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Household Energy and Water use in Hawassa, Ethiopia.

Dissertation

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently: Using only listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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In Prague, September 30, 2022 ______________________________

Signature

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Abstract

One of the consequences of increasing demand for water and energy sources is the depletion of natural resource bases while sustainable use of natural resources can substantially contribute to climate change and unwise use of these resources result in air and water pollution, as well as land degradation. This dissertation thesis examines "Household Energy and Water use in Hawassa". The main goal of the thesis is to answer research questions related to the patterns of household water use and energy source choice in the face of growing economy, socio-demographic dynamics and climate change factors-particularly in the context of local environment.

As energy and water are the two important environmental goods, the pattern of their use has an impact on local environment, where the analysis of demand for energy source choice and water use has a significant impact, as households are a unit of analysis.

A key approach we followed in this thesis is analysing of household survey data based on stratification of socio-economic and demographic variances, geographic location (urban vs peri-urban), and environmental factors. The main energy related data were generated from household survey to analyse the energy source choice based on the three main energy sources; electricity, charcoal and fuelwood along with driving factors. Household income, fuel budget share, education, geographic stratification, level of education, gender, family size, information or knowledge on alternative fuel sources are a significant factors determine household energy demand.

Household demand for biogas energy supply conditioned on flexible financing options is an important area of the thesis. Credit financing with gender balanced and extended credit share with flexible loan repayment options, home water sewage system connectivity, availability of local resources (water, land, livestock and alternative fuelwood sources), and education are relevant factors determine biogas energy demand, where local planners and promoters need to wider and sustainable biogas technology subscriptions among low-income households.

In the area of household water use, the main driving forces were economic (income) and demographic growth (household size). Large family size, number of count stock of water-using devices, and wealth at income elasticity +0.235 drives positive and significant variation in household water use in Hawassa, while demographic variable age significantly affect water use at home with a negative sign. Therefore, policies that rely on quantified characteristics and drivers of household water use and savings behaviour will promote sustainable and efficient water management options in Hawassa and in cities of similar low-income countries elsewhere.

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Table of Contents

List of Abbreviations

AGB: Above Ground Biomass

BOFED: Bureau of Finance and Economic Development

CMF: centre For Microfinance

CSA: Central Statistics Agency

DPSIR: Driving force, Pressure, State, Impact and Response

ESMAP: Energy Sector Management Assistance Program

ESMADP: Energy Sector Mapping and Database Development Program

FAO: United Nations Food and Agricultural Organization

GDP: Gross Domestic Product

GPS: Global Positioning System

IBR: Increasing Block water Tariff

ICS: Interconnected System

IEA: International Energy Agency

Kg: Kilogram

KWh: kilowatt-hour

KVA: Kilovolt Ampere

OLS: Ordinary Least Squares

UN: United Nations

EEPCO: Ethiopian Electric Power Corporation

E.C: Ethiopian Calendar

ETB: Ethiopian currency in Birr (1 ETB=0.03 USD)

SCs: Sub-Connected System

SNNPRS: South Nations Nationalities and People's Region

SNV: Schweizerische Normen-Vereinigung (Swiss Association for Standardization)

WBISPP: Woody Biomass Inventory and Strategic Planning Project

1. Introduction

Optimum resource utilization among different economic sectors, specifically, allocation in household sector has a significant impact on environmental quality while climate change is one of the primary challenges Ethiopia have to face in the course of socioeconomic, technological and demographic dynamics. In Ethiopia, like other sub Saharan Africa countries, household is the most dominant economic sector compared to others in terms of resource utilization, i.e. industrial and services. This is clearly stated on the projected scenario of the United Nations development program goal 12 (2), in which the role of household decision in usage of water and energy sources have significant contribution in achieving sustainable management and efficient use of natural resources by 2030 (UN, 2012).

In general, the demand for water and energy use is increasing with increasing global population, rapid urbanization and economic growth. Consumption of the two environmental goods along with simultaneous supply options is a domain, which requires an integrated and optimum allocation across economic sectors (UN water, 2019; Bates et al, 2008). In sub-Saharan Africa, population growth rate will double at 2030, particularly in urban areas including cities in Ethiopia. This dynamic trend because of the growing GDP and urbanization will lead to several social problems; meanwhile efficient water management in cities is facing emerging challenges because of the wide gap between demand and supply (UN-Habitat, 2011).

According to world water development, the global water cycle is intensifying due to climate change with wet regions generally becoming wetter and dry regions becoming even drier. Other global changes (e.g., urbanisation, de-forestation, intensification of agriculture) add to these challenges (world water development, 2018).

Generally cities in Africa are characterized by rapid urbanization with highest population at annual growth rate of 3.9 percent is estimated to be over 320 million, where a significant water scarcity is already exist. Over the time, the existing water supply sources are declining with land use patterns in upstream communities for agricultural cultivation, seasonal patterns of runoffs and flooding in the wet season, and more turbid in dry season have significant environmental impacts (Jacobsen et al., 2012). The alternative ground water sources are threatening by poor sanitation and intensive use of chemical fertilizer and the resulting climate change add more uncertainty to this already precarious future for African water resources. While the wise utilization of water and energy resources, distribution and effective management, as well as environment protection however, are some of the challenges that local governments to face (CLOSAS et al, 2012). The difficulty of policy performance related to environmental goods consumption and its climate change implications are associated with various dynamic factors. For example, World Bank (2012) assessment result shows that the projected urban population is to rise by half (50 percent) at 2030 or will reach 654 million population. Increasing GDP growth with a growing middle class and changing living standard will also lead to increase water consumption. While local governments require huge capital to cover expensive investment costs for developing water sources, where a significant water supply scarcity is already exist in most cities in Africa.

The substantial energy impact is already challenging Africa and approximately 621 million people have no access to electricity while the same number of people in Africa are dying because of air pollution resulting from inefficient energy source use such as biomass, of which half of them are children under the age five. Surprisingly, modern energy such as clean cooking energy that do not polluting household air will not be used until the middle of the 22nd century (Africa progress report, 2015). Experts agreed that in the last 15 years successive economic growth in Africa, the power supply shortage and power blackouts have restricted access to electricity and induced reliance on biomass for fuel is hindering the effort to reduce poverty.

