Growth: Applied Research Programme*, 1-44.

Subbiah, A., Mansoor, S., Misra, R., Jaffer, H., & Tiwary, R. (2016). Addressing Developmental Needs Through Energy Access in Informal Settlements, Decentralized Electrification and Development. *Open Edition Journals*(15), 80-91.

Sverdlik, A. (2011). Ill-health and poverty: a literature review on health in informal settlements. *Environ Urban, 23*(1), 123–155.

Tashakkori, A., & Teddlie, C. (1998). *Mixed Methodology: Combining Qualitative and Quantitative Approaches.* Thousand Oaks & London: Sage.

Thavaneswaran, A., & Lix, L. (2008). *Propensity Score Matching in Observational Studies.* University of Mqnitoba: Manitoba Centre for Health Policy.

Thoemmes, F. (2012). Propensity score matching in SPSS. *Cornell University, NY*.

Tiruye, G. A., Besha, A. T., Mekonnen, Y. S., & Benti, N. E. (2021). Opportunities and Challenges of Renewable Energy Production in Ethiopia. *13*(10381).

Todaro, D., & Smith, S. (2012). *Economic Development, 11th ed.* New York: Addison Wesley.

Tolossa, D. (2005). Rural livelihoods, poverty and food insecurity in Ethiopia: A case study at Erenssa and Garbi communities in Oromiya Zone, Amhara National Regional State, PhD Thesis. Trondheim: Norwegian University of Science and Technology, NTNU.

Torero, M. (2015). The Impact of Rural Electrification: Challenges and Ways Forward. *Revue d'économie du développement, 23*, 49-75.

Triannia, A., Cagnob, E., & ErnstWorrellc. (2013). Innovation and adoption of energy efficient technologies: An exploratory analysis of Italian primary metal manufacturing SMEs. *Energy Policy, 61*, 430-440.

UNDESA. (2014). *Electricity and education: The benefits, barriers, and recommendations for achieving the electrification of primary and secondary schools, Energy and Education.*

UNDP. (2015). *Sustainable Development Goals (SDGs).* The United Nations Development Programme (UNDP).

UNEF. (2017). *Solar Solutions: Bridging the Energy Gap for Off-Grid Settlements.* South Africa: UN Environment Frontiers (UNEF).

UNESCAP. (2019). Electricity Access for Social Change, Open meeting. Bangkok, Asia Pascific: UN Economic and Social Commision for Asia and Pascific.

UN-Habitat. (2008). *State of the African cities.*

UN-Habitat. (2014). *Global Urban Observatory, statistics.* United Nations Human Settlements Programme.

Vasilachis de Gialdino, I. (2011). Ontological and Epistemological Foundations of Qualitative Research. *Forum for Qualitative Social Research, 10(2)*.

Wassie, Y. T., & Adaramola, M. S. (2021). Socio-economic and environmental impacts of rural electrification with Solar Photovoltaic systems: Evidence from southern Ethiopia. *Energy for Sustainable Development, 60*, 52–66.

WB. (2014). *Access to electricity (% of population), https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.* World Bank.

WB. (2015). *Beyond connections: Energy Access Redefined.* Washington D.C: World Bank.

WB. (2020). *Energy Situation, Ethiopia Group.* Addis Ababa: energypedia.info.

WEF. (2014). *The Future Avaliability of Natural Resources: A New Paradigm for Global Resource Avaliability.* Geneva: World Economic Forum.

Weldegebriel, D. A. (2011). Informal Settlement in Ethiopia, the Case of two Kebeles in Bahir Dar City. *Peer reviewed paper* (pp. 1-27). Marrakech, Morocco: FIG Working Week 2011.

Winchester, H. (2000). Qualitative research and its place in human geography. In I. H. ed, *Qualitative Research Methods in Human Geography* (pp. 1-22). Oxford: Oxford University Press.

Wohlfarth, K., Eichhammer, W., Schlomann, B., & Worrell, E. (2018). Tailoring cross-sectional energy-efficiency measures to target groups in industry. *Journal of Energy Efficiency, 11*(5), 1265–1279.

World Bank & IEA. (2017). *Global Tracking Framework—Progress towards Sustainable Energy.* Washington DC, USA: International Bank for Reconstruction and Development.

World Bank. (2000). *Energy Services for the World's Poor.* Washington DC.

World Bank. (2018). Ethiopia Energy Situation, International Conference Oct. 17–19. https://energypedia.info/index.php?Ethiopia_Energy_Situation&oldid=264032".

World Population Review. (2021). *https://worldpopulationreview.com, Ethiopian Population 2021.*

World Vision. (2013). Fuel-efficient Cook Stoves: A triple win for child health, development and environment.

World Vision. (2016). *Easing Women's life: The energy effecient cook stove.* Addis Ababa.

Woubishet, D. (2008). Fuel efficient technology adoption in Ethiopi:A Case in selected Kebeles from "Adea" Wereda. *XVII*(2).

Yang, J., & Chen, B. (2016). Energy-water nexus of wind power generation systems. *Appl Energy, 169*, 1-13.

Yonas, A., Abebe, B., Köhlin, G., & Alemu, M. (2016). Modeling household cooking fuel choice: A panel multinomial logit approach. *Energy Economics, 59*, 129–137.

Young, J. D., Anderson, N. M., & Naughton, H. T. (2018). Influence of Policy, Air Quality, and Local Attitudes toward Renewable Energy on the Adoption of Woody Biomass Heating Systems. *Energies, 11*, 1-24.

Yu, L., Yaoqiu, K., Ningsheng, H., Zhifeng, W., & Lianzhong, X. (2008). Popularizing household-scale biogas digesters for rural sustainable energy development and greenhouse gas mitigation. *Renewable Energy, 33*, 2027-2035.

Zarnikau, J., Zhu, S., Russell, R., Holloway, M., & Dittmer, M. (2015). How Will Tomorrow's Residential Energy Consumers Respond to Price Signals? Insights from a Texas Pricing Experiment. *The Electricity Journal, https://doi.org/10.1016/j.tej.2015.07.004, 28*(7), 57-71.

Zenebe, G., Abebe, D. B., Bluffstonec, R., Martinssond, P., Alemu, M., & Toman, M. A. (2018). Fuel savings, cooking time and user satisfaction withimproved biomass cookstoves: Evidence from controlledcooking tests in Ethiopia. Resource and Energy Economic. *Resource and Energy Economics , 52*, 173–185.

Zeng, Y., Dong, P., Shi, Y., & Li, Y. (2018). On the Disruptive Innovation Strategy of Renewable Energy Technology Diffusion: An Agent-Based Model. *Energies, MDPI, doi:10.3390/en11113217, 11*(Switzerland), 1-21.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The Positive Influences of Renewable Energy Consumption on Financial Development and Economic Growth. *SAGE open*, 1-10.

Annexes

Annex 1: Questionnaire for Electric-Users

Ref. No.: ________________

Dear respondent,

The aim of this questionnaire is to gather data on *"Households Domestic Energy Consumption in Informal Settlements in Woreda 12, Yeka Sub City, Addis Ababa."* The data will be exclusively used for academic purpose. It may also contribute in reviewing existing energy policy and serve as a tool to execute them. Therefore, you are randomly selected participant for this interview and we kindly requested you to provide us honest and reliable information. Also you need to note that your identity is not required and the answers will be kept confidential. Thank you very much in advance for your assistance.

Part I: General Information

Specific site: ____________________ Date of interview: _______________

Enumerator's name: ____________________ Enumerator's sig.: _______________

1. Information about Household Head. *Please put a tick mark (√) in the appropriate box.*

▪ Sex	Male ☐	Female ☐		
▪ Age	≤30 ☐	31-45 ☐	46-60 ☐	Above 60 ☐
▪ Marital status	Single ☐	Marred ☐	Separated ☐	
▪ Family status of the respondent	Father/mother ☐		Son/daughter ☐	
▪ who provided the information	Brother/sister ☐		Others, specify	___________
▪ Education level	Below Grade 4 ☐	4-8 ☐	9-Diploma ☐	Above diploma ☐
▪ Employment/occupational status	Hired ☐	Self-employed ☐	Retired ☐	Unemployed ☐
▪ **If you are hired,** what is the type of employment?	Hourly ☐	Daily ☐	Contract ☐	Permanent ☐
▪ Based on last year, how many months were you engaged?	Upto 3 ☐	4-6 ☐	7-9 ☐	10-12 ☐
▪ Average monthly income (*birr*)	Below 3,000 ☐	3,001-6,000 ☐	6,001-9,000 ☐	Above 9,000 ☐

2. Family Information. *Please put a tick mark (√) in the appropriate box.*

▪ Estimated total monthly income of all family members (*birr*)	Below 3,000 ☐	3,001-6,000 ☐	6,001-9,000 ☐	Above 9,000 ☐
▪ Specify the number of families under each age group (years)	Below 14	______	31-60	______
	15-30	______	Above 60	______
▪ Among family members, how many of them are dependents?	No ☐	1-2 ☐	3-4 ☐	Above 4 ☐
▪ How long have you been living in this home/area?	up to 3 ☐	3-6 years ☐	6-9years ☐	More than 9 ☐

3. How do you describe the condition and materials from which your home is made from?

Poor (wood and mud) ☐ Good (mixed- mud and cement) ☐

Very good (steel and blocket) ☐

4. How many dwellings (bed rooms) your home has?

One ☐ Two ☐ Three ☐ More than three ☐

5. What is the size of the land you held? _______________M^2

6. How you held the land? Purchased from other people ☐ Informally held ☐ Inherited ☐ Other, specify________________________________

7. What is the *main reason* for not getting ownership certificate and a plan document for the land you held? Please put a tick mark **(√)** for your reason.

- Failure to supply urban land that goes with high population growth ☐
- Housing policies that favor only formal residents ☐
- Inability of the government to supply housing for the low income ☐
- groups /less attention given to the housing sector/ ☐
- Others, specify (if any) ____

8. Please put a tick mark ***(√)*** that describes your residence area.

Living area condition	**Yes**	**No**
a. Accessible to roads and transportation		
b. Accessible to education (school) and health services		
c. Live around critical slopes		
d. Live around river banks and low-laying areas (vulnerable to floods)		
e. Live around forests		

II: Determinants of Energy Choice

1. How long your house had been connected to electric line? ________Years ______Months

2. How much you paid for the connection fee? _______________*birr*

3. Do you face frequent power interruption/fluctuation?
Yes, always ☐ Yes, sometimes ☐ No ☐

4. What is the *primary use of electric power* under your current land holding status, economic situation and power scarcity? Please put a tick mark ***(√)*** for your choice.
Lighting and recharging cell phones and light bulbs ☐ Radio and Television ☐
Cooking and baking ☐ Refrigerator and others, specify (if any) ____________

5. What is your main back-up source during electric outages/blackouts for the uses listed below? Put a tick mark ***(√)*** for your choice.

Energy Use	**Fuel wood and charcoal**	**Kerosene**	**Rechargeable battery and candle**	**No back up source**
Baking				
Cooking				
Lighting				

6. How many times the supplier revised/increased electric tariffs since the last ten years or you first received the service, whichever is longer?
Once ☐ twice ☐ more than two ☐ not changed to date ☐ I don't know ☐

7. Based on last 12 months, which source your household used for uses/reasons listed below?

1=Fuel wood, animal dung and charcoal *2=Kerosene and cylinder gas /LPG/*
3=Electric power including solar energy

I. Uses of energy source	**The best energy source**
a. Baking	
b. Cooking	
c. Heating and boiling	
d. Lighting/illumination	
II. Determinants for using the energy source	
a. Widely available in abundant quantities and secured	
b. The most expensive energy source and price is becoming prohibitive to use	
c. Relatively cheaper /affordable/	
d. A source to be used if all sources were widely available	
e. Availability of energy saving technologies/appliances	
f. Has lower cost of appliances	
g. Saves family labor and time	
h. Clean, safe and healthy to use	

8. Do you think the following constraints influence your choice of energy? Place a tick mark ***(√)*** on the appropriate column.

	Yes	**No**
a. Socio-cultural pressures influence energy choice and consumption behaviors		
b. Individuals' feelings, lifestyles and knowledge levels influence energy consumption patterns and conservation measures		
c. The dwelling space is not suitable and contradict with the urban plan		

9. Compared to the price of electricity, how does the price of traditional energy sources (firewood and charcoal) changed over time?
No change ☐ Slightly increased ☐ Significantly increased ☐

10. Based on Q9, what do you think is the ***main reason*** for the increase in price of traditional sources more than that of electricity? Describe your opinion by placing a tick mark ***(√)***.
Scarcity of biomass ☐ Population pressure ☐ Increased consumption level ☐
Suppliers' failure to provide electricity ☐
Others, specify (if any) _______________

11. How do you rate the *availability and reliability* of energy for ***cooking and baking*** in your locality?

1=More accessible (6-7 days/week) *3=Available 1-2 days/week*
2=Limited supply (3-5 days/week) *4=Not available at all*

Source of energy	**Fuel wood**	**Charcoal**	**Kerosene**	**Electric power**
Availability/week				

12. From your stay in this area, how do you explain the electric supply?

- Adequate in supply and no need to improve ☐
- Moderate and needs some improvement ☐
- Poor and needs substantial improvement ☐

13. What is your opinion about the current electric bill or service charge?

- Cheap: Subsidized by the government ☐
- Expected to cover its cost ☐
- Expensive: Price set based on market principles ☐

14. The choice of energy is measured by the frequency of use. How many times do you use each source of energy for ***cooking and baking***?