The per capita energy use is significantly vary between Africa and the rest of the World. Per capita energy consumption in Sub Sahara Africa is declining from 30 percent to 24 percent in the last 15 years. Access to clean cooking energy is even more restricted and almost four in five rely on solid biomass, mainly fuelwood and charcoal (IEA, 2014). On the other hand, according to the UNEP (2012) report: "*Energy production and use is the single biggest contributor to global warming, accounting for roughly two-thirds of human induced greenhouse gas emission".*

In analysing the relationship between energy use, water consumption and climate change, the role of household is increasingly important in the context of developing countries, where household is a dominant sector in using water and energy compared to services and industry. It is important understanding of whether household units have conservation motives in their water and energy use decision will have a significant contribution to climate change locally (Verdugo et al, 2002). Moreover, modelling energy and water consumption patterns can be regarded in the framework of decision at household level is an important indicator for policy choices to make consumption environment friendly and sustainable.

Research conducted by several scholars show that to attain the goals of green economic transformation and sustainable environment, it requires policies that motivate eco-friendly growth strategies and instruments with clear objective measures that can prevent environmental pollutions related to household consumption behaviour (Spaargaren & Van Vliet, 2000; Gatersleben et al., 2002; Ščasný & Urban, 2009). In the meantime, combating climate change resulting from environmental pressure will require an integrated effort to address the increasing consumption and supply scarcity, including encouraging more efficient resource use in meeting the increasing demand (Hanssen, 2014). The consumer demand and supply framework also suggests that governments need to promote sustainable household consumption in such way be well- targeted to the different economic sectors. If these actions to be achieved, it necessitates a combination of policy measures (economic, regulatory, and social) as well as strategies that provide consistent indicators and environmentally friendly consumption options to promote efficiency gains and resource saving behaviour.
Therefore, all this has motivated my research focusing on energy demand and residential water use behaviour, where households are unit of analysis.

The dissertation has three papers based each on household energy demand and water uses. Specifically, focusing on assessment of energy expenditure, and fuel choice among households in Hawassa, Flexible Financing and Investment in Renewable Energy Source in Hawassa, and Residential Water Saving Behaviour and Water Use in Hawassa, Ethiopia. The analysis has followed investigating the driving factors of household demand decision, and analyses the characteristics of households in terms of the usage of these scarce resources at household level.

The dissertation report consists of five chapters.

Chapter One presents a general description of water and energy situation and existing problems in developing countries, particularly in Africa. It also presents the general overview of study area, location, agro-ecology, socio-economic and demographic information and resources: woodland and forest coverage, water and energy resources. In part, the overall study objective and research questions are being briefly outlined.

Chapter Two; in this article, using the data from an original survey, we analyse energy use patterns and, in particular, energy use for cooking in households from Hawassa City, Ethiopia. Cooking is the main energy-related activity on which households spend money. This expenditure represents 89% of total energy expenditure and a fifth of a household's total budget. Expenditure on modern energy and electricity represents only about a fifth of an energy budget, whilst fuelwood, a potentially health damaging energy, still prevails as the main energy used for cooking in Hawassa. There are, however, large differences in energy use between urban and suburban areas. While fuelwood and charcoal are the main sources for cooking among the poorest households, and fuelwood is the dominant source for cooking in suburban locations, electricity is the energy source used mainly in urban areas and especially among richer households. Our research is also in line with results found for other countries in sub-Saharan Africa. Energy expenditure, as well as the use of electricity for cooking, are both sharply increasing with household income. The effect of income on using fuelwood is the opposite. Large families are more likely to prefer fuelwood and less likely to choose charcoal. Female-headed households are more likely to choose charcoal for cooking; however, if females make decisions about household purchases, they prefer to use fuelwood. Formal education increases the likelihood of using cleaner electricity and decreases the usage of fuelwood. Formal education, alongside income, seems to be the key factor in moving from traditional health-damaging energy sources towards modern and clean energy sources.

Third Chapter This article, analyses that in meeting energy demand via provision of renewable energies such as biogas technology, credit arrangements and local involvement in decision-making are key elements for households of low-income, while the link between investment cost, affordability, financing, and other socioeconomic differences may affect investment in biogas energy source for cooking and others uses. A survey of 298 households is used to estimate the drivers of investment in biogas energy. The results being conditioned on credit access with flexible loan repayment options. The estimates of marginal effects from conditional (multinomial) logit model show that flexible loan repayment options might encourage a broader spectrum of households to invest in biogas energy. The key drivers of willingness to invest in short-term loan repayment options were the education and gender of household heads, access to fuelwood sources and wastewater systems, and, livestock ownership. Similarly, households' willingness to invest in biogas energy funded via medium term financing varies with the level of formal education of household heads, wastewater system, and livestock ownership. However, willingness to fund biogas energy with long-term loans was positively correlated with the area of land in use. Policy implications are that local authorities should work with financial institutions to provide credit at market rates, but with flexible loan repayment options. This will reduce the burden of the biogas market on both users and supplier's, increase functional sustainability, and promote biogas technology among low-income communities.

The **Fourth** chapter of the dissertation analyses 'Residential Water Saving Behaviour and Water Use in Hawassa''. It starts with the overview of water situation in the study region, where with water scarcity and access to potable sources is the prime problem. A growing economy and the resulting change in wealth and lifestyle, fast urbanization and socio-demographic changes, technological and environmental factors substantially increasing the demand for water consumption residentially (see section 4.2). The existing efforts have not adequately meeting the increasing demand to clean water supply for the majority of residents in the study area while the residential customers connected to a pipe water system were 23,043 people (58 percent) and the rest were non-connected residents who were relying on unprotected water sources. According to SNNPR Water Resources Bureau inventory report (2015), a total annual residential water consumption by the pipe connection in Hawassa city was estimated to be 3,406,893 m3 in 2014 while non- efficient use of this scarce water supply result in water loss up to 15 percent of annual water production, which could have been used for needy households.

The aim of this paper was analysing the drivers of residential water use and saving behaviour among the households in the study area. We analyse the descriptive statistics of two-sample t-test with equal variances for continuous and dummy variables for connected vs. non-connected respondents. We compared the mean and standard deviation as well as the actual results from the independent t-test. The two-sample t-test result revealed that householders, non-connected to pipe water supply characterized by lower income, lower level of education, family size, private business occupation, and less water use. Econometrically, we analysed the key factors predicting water savings behaviour at home on 85 percent of survey respondents (only connected households) using logistic regression procedures, while regression model (OLS) was used to capture the variation in water use controlling for income elasticity, number of water using devices, socio-demographic and environmental perception variables.

The results from model estimation shows that large family has a 4 percent increase in kitchen sink water savings is associated with large family size, while the income effect of 1 birr or 0.03$ will increase 1 percent tap water saving and 3 percent shower savings performance respectively. High education raises the tap water saving performance by 22.7% compared to low educated households. The probability of tap water and shower savings increase by 18% if a joint agreement between households and the municipality for water source protection. As to water consumption results, a family's wealth is a key predictor of water consumption at an income elasticity +0.235, and both larger families and more water-using devices are significantly increase water use, while the demographic variable age predicts household water use negatively but significantly in the study area.