1=Once   2=twice   3=3 times   4=More than 3   5= I do not use it at all

Energy source	**Fuel wood**	**Charcoal**	**Kerosene**	**Electric power**
Cooking per day				
Baking per week				

15. How much you paid for energy source listed below based on average consumption level of the last ***three months (Dec. - Feb.)?*** Please evaluate their price by putting a tick mark ***(√)*** for each source?

Energy source	**Expenditure per month (*birr*)**	**Evaluation of price levels**		
		Cheap	**Fair**	**Expensive**
a. Fuel wood				
b. Charcoal				
c. Kerosene				
d. Electric power				

16. Is the quality of electric service (consistency) the same throughout the year?
Yes ☐   No ☐

17. By taking the two extreme periods (cold and dry) from last year, in which period electric supply became very limited/scarce and power rationing reached the peak (worst season)?
June-Aug. (Summer) ☐   Dec.-Feb. (Winter) ☐
Others, specify___________

18. Which energy source do you use more during *cold and hot season*? Provide your choice from the list given below and specify the amount of energy consumed per month in *birr* for the selected energy source by taking the average of the prior seasons' expenditure.

1=Fuel wood   2=Charcoal   3=Kerosene   4=Electric power

Season	**More used energy**	**Energy consumed per month (*birr*)**
Cold		
Hot		

19. When do you use energy sources for **cooking and baking** regularly? Use the levels given below.

1 = Morning   2 = Afternoon   3 = Night time
4 =Any time, not clearly known   5 = I do not use it at all

Energy source	Fuel wood	Charcoal	Kerosene
Time			

Part III. Impact of Energy on Households' Economic Status

1. Specify the energy source that gives the most benefit in your life from the list given below.

1= Firewood and charcoal *2= Kerosene and cylinder gas /LPG/*
3= Electric power *4= The mix of the two* *5= No difference*

Use of energy source	The best energy source
a. Helps to improve family income	
b. Often consumed more by the family	
c. Lowers the total monthly energy expenditure of the family	
d. Used by low income households	
Consumed by high income households	
e. Minimize indoor air pollution, reduce headache and burning of eyes	
Expose more to indoor air pollution/gas emissions	
f. Increase literacy rate of family members	
g. Reduce workloads on family members	
h. Energy source that improves food consumption habits	
▪ To get a variety of foods (nutrition)	
▪ Frequently cook and get fresh foods	
▪ Add flavor/taste to food staffs	
▪ To have enough foods /sufficient meals/ per day	
▪ Drying and boiling coffee	
▪ Drying and frying cereals and sweet corn	
▪ Chicken and *Shero Wot* (Ethiopian cultural dishes)	
▪ Baking *Injera* and bread	

2. Is there labor that is shifted to household activities due to energy problem that would otherwise be hired elsewhere in income generating activities? Yes ☐ No ☐

3. In cooking, baking and washing activities, which family member has more workloads? Put a tick mark ***(√)*** Women including servants ☐ Men ☐ Children (mainly girls) ☐

4. **a.** In any typical day in a week, how much time is spent in **cooking** using electricity?
Less than 1:30 ☐ 1:30-3:00 ☐ More than 3:00 ☐ I don't know ☐

b. In any typical day in a week, how much time is spent in **baking** using electricity?
Less than 1:30 ☐ 1:30-3:00 ☐ More than 3:00 ☐ I don't know ☐

c. On average, how many times/days do your household bake per week?
Once ☐ Twice ☐ Three times ☐ More than three ☐ I do not know ☐

5. Do you have any sideline (home-based) business?
Yes ☐ No ☐ If your answer is **'yes',** answer the following

a. What is this business activity (such as baking *Injera* and bread, boiling coffee, making potato chips and drying cereals, weaving, retail trade, selling fruits and juice, renting a house, selling charcoal, etc.)? ___________________________________

b. What is the *main source of energy* for this activity? Put a tick mark ***(√).***
Fuel wood ☐ Charcoal ☐ Kerosene ☐ Cylinder gas /LPG/☐ Electric power ☐

c. Based on the last month's data, what is the estimated revenue generated from this business activity? ____________*birr*.

6. What is the household's main source of drinking water and sanitation? Specify your source by placing a thick mark ***(√)***. Tap water ☐ Hand-pumped boreholes ☐
Others such as rain water, river water, Bono Woha, etc. (specify) ____________________

7. Which source of energy has the most effect on quantity and quality of water consumed by your family? Place a tick mark **(√)**.
Fuel wood ☐ Charcoal ☐ Kerosene ☐ Electric power ☐

Part IV: The Adoption of Improved Cook Stoves

1. Which energy saving technology (stove) your household mainly uses now?
3-stone traditional stove and butagas ☐ *Mirt* stove ☐ *Lakech* stove ☐
Electric stove ☐ A mix of two or more (specify if any) ___________________________
2. If you currently owned any one of energy saving stoves listed above, how long you used it? (If you owned more than one, take the former stove). __________ Years
3. Which ***stove is best*** for the benefits and **reasons listed below? Put a tick mark (√) for your choice.**

Uses/reasons of owning a stove	3-stone	Mirt	Laketch	Electric
a. Lowers energy price (operational cost)				
b. Saves labor and time				
c. Widely available				
d. More durable/quality				
e. Cheap stove				
f. Expensive stove				
g. Convenient/simple to use				
h. Safe and clean to use				
i. Highly subsidized and easy to obtain credit				
j. Well-known stove				

Note: *The order of stoves in terms of technology: 1) 3-stone traditional stove, 2) Improved biomass stove /Mirt/,3) Improved charcoal stove /Lakech/, 4) Cylinder gas /LPG/ 5) Electric stove.*

4. How you owned or expect to own energy saving stove in the future? Please put a tick mark **(√)** for your decision.
   - Directly purchased on cash ☐ Obtained loan facilities ☐
   - Got it through subsidy and price discounts ☐ Receive gift or support ☐
   - Paid price at time-of-use on installment bases ☐
   - Others (if any, specify) ____
5. Which one drives you to use energy efficient cooking stoves and transit to renewable energy sources? Place a tick mark **(√)** for your most pressing reason.
   - Lowers operational cost /expenditures/ per month ☐
   - Using new technologies save labor, time and reduces workloads ☐
   - Efficiently convert biomass to energy and reduce waste ☐
   - To protect forests and sustainably utilize scarce resources ☐
6. What ***major problem*** did you encountered while using energy efficient stoves?
   - Very expensive to obtain ☐ Maintenance problem (not available) ☐
   - Short service period ☐ No problem ☐
   - Cannot power large appliances Others, specify (if any) ___________________
7. Do you use solar energy/panels? Yes ☐ No ☐
8. If yes for Q7, for what purpose do you use it?
Lighting ☐ Cooking ☐ Heating ☐ Others, specify ____________________
9. How do you evaluate electric consumption /demand/ over time?
Decreased considerably ☐ The same as before ☐ Increased significantly ☐

10. Why you prefer to use electric stoves? Provide your main reason by placing a tick mark **(√).**

- Availability of electric power and access to it ☐
- Recognizing the benefits of using electricity ☐
- Shortage of fuel wood and its high price ☐
- Increase in income and fulfillment of electric appliances ☐

11. How frequently do you use electric oven?
Always ☐ Sometimes ☐ I do not use it at all ☐

12. Do you have a 3 stone traditional stove now? Yes ☐ No ☐

13. If your answer for Q14 is **yes**, when do you use it?
Any time when a need arises ☐
In the absence/shortage of power supply ☐
Since the price of electricity has increased ☐

14. Do you expect that your shelter type and age affects the use of energy efficient stoves?
Yes ☐ No ☐

15. If your answer is **yes** for Q14, which type of home is convenient to use the preferred stove?
Wood and mud ☐ Mud and cement ☐ Steel and blocket ☐

16. In your opinion, what factor intensifies the depletion of forest resources? Provide your main reason by placing a tick mark ***(√)***.

- Continued reliance on traditional sources ☐
- Increased amount of energy consumption ☐
- Users' social and behavioral problems ☐
- Electric supply problems ☐
- Technological constraints ☐

17. Among the following list, which measure do you think solves the energy problems of households in informal settlements and protect the local environment? Provide your first choice by putting a tick mark ***(√).***

- Subsidize electric prices and provide new and less polluting appliances at fair price to encourage fuel switching strategies ☐
- Remove subsidies on energy sources like kerosene that pollute the environment making the prices more expensive ☐
- Provide alternative energy sources (diversification) ☐
- Make producers and users pay for externalities /pollution effects/ they create in the form of taxes, carbon emission fees and fines ☐
- Provide incentives including credit facilities to secured energy suppliers and efficient users ☐
- Switch from conventional energy sources and consumption habits ☐
- Others, specify (if any) ______________________________

Part V: Households' Challenges to Access Electricity and Coping Strategies

1. What do you think is the ***main challenge*** for households in getting electric service and suppliers' refusal/*reluctance* to provide the required electric service? Put a tick mark ***(√)***.

- Informal settlers' low and irregular income ☐
- Squatter settlement and lack of trust on households ☐
- High electric price /financially less viable source/ ☐
- Suppliers' limited energy supply capacity ☐
- Suppliers' lack of response and mismanagement ☐
- Far from electric lines and scattered settlement ☐
- Households' increased demand patterns ☐
- Households' low level of electric consumption ☐

2. If your first energy choice/requirement is fulfilled, how many meals do you take per day?
Once ☐ Twice ☐ Three times ☐ Four times ☐ No relation ☐

3. Using the following labels, answer the questions below.

1=Firewood and charcoal 2=Kerosene 3=Cylinder gas 4=Electric power

- ______ Energy source that must be subsidized
- ______ Energy source from which subsidy must be totally removed
- ______ Energy source that must be substituted/ by others
- ______ Energy source that best replaces others
- ______ Energy sources you want to *integrate/mix* (choose any two)

4. What is your main reason for ***substituting*** existing energy source (s)? Place a tick mark ***(√).***

- Scarcity and unreliability ☐ Requires a lot of labor and time ☐
- More expensive ☐ Not safe and not clean to use ☐

5. What is your primary reason for ***using alternative energy sources at the same time?*** Please put a tick mark for your answer **(√)**.

- To get secured and reliable energy ☐
- Save labor and time ☐
- Affordability/cheaper energy sources ☐
- Availability of low cost appliances ☐
- Each source is needed for different uses ☐

6. For the energy problem, which one is the most widely practiced *behavior* of your household? Indicate your response measures to the energy problem by placing a tick mark ***(√).***

I. Food consumption habits/actions	**Yes**	**No**
a. Minimize variety of foods consumed (nutrition level)		
b. Reduce the frequency/rate of cooking		
c. Reduce the taste and flavor (level of freshness) of foods		
d. Consume foods that stay long		
e. Reduce the amount and number of meals per day		
II. Energy conservation measures		
a. Use energy efficient electrical and biomass stoves		
b. Use power saving light bulbs and florescent lights		
c. Switch-off light bulbs and stoves when not using		
d. Reducing or not using peak time energy demand		
e. Shift energy consumption habits to other sources		

7. Which adaptive measure do you personally take to the electric problem? Choose the household's ***best coping*** mechanism by placing a tick mark ***(√).***

☐ Shift to cheaper energy sources
☐ Reduce the overall energy consumption level
☐ Use energy efficient expensive technologies
☐ Use low cost appliances
☐ Reduce non-energy expenses (use personal assets for energy)
☐ In addition to other household activities, let women and children cook food

If someone such as the government, NGO or private investor wants to improve the current electric supply (accessibility/availability, timing and reliability of energy service), making additional investment through cost sharing /users' participation/ is often seen as the best strategy. This concept also applies to households who want to purchase improved cook stoves.

8. Therefore, compared with your current monthly pay, do you accept to pay more?
Yes ☐ No ☐

9. ***If yes,*** start from the lowest and increase the bill for 50% of the respondents until they say No **OR** start from the *highest and reduce the bill for the other 50%* until they say Yes I am WTP the required amount. Up to 33% ☐ 33-66% ☐ 66-100% ☐ Above 100% ☐

10. If ***not WTP*** for all proposed improvements, what is your main reason for this decision?

- I cannot afford the payment/no income ☐
- Monthly fee is too expensive ☐
- Electricity service is not reliable ☐
- It is government's responsibility to finance energy ☐
- Existing supply is enough and no need to improve ☐

11. Are you WTP if the electric rate varies based on the following explanatory variables? Place a tick mark ***(√)*** on the appropriate column for each item**.**

Factors to be considered	**Yes**	**No**
▪ Source of energy generated		
▪ Area/location differences among residents		
▪ Seasonal differences in a year		
▪ Time of electric use in a day		
▪ Households ability to pay (income/wealth level)		

12. Which payment method/vehicle do you prefer to pay your electric bills?

- Providing collateral and making payments after the service ☐
- Making advance payment using prepaid electric cards ☐

13. Which billing system encourages you to pay on time for the energy service? Please choose the main reason by placing a tick mark ***(√)*** among the list given below.