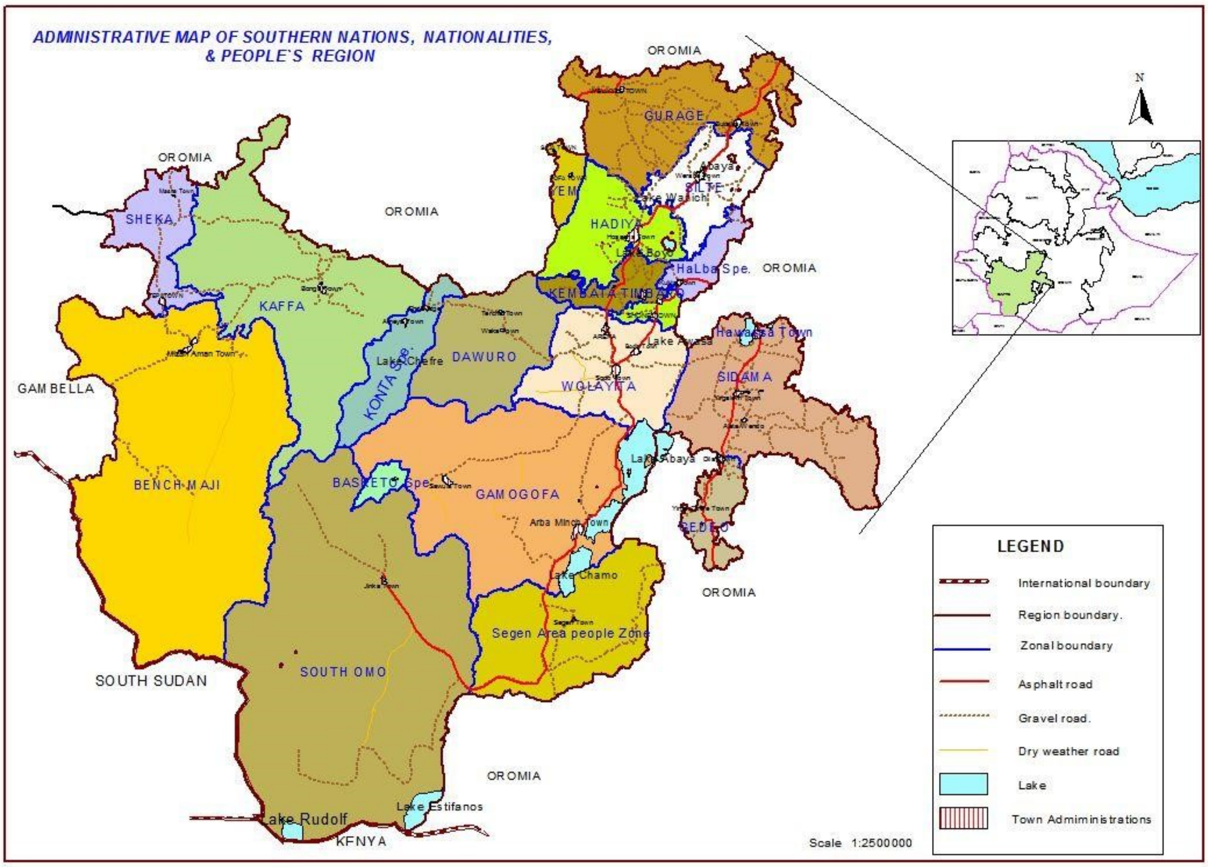
Chapter Five is the final part of the dissertation, which summarizes the results of these three case study papers and draw a conclusion based on the study findings under the references of tested hypothesis. In this part, environmental implications of household consumption decisions are briefly analysed.

1.1 Study area Context: South Ethiopia

The Southern Nations, Nationalities and People's Region (SNNPR) is located in the Southern and southwestern part of Ethiopia. Astronomically, it is roughly lies between 4 º.43" - 8 º.58" north latitude and 34 º.88"- 39 º.14" east, longitude. It bordered with Kenya in the south, the South Sudan in southwest, Gambella region in northwest and surrounded by Oromia region in northwest, north and east directions.

The total area of the region is estimated to be 109,015 Sq. kilometres which shares 10 percent of the country and the population size is 18,954,361 accounting nearly 20 percent of the total population of the country (in 2007 E.C.). The average population density of the region is 176 persons per Sq. kilometres, which makes the region one of the most populous parts of the country.

Figure 1: Administrative Map of SNNPR



The region is with a multinational, which consists of about 56 ethnic groups with their own distinct geographical location, language, cultures, and social identities living together. These diversified ethnic groups classified in to the, Cushitic, Omotic, Semitic, and Nilo-Saharan super language families. Among them Omotic and Cushitic are the most populous and diversified ones with the largest area coverage in region respectively. Based on ethnic and linguistic identities the region divided into 14 zones-sub-divided in to 131 woredas and 4 special woredas and 22 town administrations. According to zonal and special woredas reports as of 2016, there were 399 urban and 3735 rural kebeles in the region.

Climate

Climate is a long average weather condition with a defined geographical area determined by altitude, latitude, prevailing winds, cloud cover, pressure and wind belts. Altitude is by far determinant factor for the spatial variation of weather and climate. Among the elements of weather and Climate, temperature and rainfall are important elements in determining the pattern of population settlement, the range of crops and vegetation that can be grown, soil formation processes, and biodiversity and agro ecology of a given area.

According to the meteorological agency, in 2011 there were 165 meteorological stations in the region recording climatic data. Depending on the instruments they use and weather elements they record, the meteorological stations are categorized into four classes. Two stations, Hawassa and Arbaminch, are synoptic that record all weather elements and receiving satellite data. 63 stations ranked fourth record only rainfall, 82 stations rank 3rd record temperature & rainfall while 18 stations stood principal and 1 st class record temperature, rainfall, humidity, sunshine and other weather elements.

Rainfall

The amount, duration and intensity of rainfall in the region vary considerably. It decreases from west and northwest to South eastwards. The main dry season is shorter in southern Ethiopia conversely; the main rainy season is larger in the west and southwest. For the past three decades rainfall data has shown that the mean annual rainfall of the region was ranging from the lowest about 400 mm in the extreme south of Debub Omo zone to over 2200 mm in the west in Sheka and Kaffa zones. According to Southern Region Meteorological Agency, although there is a lack of complete rainfall data, in 2015 lowest is experienced in konso and in parts of Debub Omo Zone such as weyito and Dimeka area. On the other hand, the highest values (1500-2000 mm) are recorded in Tercha, Jinka, and Bule towns. Generally, in the western part of the region the rain occurs most of the year round while it is bimodal in the eastern and southern part of the region. Relying on the reliability of rainfall for crop production and duration of growing periods, the three seasonal pattern of rainfall in the region is experienced. In Bega season, December – February, in some parts of the region receive limited rain, while in Belg March, April and May the amount of rainfall received is relatively lower than the kiremt rainfall that occurs in June, July and August. However, in each of the seasons the rain may begin earlier/later and lasts before the usual time. This has an impact on growing period and reliability of rainfall.