- Paying according to household income and wealth level Decreasing rate ☐
- Progressive tariff (volume pricing) ☐ Flat metering /constant rate/ ☐

14. When do you think billing according to household income and wealth becomes feasible?
When there is energy shortage ☐
When adequate and reliable power exists ☐
Any time ☐

15. Compared to the previous month, if your income increases by 100%, how much do you allocate to energy sources? Place a tick mark ***(√).***

Energy source	**Decrease by more than 25%**	**Never change**	**Increase by 25-100%**	**Increase by more than 100%**
a. Fuel wood				
b. Charcoal				
c. Kerosene				
d. Cylinder gas/LPG				
e. Electric power				

16. Households have different perceptions and suggest various methods to solve their energy problem. Describe your level of agreement on energy sources that you might use and policy measures that stakeholders could take to this problem using a five level scale by placing ***a tick mark (√)*** on the appropriate column.

Strongly agree (1 ***Agree (2)*** ***Indifferent (3)*** ***Disagree (4)*** ***Strongly disagree (5)***

	1	2	3	4	5
I. Household's opinions on energy sources					
a. Electricity benefits residents through economic, social and business development.					
b. Electricity helps households with domestic tasks (cooking, washing and caring children).					
c. Todaylity of life is better than it was few years ago.					
d. Electricity has made my family free from smoke.					
e. My family is highly satisfied with the current electric service.					
f. The monthly electric bill is a financial burden for my family.					
g. Firewood and charcoal are becoming hard to obtain in the market.					
h. Certain food tastes are better when cooked with biomass than electricity.					
II. Stakeholders policy options					
a. Legalize land titles of informal dwellers to provide electric meters					
b. Subsidize, set affordable and tailored electric tariffs					
c. Set higher electric prices to push households use efficient technologies					
d. Provide credit facilities to support households use energy efficient devices					
e. Provide utility-scale rooftop solar panels (PVs) in groups at low cost/freely					
f. Lower thermostat settings, servicing and repair appliances					
g. Reduce peak electric demand using energy storages during slack periods					
h. Manage energy demand through load limiting (smart metering)					
i. Involve a broad range of private suppliers /market-based approach/					

17. If electric is supplied by *private suppliers*, what do you expect its accessibility, price and service?
Increases/improves ☐ Remains the same as it is now ☐ Decreases/worsens ☐

******Thank you for your cooperation******

Annex 2: Questionnaire for Non-Users of Electricity

Ref. No.: _______________

Dear respondent,

The aim of this questionnaire is to gather data on *"Households Domestic Energy Consumption in Informal Settlements of Woreda 12, Yeka Sub City, Addis Ababa."* The data will be exclusively used for academic purpose. It may also contribute in reviewing existing energy policy and serve as a tool to execute them. Therefore, you are randomly selected participant for this interview and we kindly requested you to provide us honest and reliable information. Also you need to note that your identity is not required and the answers will be kept confidential. Thank you very much in advance for your assistance.

Part I: General Information

Specific site: ____________________ Date of interview: ______________

Enumerator's name: ____________________ Enumerator's sig.: ______________

1. Information about Household Head. *Please put a tick mark* **(√)** *in the appropriate box.*

▪ Sex	Male ☐	Female ☐		
▪ Age	≤30 ☐	31-45 ☐	46-60 ☐	Above 60 ☐
▪ Marital status	Single ☐	Marred ☐	Separated ☐	
▪ Family status of the respondent	Father/mother ☐		Son/daughter ☐	
▪ who provided the information	Brother/sister ☐		Others, specify	___________
▪ Education level	Below Grade 4 ☐	4-8 ☐	9-Diploma ☐	Above diploma ☐
▪ Employment/occupational status	Hired ☐	Self-employed ☐	Retired ☐	Unemployed ☐
▪ *If you are hired,* what is the type of employment?	Hourly ☐	Daily ☐	Contract ☐	Permanent ☐
▪ Based on last year, how many months were you engaged?	Upto 3 ☐	4-6 ☐	7-9 ☐	10-12 ☐
▪ Average monthly income (*birr*)	Below 3,000 ☐	3,001-6,000 ☐	6,001-9,000 ☐	Above 9,000 ☐

2. Family Information. *Please put a tick mark* **(√)** *in the appropriate box.*

▪ Estimated total monthly income of all family members (*birr*)	Below 3,000 ☐	3,001-6,000 ☐	6,001-9,000 ☐	Above 9,000 ☐
▪ Specify the number of families under each age group (years)	Below 14 ______ 15-30 ______		31-60 ______ Above 60 ______	
▪ Among family members, how many of them are dependents?	No ☐	1-2 ☐	3-4 ☐	Above 4 ☐
▪ How long have you been living in this home/area?	up to 3 ☐	3-6 years ☐	6-9years ☐	More than 9 ☐

3. How do you describe the condition and materials from which your home is made from?
Poor (wood and mud) ☐ Good (mixed- mud and cement) ☐
Very good (steel and blocket) ☐

4. How many dwellings (bed rooms) your home has?
One ☐ Two ☐ Three ☐ More than three ☐

5. What is the size of the land you held? _______________M^2

6. How you held the land? Purchased from other people ☐ Informally held ☐

Inherited ☐ Others (if any, specify) ____________________________

7. What is the *main reason* for not getting ownership certificate and a plan for the land you held? Please put a tick mark ***(√)*** for the reason.

- Failure to supply urban land that goes with high population growth ☐
- Housing policies that favor only formal residents ☐
- Inability of the government to supply housing for the low income ☐
- Less attention given to the housing sector ☐
- Others (if any, specify) ______________________________________

8. Please put a tick mark ***(√)*** that describes your residence area.

Living area condition	**Yes**	**No**
a. Accessible to roads and transportation		
b. Accessible to education (school) and health services		
c. Live around critical slopes		
d. Live around river banks and low-laying areas (vulnerable to floods)		
e. Live around forests		

Part II: Determinants of Energy Choice

1. How far is your home from the **nearest transformer**? _______ Kilo meters OR
To closest electric **pole** that is currently connected to your neighbor? _____Meters

2. Compared to the residents currently receiving electric service, your living area is far from the closest electric pole, transmission line or a transformer. Do you agree?Yes ☐ No ☐

3. Does your household use energy from your neighborhood for ***lighting only*** by sharing the electric meter /electric counter/? Yes ☐ No ☐

4. Based on last 12 months, which source your household used for uses/reasons listed below?

1=Fuel wood, animal dung and charcoal *2=Kerosene and cylinder gas /LPG/*
3=Electric power including solar energy

I. Uses of energy source	**The best energy source**
a. Baking	
b. Cooking	
c. Heating and boiling	
d. Lighting/illumination	
II. Determinants for using the energy source	
a. Widely available in abundant quantities and secured	
b. The most expensive energy source and price is becoming prohibitive to use	
c. Relatively cheaper /affordable/	
d. A source to be used if all sources were widely available	
e. Availability of energy saving technologies/appliances	
f. Has lower cost of appliances	
g. Saves family labor and time	
h. Clean, safe and healthy to use	

5. Do you think the following constraints influence your choice of energy? Place **a tick mark *(√)*** on the appropriate column.

	Yes	No
a. Socio-cultural pressures influence energy choice and consumption behaviors.		
b. Individuals' feelings, lifestyles and knowledge levels influence energy consumption patterns and conservation measures.		
c. The dwelling space is not suitable and contradicts with the urban plan.		

6. Compared to price of electricity, how does the price of traditional energy sources (animal dung, firewood and charcoal) change over time?
No change ☐ Slightly increased ☐ Significantly increased ☐

7. Based on Q6, what do you think is the ***main reason*** for the increase in price of traditional sources more than electricity? Describe your opinion by placing a tick mark ***(√)***.
Scarcity of biomass ☐ Population pressure ☐ Increased consumption level ☐
Suppliers' failure to provide electricity ☐ Others, specify ___________________

8. How do you rate the *availability and reliability* of energy for ***cooking and baking*** in your locality?
1=More accessible (6-7 days/week) *3=Available 1-2 days/week*
2=Limited supply (3-5 days/week) *4=Not available at all*

Source of energy	**Fuel wood**	**Charcoal**	**Kerosene**	**Cylinder gas /LPG/**	**Electricity**
Availability/week					

9. What is your opinion about the current electric bill or service charge?
- Cheap: Subsidized by the government ☐
- Expected to cover its cost ☐
- Expensive: Price is set based on market principle ☐

10. The choice of energy is measured by the frequency of use. How many times do you use each source of energy for ***cooking and baking***?

1=Once 2=twice 3=3 times 4=More than 3 5= I do not use it at all

Energy source	**Fuel wood**	**Charcoal**	**Kerosene**
Cooking per day			
Baking per week			

11. How much you paid for energy source listed below based on average consumption level of the last ***three months (Dec. - Feb.)?*** Please evaluate their price by putting a tick mark***(√)*** for each source?

Energy source	**Expenditure per month (*birr*)**	**Evaluation of price levels**		
		Cheap	**Fair**	**Expensive**
a. Fuel wood				
b. Charcoal				
c. Kerosene				
d. Electric power (only for lighting)				

12. Which energy source do you use more during *cold and hot season*? Provide your choice from the list given below and specify the amount of energy consumed per month in *birr* for the selected energy source by taking the average of the prior seasons' expenditure.

1=Fuel wood *2=Charcoal* *3=Kerosene* *4=Electric power*

Season	More used energy source	Energy consumed per month (*birr*)
Cold		
Hot		

12. When do you use energy sources regularly for **cooking and baking**? Use the levels given below.

1 = Morning *2 = Afternoon* *3 = Night time*
4 = Any time /not clearly known / *5 = I do not use it at all*

Energy source	Fuel wood	Charcoal	Kerosene
Time			

Part III. Impact of Energy on Households' Economic Status

1. Specify the energy source that gives the most benefit in your life from the list given below.

1= Firewood and charcoal *2= Kerosene and cylinder gas /LPG/*
3= Electric power *4= The mix of the two* *5= No difference*

Use of energy source	The best energy source
a. Helps to improve family income	
b. Often consumed more by the family	
c. Lowers the total monthly energy expenditure of the family	
d. Used by low income households	
Consumed by high income households	
e. Minimize indoor air pollution, reduce headache and burning of eyes	
Expose more to indoor air pollution/gas emissions	
f. Increase literacy rate of family members	
g. Reduce workloads on family members	
h. Energy source that improves food consumption habits	
▪ To get a variety of foods (nutrition)	
▪ Frequently cook and get fresh foods	
▪ Add flavor/taste to food staffs	
▪ To have enough foods /sufficient meals/ per day	
▪ Drying and boiling coffee	
▪ Drying and frying cereals and sweet corn	
▪ Chicken and *Shero Wot* (Ethiopian cultural dishes)	
▪ Baking *Injera* and bread	

2. Is there labor that is shifted to household activities due to energy problem that would otherwise be hired elsewhere in income generating activities? Yes ☐ No ☐

3. In cooking, baking and washing activities, which family member has more workloads? Put a tick mark ***(√).***Women including servants ☐ Men ☐ Children (mainly girls) ☐

4. **a.** In any typical day in a week, how much time is spent in **cooking** using biomass?
Less than 1:30 ☐ 1:30-3:00 ☐ More than 3:00 ☐ I don't know ☐
b. In any typical day in the week, how much time is spent in **baking** using firewood?
Less than 1:30 ☐ 1:30-3:00 ☐ More than 3:00 ☐ I don't know ☐
d. On average, how many times/days do your household bake per week?
Once ☐ Twice ☐ Three times ☐ More than three ☐ I do not know ☐

5. Do you have any sideline (home-based) business?
Yes ☐ No ☐ If your answer is **'yes'**, answer the following
d. What is this business activity (such as baking *Injera* and bread, boiling coffee, making potato chips and drying cereals, weaving, retail trade, selling fruits and juice, renting a house, selling charcoal, etc.)? ___________________________________
e. What is the ***main source of energy*** for this activity? Put a tick mark ***(√).***
Fuel wood ☐ Charcoal ☐ Kerosene ☐ Cylinder gas /LPG/ ☐ Electric power ☐
f. Based on the last month's data, what is the estimated revenue generated from this business activity? ____________*birr*.

6. In the absence of access to electric power, what response measures do you often take? Provide your frequent measure by placing a tick mark ***(√)***.
   - Waiting at home and cooking food with other household activities ☐
   - Going out, getting some job and buying cooked food like *Injera* ☐
   - Preparing foods that can be easily cooked in large quantities at once ☐
   - Reduced the number of meals taken per day ☐
   - Do noting (not cooking at all) ☐

7. What is the household's main source of drinking water and sanitation? Specify your source by placing a thick mark ***(√)***. Tap water ☐ Hand-pumped boreholes ☐
Others such as rain water, river water, Bono Woha, etc. (specify) __________________

8. Which source of energy has the most effect on quantity and quality of water consumed by your family? Place a tick mark ***(√)***.
Fuel wood ☐ Charcoal ☐ Kerosene ☐ Electric power ☐

Part IV: The Adoption of Improved Cook Stoves

1. Which energy saving technology (stove) your household mainly uses now?
3-stone traditional stove and butagas ☐ *Mirt* stove ☐ *Lakech* stove ☐
Electric stove ☐ A mix of two or more (specify if any) __________________________

2. If you currently owned any one of energy saving stoves listed above, how long you used it? (If you owned more than one, take the former stove). _________ Years