Temperature

The Meteorological data of the year of 2015 indicated that the mean annual maximum temperature recorded comparatively high in Arbaminch and Halaba kulito town i.e 31. ºC. According to their order while the lowest mean minimum temperature recorded 8.8ºC in Yirgalem, 10.5 ºC in Dilla & Hosanna town. However, temperatures are generally high medium & low in different parts of the region with little variations among seasons.

Agro-ecology

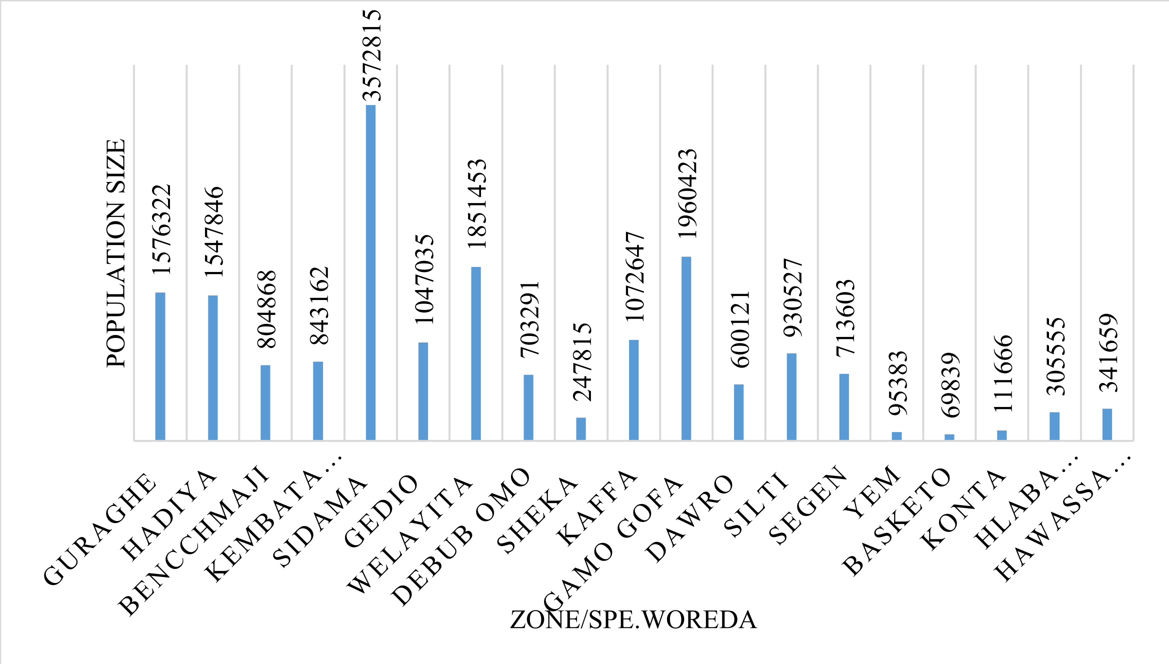
The region has very diverse agro ecological zones ranging from hot arid and semi-arid climate (Kolla & kefil-Bereha type) in the southernmost parts such as in the flat plain of Debub Omo Zone to a tropical humid (Dega and Kefil-wurch) type in the highlands of the North and Northwest. Intermediate between these extremes the climate is defined to be Tropical sub-humid type (Woina Dega type) 34 percent of the region that is moderately suitable for settlement and crop production. Most part of the region, about 57.4 percent lies under kolla and kefil bereha type of agro-ecology while dega and wurch conditions constitute 8.6 percent of the region. The varied agro climatic conditions made the region to have endowments with the production of diverse commercial and food crops.

Socio-Demographic distribution

The expected population of Africa including Ethiopia is to double over the next 20 years and the rapid population growth rate have substantial impact on water and energy security and the ability to provide access to clean water and improved energy supply (World Bank, 2012)
To intervene at any socio-economic development endeavours availability of realistic, current and consistent demographic data pertinent to the region is very crucial. Hence, among various demographic variables, information on population size and distribution are very crucial for planning, monitoring and evaluation of any development programs. Since population has direct relationship with development efforts, planning and implementation of any development programs requires the actual size of population, distribution by size, and other major population dynamics. According to the C.S.A. of National population and Housing census, the total population size of the region in 1999 E.C was 14,945,992. Based on this with an average annual growth rate of 2.9 percent, the region's population size projected and estimated to be 18,954,361 in 2014/2015 of which 87 percent reside in rural areas while the remaining 13 percent inhabited in urban areas. Regarding population distribution, in the year 2014/2015 only 7 zones having a

population between 1 and 3.6 million which constitute about 68.6 percent of the region's population

Figure 2: Population size by zone & Special Woreda by 2016



Source: BOFED, 2016

Sidama, Gamogofa, Wolayita, Gurage, Hadiya, Kaffa, and Gedio are zones with the largest population resides and totally accounted for 68.6 percent of the total population. Sidama, Gamogofa and wolayita each of them constitute 19.4 percent, 10.7 percent &10.1 percent of the total population respectively. While Basketo, Yem & konta spe.woredas are areas where the lowest population reside.