3. Which ***stove is best*** for the benefits and reasons listed below? Put a tick mark ***(√)*** for your choice.

Uses/reasons of owning a stove	**3-stone**	***Mirt***	***Laketch***	**Electric**
a. Lowers energy price (operational cost)				
b. Saves labor and time				
c. Widely available				
d. More durable/quality				
e. Cheap stove				
f. Expensive stove				
g. Convenient/simple to use				
h. Safe and clean to use				
i. Highly subsidized and easy to obtain credit				
j. Well-known stove				

Note: *The order of stoves in terms of technology: 1) 3-stone traditional stove, 2) Improved biomass stove /Mirt/,3) Improved charcoal stove /Lakech/, 4) Cylinder gas /LPG/ 5) Electric stove.*

4. How you owned or expect to own energy saving stove in the future? Please put a tick mark ***(√)*** for your decision.

- Directly purchased on cash ☐ Obtained loan facilities ☐
- Got it through subsidy and price discounts ☐ Receive gift or support ☐
- Paid price at time-of-use on installment bases ☐
- Others (if any, specify) ______________________________

5. Which one drives you to use energy efficient cooking stoves and transition to renewable energy sources? Place a tick mark ***(√)*** for your most pressing reason.

- Lowers operational cost /expenditures/ per month ☐
- Using new technologies save labor, time and reduces workloads ☐
- Efficiently convert biomass to energy and reduce waste ☐
- To protect forests and sustainably utilize scarce resources ☐

6. What ***major problem*** did you encountered while using energy efficient stoves?

- Very expensive to obtain/buy ☐ Maintenance problem (not available) ☐
- Short life (service period) ☐ No problem ☐
- Cannot power large appliances ☐ Others, specify (if any) ___________________

7. Do you use solar energy/panels? Yes ☐ No ☐

8. If Y**es** for Q7, for what purpose do you use it?
Lighting ☐ Cooking ☐ Heating ☐ Others, specify___________________

9. If you are currently electric user, which device would you like to own first?

- Power saving lumps, florescent lights and mobile charger ☐
- Cooking and baking stoves ☐
- Radio and Television ☐
- Refrigerator ☐
- A mix of the above, specify___________________________

10. How do you evaluate biomass consumption trend over time?
Decreased considerably ☐ The same as before ☐ Increased significantly ☐

11. Do you expect that your shelter type and age affects the use of energy efficient stoves?
Yes ☐ No ☐

12. If your answer is **yes** for Q11, which type of home is convenient to use the preferred stove?
Wood and mud ☐ Mud and cement ☐ Steel and blocket ☐

13. In your opinion, what factor intensifies the depletion of forest resources? Provide your main reason by placing a tick mark ***(√)***.

- Continued reliance on traditional sources ☐ Electric supply problems ☐
- Increased amount of energy consumption ☐ Technological constraints ☐
- Users' social and behavioral problems ☐

14. Among the following list, which measure do you think solves the energy problems of households in informal settlements and protect the local environment? Provide your first choice by putting a tick mark ***(√).***

- Subsidize electric prices and provide new and less polluting appliances at fair price to encourage fuel switching strategies ☐
- Remove subsidies on energy sources like kerosene that pollute the environment making the prices more expensive ☐
- Provide alternative energy sources (diversification) ☐
- Make producers and users pay for externalities /pollution effects/ they create in the form of taxes, carbon emission fees and fines ☐
- Provide incentives including credit facilities to secured energy suppliers and efficient users ☐
- Switch from conventional energy sources and consumption habits ☐
- Others, specify (if any) ______________________________

Part V: Households' Challenges to Access Electricity and Coping Strategies

1. Do you expect to get grid connection soon? Yes ☐ No I don't expect ☐

2. If you ***cannot pay*** the initial connection fee alone, are you willing to share electric meter with your neighbors for common use by paying the monthly bills together? Yes ☐ No ☐

3. Are you willing to accept *temporary electric service for* uses such as lighting, recharging mobiles and batteries, radio and television *without* subsidy***?*** Yes ☐ No ☐

4. What do you think is the ***main challenge*** for households in getting electric service and suppliers' refusal/*reluctance* to provide the required electric service? Put a tick mark ***(√)***.

- Informal settlers' low and irregular income ☐
- Squatter settlement and lack of trust on households ☐
- High electric price /financially less viable source/ ☐
- Suppliers' limited energy supply capacity ☐
- Suppliers' lack of response and mismanagement ☐
- Far from electric lines and scattered settlement ☐
- Households' increased demand patterns ☐
- Households' low level of electric consumption ☐

4. If your first energy choice/requirement is fulfilled, how many meals do you take per day?
Once ☐ Twice ☐ Three times ☐ Four times ☐ No relation ☐

5. Using the following labels, answer the questions below.
1=Firewood and charcoal *2=Kerosene* *3=Cylinder gas* *4=Electric power*

- ______ Energy source that must be subsidized
- ______ Energy source from which subsidy must be totally removed
- ______ Energy source that must be substituted by others
- ______ Energy source that best replaces others
- ______ Energy sources you want to *integrate/mix* (choose any two)

7. What is your main reason for ***substituting*** existing energy source (s)? Place a tick mark ***(√).***

- Scarcity and unreliability ☐ Requires a lot of labor and time ☐
- More expensive ☐ Not safe and not clean to use ☐

8. What is your primary reason for using alternative energy sources at the same time? Please put a tick mark for your answer ***(√)***.

- To get secured and reliable energy ☐ Save labor and time ☐
- Affordability/cheaper energy sources ☐ Availability of low cost appliances ☐
- Each source is needed for different uses ☐

9. For the energy problem, which one is the most widely practiced *behavior* of the household? Indicate your response measures by placing ***a tick mark (√)***.

I. Food consumption habits/actions	**Yes**	**No**
a. Minimize variety of foods consumed (nutrition level)		
b. Reduce the frequency/rate of cooking		
c. Reduce the taste and flavor (freshness level) of foods		
d. Consume foods that stay long		
e. Reduce the amount and number of meals per day		
II. Energy conservation measures		
a. Use energy efficient electrical and biomass stoves		
b. Use power saving light bulbs and florescent lights		
c. Switch-off light bulbs and stoves when not using		
d. Reducing or not using peak time energy demand		
e. Shift energy consumption habits to other sources		

10. Which adaptive measure do you personally take to the electric problem? Choose the household's ***best coping*** mechanism by placing a tick mark ***(√).***

☐ Shift to cheaper energy sources
☐ Reduce the overall energy consumption level
☐ Use energy efficient expensive technologies
☐ Use low cost appliances
☐ Reduce non-energy expenses (use personal assets for energy)
☐ In addition to other household activities, let women and children cook food

11. If you are given access to adequate modern sources, how *fast* do you respond to it?

a. My consumption changes *with lapse of time* ☐
b. Shift to new sources, technologies and consume more *instantaneously* ☐
c. Never shift to new sources at all and energy use *remains as usual* ☐

12. If you decide to switch the new energy source and technologies ***with lapse of time (Q10a),*** in how ***many years*** do you consume the maximum amount of energy and fully shift?