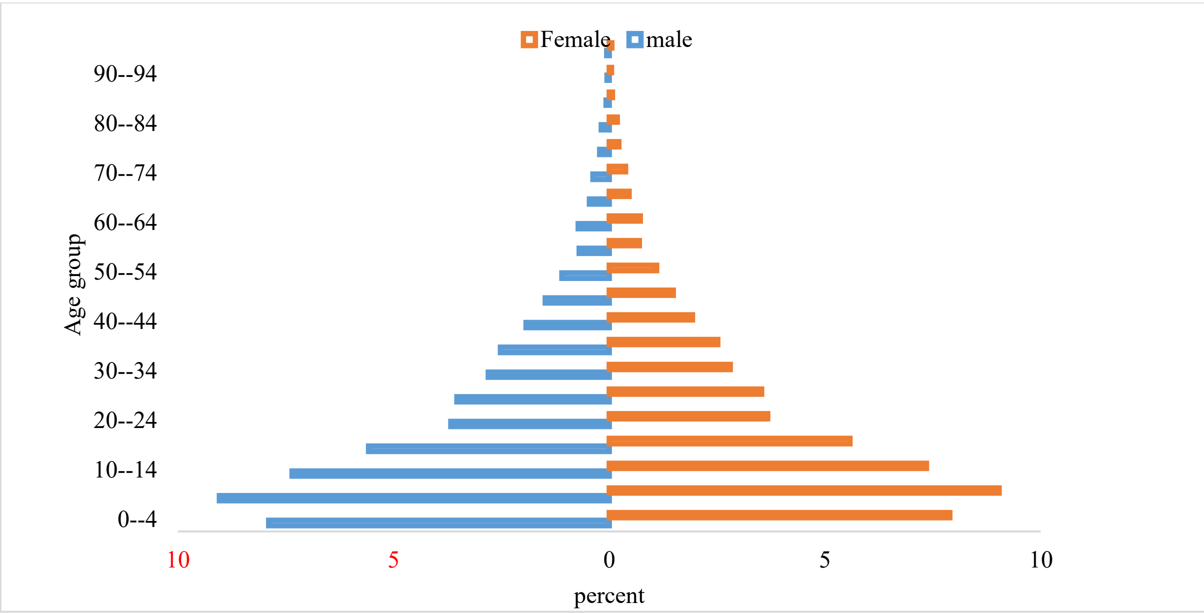
Household Composition and Average Household Size

According to 1999 E.C. (2007) census results, there were 3,110,995 households and an average household size of 4.8 in the region. In 2007 E.C. (2014/2015), the adjusted household size was 3,868,237 revealing the average household size (family size) of 4.9 in the region. The average number of family size varies significantly from one zone to another and from one special woreda to another. For instance, the highest average family size was observed in Kembata Tembaro, Hadiya & Dawuro zones (5.5 and 5.4) followed by Dawuro and the Segen people area zones with family size of (5.4) and 4.9 respectively. While the lowest was observed in Bench Maji & sheka zones (4.1). Among the special woredas, Halaba was recorded as being the highest average family size 5.0 and the lowest family size observed in Hawassa, konta & Basketo (4.2) in 2014/15.

Age Structure

Southern Nations Nationalities and Peoples region like other regions of Ethiopia has a youthful age structure. According to the projected population of CSA, in 2014/15 about 48 percent of the population is under age 15 and the elderly (65+) accounts for 2.5 percent totally 50.4 percent, which are not economically productive population. The remaining belongs to working age population (aged 15-64) accounts for about 49.6 percent of the total region's population. The population pyramid of SNNPR has broad base that implies a very large proportion of the population that belongs to younger age groups. The pyramid is the result of very high fertility since new births rates naturally added to the bottom producing a broad based age and sex distribution.

Figure 3: Population Pyramid of SNNPR, 2016



Source: BOFED, 2016

Dependency ratio

Age dependency indicates the number of economically inactive (non-productive) people of a given region or country. The age group under 15 and above 65 considered unproductive. While the people from age 15 to 64 are economically productive which enter in to the labour force. In figure 2 based on the 2007 E.C. age group population size of the region, the calculated dependency ratio for the region is 101, which means 101 inactive persons depend on every 100 economically active /productive/ people in the region. Across zones, the pattern of dependency ratio indicates every 100 economically productive persons with 117,113,113,107,106 in Dawuro, Sdama, Gedeo, Debub Omo & kaffa respectively have dependent group of population. While in Hawassa city administration, sheka, Hadiya, Gurage, Kembata Tembaro and in some special woredas the dependency ratio pressure is comparatively low and fall within the range of

60- 91 dependent population for every 100 productive people.

Forestry and Other woodland

The Ethiopian government economic policy recognizes reversal of deterioration of forest and other woodland resource bases and protecting land degradation. Knowing the current conditions of forestry and woodland information is therefore an important foundation for analyses of water and energy consumption and demand management policy options. Accordingly, the forest and other woodland base line projected for different scenarios are presented in table 1. Using a linear extrapolation, the areas of forest and other woodland (in 1990 and 2000) were projected.

Table 1: Project estimates of Forestry and Other woodland (1990-2010)

	1990	2000	2005	2010
Forestry	15 113 503	13 704 675	13 000 261	2 295 847
Other woodland	764 44 649	44 649 764	44 649 764	44 649 764

Source: FAO, 2010 (based on the WBISPP projections for 2005)

Because of over utilization of the forest and other woodland as energy sources, the stock of these resources is declining over time in the projected periods. Table 1 percent other woodland and Forestry, project estimates that the total area under forest according to national definitions for the year 2000 and 2005 is 4 073 213 ha and 2 699 561 hectares respectively.

Fuelwood biomass land cover by hectare in SNNPR

Exploring the distribution of the stock of biomass resource information in terms of quantity and quality across different regions is required for developing strategic options for sustainable utilisation and management of natural resources, with an emphasis on woody biomass. This information would assist decision makers and planners in understanding not only the socio-economic implications of policies related to woody biomass resources, but also the key parameters that should orient policies and programs at the national and regional levels (FAO, 2010). In Ethiopia, a lack of up-to-date land use / land cover maps at a reconnaissance scale covering, a large number of map sheets are required to cover the whole country at a scale of 1:250,000 (84 sheets). Remote sensing data with its synoptic view, frequency of coverage, and low cost per unit area, while maintaining acceptable standards accuracy, have been identified as very appropriate and powerful tool to assess woody biomass resources type, distribution, and extent. *According to WBISPP (2004), Ministry of Agriculture, Ethiopia:*

*"**Woody biomass**" refers to the total usable aboveground part of a tree or a shrub. The project identified two basic woody biomass types: (i) tree, and (ii) shrub. The following are the*

definitions of what constitutes a "shrub" and a "tree". ***Shrub: "****A ligneous species, constituted by many short stems rising from the ground, or by main short stem (less than 30 cms) which becomes subdivided into many branches. Whole specimens can reach up to 7 meters from the ground;* ***Tree*** *refers to a ligneous perennial species, with a single (and occasionally double) stem, trunk or bole, and which branches more than 30 cms from the ground."*

The region's woody biomass coverage proportion compared to other land (uncovered one) is a very small proportion. Forest coverage is 638,427 or less than

Table 2: Share of Woody biomass coverage in hectares, SNNPR

Land coverage	2000		2005	
	Hectare	percent	Hectare	percent
Forest	740271	6.91	638,427	5.96
High woodland	560000	5.23	548480	5.12
Plantation	237198	2.22	237,198	2.22
Low Woodland + shrub land	1349431	12.60	1349431	12.60
Other land	7667390	71.61	7780755	72.67
Water	152860	1.43	152860	1.43
Total	10707150	100.00	10,707,151	100.00

Source: FAO, 2010 (based on the WBISPP projections for 2005)

Water Supply

As water demand grows faster, the clean water source supply requires huge investment to provide the services and the land use patterns to change the flow of streams, seasonal patterns of runoffs, flooding in the wet season and less but more turbid water in the dry season cause significant environmental impacts (Jacobsen et al., 2012).