Within 1 year ☐ 2-3 years ☐ More than 3 years ☐

13. **I**f you ***do not want to switch*** to the new energy source, stove or technology ***(Q10c)*** or current energy consumption habits at all, what is the ***most pressing*** reason for this decision?

- Lack of trust on the reliability of new energy sources ☐
- Imperfect knowledge and fear of new technologies ☐
- Prior psychological influence and consumption habits ☐
- The desire to use the scarce money elsewhere ☐

If someone such as the government, NGO or private investor wants to improve the current electric supply (accessibility/availability, timing and reliability of energy service), making additional investment through cost sharing /users' participation/ is often seen as the best strategy. This concept also applies to households who want to purchase improved cook stoves.

14. Therefore, compared with your current monthly pay, do you accept to pay more?

Yes ☐ No ☐

15. ***If yes,*** start from the lowest and increase the bill for 50% of the respondents until they say No **OR** start from the *highest and reduce the bill for the other 50%* until they say Yes I am WTP the required amount. Up to 33% ☐ 33-66% ☐ 66-100% ☐ Above 100% ☐

16. Can you afford to pay the connection fee? Yes ☐ No ☐

If not, are you willing to accept credit and make the payment in the future with monthly bill?

Yes ☐ No ☐

17. If yes **for Q16**, in how many months/years can you pay the connection fee required?

Up to 6 months ☐ 6-12 months ☐ 1-2 years ☐ More than 2 years ☐

18. Based on **Q14 and Q16**, if *you are* ***not WTP*** for the proposed improvements and credit scheme, what is your main reason for this decision?

- I cannot afford the payment/no income ☐
- Monthly fee is too expensive ☐
- Electric service is not reliable ☐
- It is government's responsibility to finance energy ☐
- Existing supply is enough and no need to improve ☐

19. Are you WTP if the electric rate varies based on the following explanatory variables/factors? Place a tick mark ***(√)*** on the appropriate column for each item**.**

Factors to be considered	**Yes**	**No**
▪ Source of energy generated		
▪ Area/location differences among residents		
▪ Seasonal differences in a year		
▪ Time of electric use in a day		
▪ Households ability to pay (income/wealth level)		

20. If your income increases by 100%, compared to the previous month, how much do you allocate for energy sources? Place a tick mark ***(√).***

Energy source	**Decrease by more than 25%**	**Never change**	**Increase by 25-100%**	**Increase by more than 100%**
a. Fuel wood				
b. Charcoal				
c. Kerosene				
d. Cylinder gas/LPG				
e. Electric power				

21. Households have different perceptions and suggest various methods to solve their energy problem. Describe your level of agreement on energy sources that you might use and policy measures that stakeholders could take to this problem using a five level scale by placing ***a tick mark (√)*** on the appropriate column.

Strongly agree (1) Agree (2) Indifferent (3) Disagree (4) Strongly disagree (5)

	1	**2**	**3**	**4**	**5**
I. Household's opinions on energy sources					
a. Electricity benefits residents through economic, social and business development.					
b. Electricity helps households with domestic tasks (such as cooking, washing and caring children).					
c. Firewood and charcoal are becoming hard to obtain in the market.					
d. Certain food tastes are better when cooked with biomass than electricity.					
II. Stakeholders' policy options					
a. Legalize land titles of informal dwellers to provide electric meters					
b. Subsidize, set affordable and tailored electric tariffs					
c. Set high electric prices to push households use energy efficient technologies					
d. Provide credit facilities to support households use energy efficient devices					
e. Provide utility-scale rooftop solar panels (PVs) in groups at low cost/freely					
f. Lower thermostat settings, servicing and repair appliances					
g. Reduce peak electric demand using recharging during slack periods					
h. Manage energy demand through load limiting (smart metering)					
i. Involve a broad range of private suppliers /market-based approach/					

22. If electric is supplied by *private suppliers*, what do you expect its accessibility, price and service?
Increases/improves ☐ Remains the same as it is now ☐ Decreases/worsens ☐

******Thank you for your cooperation******

Annex 3: Plagiarism Test Results

Document Information
Analyzed document
D179.docx (D140808928)
Submitted
2022-06-20 09:07:00
Submitted by
Submitter email
nibretukebede@gmail.com
Similarity
7%
Analysis address
tamirat.tefera.aauni@analysis.urkund.com

Sources included in the report
University of Addis Ababa / Tinsae w. Thesis.docx
Document Tinsae w. Thesis.docx (D111025725)
Submitted by: zedgutu@gmail.com
Receiver: sisay.debebe.aauni@analysis.urkund.com

URL: https://www.ajol.info/index.php/jssd/article/download/222917/210288
Fetched: 2022-06-20 09:09:42
89
URL: http://etd.aau.edu.et/bitstream/handle/123456789/3653/Ahmed%20Mustofa%20Ali.pdf?sequence=1&isAllowed=y
Fetched: 2021-07-21 03:41:24

PhD Research final edited.docx
Document PhD Research final edited.docx (D24541563)

Entire Document
Households' Domestic Energy Consumption in Informal Settlements in *Woreda 12*, Yeka Sub City. Addis Ababa
Nibretu Kebede Desta
Dissertation Submitted in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Development Studies (Environment and Development)
Addis Ababa University
College of Development Studies June, 2022

Households' Domestic Energy Consumption in Informal Settlements in *Woreda 12*, Yeka Sub City. Addis Ababa
Nibretu Kebede Desta
Supervisors: Degefa Tolessa (Prof.) Tamirat Tefera (PhD)
Addis Ababa University College of Development Studies

Ethiopia, June, 2022 Addis Ababa University School of Graduate Studies

Dissertation Approval

This is to certify that the dissertation prepared by Nibretu Kebede entitled: Households' Domestic Energy Consumption in Informal Settlements of *Woreda 12*, Yeka Sub City. Addis Ababa and submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in Development Studies (Environment and Development Studies) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee

Chair, Examining Committee Signature Date --------------------------- ---------------- ------------

External Examiner Signature Date ------------------------------- ------------------- ----------------

Internal Examiner Signature Date ------------------------------- --------------------- ----------------

Advisor Signature Date ------------------------------------- ------------------------ ------------------

Advisor Signature Date ------------------------------------- ------------------------ ------------------

----

Chair of the Center or Graduate Program Coordinator

Declaration

I, the undersigned, declare that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation are fully acknowledged.

Name: Nibretu Kebede Desta Signature: ------------------------ Date: ------------------------------

Place: Addis Ababa Date of submission: ---------------------------------

This dissertation has been submitted for examination with my approval as University supervisor.

Supervisor name: -------------------- Signature: -------------------- Date: -------------------------