Ground water source is the key alternative, but threatened by poor sanitation and climate change will add uncertainty to this already precarious future for the regional water resources. Sustainable water source protection and distributional issues, improving the quality of residential and other economic sectors allocation are the required solution in the study area context (BOFED, 2016).

The goal of Southern Nations and Nationalities Regional Water Bureau therefore is increasing access to safe water supply through provision of adequate and optimum quality to improve the living conditions of the society, reduce water related diseases while increasing healthy and productive population in the region.

The water service coverage has shown based on different water schemes throughout a region shows that number of people reached with safe drinking water was 9,470,089 in 2016. In rural-8,326,729 and in the urban 1,143,360. Regarding institutions in SNNP region, in 2016 some additional newly constructed water schemes have started services delivery. Table 3 presents number of water supply schemes based on their source type (both functional and non-functional)

Table 3: Summary of water supply type and quantity

Water supply(sources)	Quantity
Hand dug wells fitted with hand pump	274
shallows wells fitted with hand pump	5122
Deep wells with distribution	905
Water points	7647
spring with distribution	1782
Small springs distributors	1782

Source: statistical abstract 2016, SNNPR

In 2016, the SNNP region safe drinking water coverage reached 57 percent in rural, 82.6 percent in urban areas and total 52.3 percent. The water consumption and saving behaviour in chapter four of the thesis has sought as underlining institutional or background information help to validate the analysis and its findings in this context.

Energy resources

The Horn African country known by abundant but unexploited diverse energy resources such as hydro, geothermal, natural gas, coal, bio-energy, solar and wind energy. The gross hydro-energy potential of the country is estimated at 650,000 GWh per year of which 25 percent (160,000 GWh per year) could be economically exploited for power.

The country's geothermal resources potential is about 5,000 MW. The natural gas reserve so far discovered estimated to be 110 billion cubic meters, while the energy potential from coal estimated to be 300 million tons (Energy policy, 2013).

Woody biomass resources estimate for the standing stock and annual yield is about 1,149 million tons and 50 million tons, respectively, for the year 2000 (WBISPP, 2004). This translates into a per capita yield of about 0.79 tons of woody biomass.

Regarding the solar energy potential and current capacity utilization, the national average radiation received at ground level is estimated at 5.20 kWh/m^2 per day. Apparently, there are seasonal variations (with a minimum of 4.55 kWh/m^2 in July, to a maximum of 5.55 kWh/m^2 in February and March), and variations with physical locations (ranging from 4.25 kWh/m^2 for Itang, in the south west, to 6.25 kWh/m^2 for Adigrat, in northern Ethiopia).

Annual mean wind speed, measured at 10 meters from the ground, for the eastern and southern parts of the country is 3.5 m/s - 5.5 m/s. However, recent studies by the SWERA project pointed that several localities in the country with annual average speeds exceeding 7 m/s. The electricity generation potential of the wind resource in these localities (total area about 20,000 km^2) estimated to be 100,000 MW (890,000 GWh/year).

Table 4: Energy type and supply potential of Ethiopia

Energy source	Measurement unit	Total Stock	Potential	Exploited
Woody biomass	Million tons	1,150	74/year	60
Crop residue	Million tons		20.1/year	4.9/year
Dung	Million tons		29.8/year	7/year
Solar	kWh/m^2/day		5.2	≈5 MW
Wind	m/s		3 - 9	
Hydropower	MW		45,000	2,000
Geothermal	MW_e		5000	7
Bio-ethanol	Million litres		300-2000/year	8/year
Natural gas	Billion m^3		110	
Coal	Million tons		260	

Source: Energy Policy (2013) and WBISPP (2004), Ministry of water and Energy

Regardless of huge variety of energy resources in Ethiopia, the major economic sectors depend on biomass energy consumption, which accounts for about 89 percent of total final energy consumption. Petroleum fuels and electricity met merely 7.6 percent and 1.1 percent of the national energy consumption, respectively. The absolute imported Petroleum fuels mainly used in the transport sector with a smaller share of demand by the household sector (kerosene for cooking and lighting) and the industrial sector (fuel oil for thermal energy).

Distribution of energy consumption by economic sectors

The energy sector is characterized by the predominance of the household sector, which in 2016 accounted for 89 percent of total final energy consumption (74 percent by rural and 15 percent by urban households), and projected to be an increase in 1.6 percent annually at 2030. The household sector continues to consume the largest share of total final energy compared to other economic sectors with a projected energy demand of 84 percent in 2030 (Mondal et al., 2018). This is similar to developing and under developed countries with dominant household sector, while unlike OECD household sector constituted about 20 percent of final energy consumption. The second largest energy-consuming sector is transport, accounted for 6.1 percent followed by the services sector, which consumed about 3.6 percent. Energy consumption in the agricultural and industrial sectors was merely 0.9 percent and 0.5 percent of total final consumption, respectively.

The household energy requirements mostly met from fuelwood, animal dung and agricultural residuals or together the so-called biomass. The national percentage distribution of cooking fuel source demand in the household sectors show 81 percent use firewood, 11.5 percent use agricultural residues, cattle dung, and only 2.4 percent use kerosene.

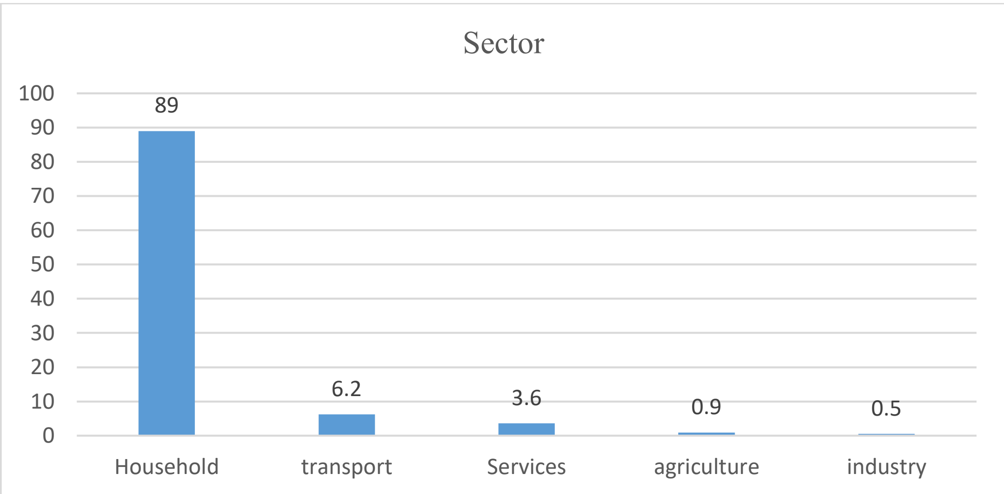
The distribution of biomass energy source by economic sector indicates household constituted 89 percent, services sector (3.6 percent), and agriculture sector use only 1 percent.

As to petroleum fuels, the largest share is for transport sector constituted 80 percent of the total consumption of petroleum products. A smaller share of household sector demand kerosene for cooking and lighting, while industrial sector use fuel oil for thermal energy.

Electric consumption is dominated by three main economic sectors include industrial (40 percent), household (33 percent), and the service sector (26 percent).

The agricultural sector in rural areas relies almost entirely on human and animal power and to a limited extent on commercial sources of energy like diesel. Most rural cottage industries produce food products or household goods such as clothes, woven articles, wooden utensils, handicrafts, pottery and metal products. These industries generally use very little fuel and are largely labour intensive.

Figure 4: share of total final energy by economic sector



Source: Ministry of Water and energy (2013), Ethiopia

In the study region, SNNPRS, the primary energy supply is from biofuel sources and access to modern energy such as electricity is very low, while the public company or electric utility generate it centrally at monopoly market power. Hence, electricity is a modern source of energy used as a source of Power for industries, while for residential sectors used as a clean energy source could replace traditional fuelwood, kerosene, and cattle dung.

The regional distribution of electric service expanded through both /ICS/ inter- connected system and SCS sub connected system. Electrification in SNNPR Only in 2007 E.C. 178 towns and Villages centres have access to electric service through the connected system. The generating capacity of electricity and distribution Capacity of Transformers with KVA 393655 and number of customers reached 177218 making annual revenue of birr 258647097.13 in the SNNPRS.

Table 5: EEPCO ICS electricity customer number SNNPRS

	SNNPR	**National ICS Total**
Domestic.	137,724	1,203,522
Commercial	18,833	162,165
Street Light	377	2,635
Large industrial Low Voltage	2,195	18,104
Large industrial High Voltage	24	169
EEPCO	908	10,672
Retired Staff Consumption	29	1135
Customer total	160,162	1,400,410

Source: Ministry of Mines and Energy (2012)

1.2 Study Methodology and variables

The structure of dissertation consists of the theoretical part followed by a description of empirical analysis. The research focuses on primary sources along with local, national and international literature assessing water use and energy source choices in households. The methodological framework starts with modelling and characterization of energy and water use, and behavioural factors among household units in the study area.

Methodologically the thesis lie with patterns of residential water use, and cooking energy choice decision along with drivers than direct effect on climate change.

The literature review suggests the causal relationship between sustainable residential consumption behaviour, in particular water and energy and climate change implications at household sector in the course of developing green growth models mostly applied in behavioural economics (Randolph & Troy, 2008; Ščasný & Urban, 2009). These econometric modelling's attempt to analyse the association between the indicators of sustainable consumption patterns and technology choice behaviour along with drivers, which are underlined in the study research questions.

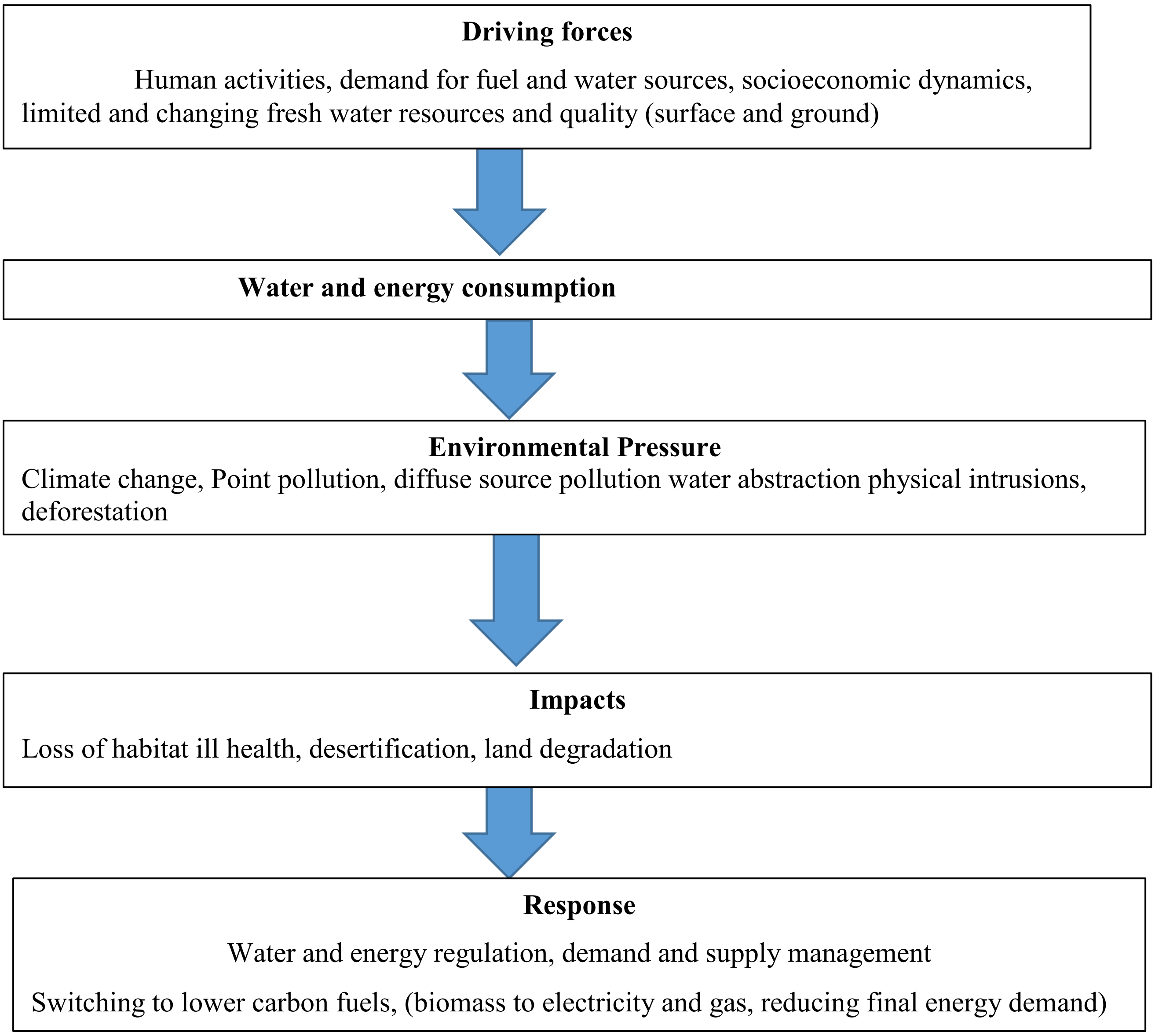
This dissertation thesis is based on research information collected primarily from household surveys. The questionnaire survey was consists of two categories: household energy and residential water uses. The energy part of the thesis allows a comparison of consumption in two geographic location (urban and peri-urban areas of Hawassa city administration), socio-economic and demographic differences, wealth and living standards, which was used to analyse different levels of energy consumption and source choices. Similarly, questionnaire was developed to generate water use patterns across households in the urban areas.

To estimate the main driving forces of water use and energy choice, we use the system of demand and supply framework adopted from DPSIR. The demand system framework deals with a driving forces, pressures, states, impacts and responses (Kristensen, 2004). As household units require access to water and fuel sources such as cutting trees for fuelwood and home building or construction, land use for agricultural production, water for domestic use, agricultural use and related purposes. The analysis in this regard focused on consumption and source choices as active process and making factor analysis with relevant socio-economic and demographic covariates.

In demand theory, understanding consumption patterns along with driving factors, and sustainable consumption behaviour is becoming increasingly important (Marchand & Walker, 2008; Mont & Plepys, 2008). In this regard, environmentally significant and consciously motivated household behaviour is expressed in terms of water use e.g. bathing, washing, food preparation, gardening, etc. and energy use behaviour in terms of switching from traditional to modern fuel sources e.g. instead of using traditional stove, use improved cook stoves, from biomass use to biogas energy source (Sammer & Wüstenhagen, 2006; Gram-Hanssen, 2013). This indicates household's goods or services consumption have social norms or activities carried out by applying sets of rules, and decisions to be made to promote shared values.

The system of demand theory will also have causality effect in connection with production and distribution systems (technology and infrastructure network; electric grid, water pipe, etc.) that enable certain life styles and that connect consumers to one another. It also happen to make ease policy related investment decision for public provision (Hussey and Pittock, 2012). To this end, the deal with exploring the patterns of household water and energy consumption and its implication to climate change mitigation, the methodology integrates economic, socio-demographic and environmental dimensions based on the two broad objectives being emphasized in the economic modelling (energy and water demand).

Figure 5: Conceptual Framework



Source: Adopted from DPSIR

The conceptual framework in figure 4 elaborates how and where the thesis modelling, variable indicators and factor analysis is done. For instance, residential energy and water efficiency and conservation are assumed as the key means for reducing greenhouse gas emissions and achieving green growth goals.

To analyse consumption patterns the thesis uses the demand system and analyses it as an active process while households are actors demanding for basic resources (water and energy) and establishing the quantity needed by selective consumption purposes. Within this demand system, consumers interact, shape and are being act by the way in which systems of provision are designed. In this light, it becomes clear that by the way governments design and transform energy and water systems that can either enable or obstruct household behaviour towards sustainable consumption.

Econometrically, household water and energy demand is derived from a theory of utility maximization modelling adopted by Greene (2012), Ščasný & Urban (2009), Jumbe & Angelsen (2011). The theory of demand model for choice settings and consumption patterns is used to provide the corresponding econometric methodology for empirical analyses. For source choices or household consumption decision, such variables that are unobservable to the econometrician (and possibly also to the individual agents themselves), the observations from a sample of agents' discrete choices can be viewed as outcomes generated by a stochastic model. Statistically, these observations considers outcomes of multinomial experiments, since the alternatives typically are mutually exclusive. In the context of choice behaviour, the probabilities in the multinomial model are to be interpreted as the probability of choosing the respective alternatives (choice probabilities), and the purpose of the theory of discrete choice is to provide a structure of the probabilities that can be justified from behavioural arguments. Specifically, one is, analogously to the standard textbook theory of consumer behaviour, interested in expressing the choice probabilities as functions of the agents' preferences and the choice constraints. The choice constraints are represented by the usual economic budget constraint and in addition, the choice decision (possibly individual specific), which is the set of alternatives that are feasible to the agent. In this case, for example, energy and water demand modelling some respondents may have access to clean water supply and electricity while others may not.

The theoretical framework of production theory in microeconomics applies for household demand for water and energy supply at the household level. The theory suggests optimizing the benefits from consumption of final goods and services, household's utility function is a typical measurement option. This implies that households use combination of commodities or services subject to a budget requirement to produce a composite good. Therefore, the relevant models assumed to estimate the relationship between consumption and covariates or independent factors are linear and logarithmic form of analysis. The independent factors assumed were income, budget or expenditure, and a number of socioeconomic and environmental factors.

This dissertation will contribute to the existing body of knowledge through implementation of policies that are based on empirical evidences of household consumption decision on water and energy services.

Understanding consumption decisions at the household level will increase efficiency on using scarce environmental resources; water and energy.

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2. Energy expenditure and fuel choices among households in the Sidama region, Southern Ethiopia[1]

Abstract

Using the data from an original survey, we analyse energy use patterns and, in particular, energy use for cooking in households from Hawassa City, Southern Ethiopia. Cooking is the main energy-related activity on which households spend money. This expenditure represents 89% of total energy expenditure and a fifth of a household's total budget. Expenditure on modern energy and electricity represents only about a fifth of an energy budget, whilst fuelwood, a potentially health damaging energy, still prevails as the main energy used for cooking in Hawassa. There are, however, large differences in energy use between urban and suburban areas. While fuelwood and charcoal are the main sources for cooking among the poorest households, and fuelwood is the dominant source for cooking in suburban locations, electricity is the energy source used mainly in urban areas and especially among richer households. Our research is also in line with results found for other countries in sub-Saharan Africa. Energy expenditure, as well as the use of electricity for cooking, are both sharply increasing with household income. The effect of income on using fuelwood is the opposite. Large families are more likely to prefer fuelwood and less likely to choose charcoal. Female-headed households are more likely to choose charcoal for cooking; however, if females make decisions about household purchases, they prefer to use fuelwood. Formal education increases the likelihood of using cleaner electricity and decreases the usage of fuelwood. Formal education, alongside income, seems to be the key factor in moving from traditional health-damaging energy sources towards modern and clean energy sources.

Keywords: energy for cooking; fuel choices; energy expenditure; fuelwood; Southern Ethiopia

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2.1. Introduction

In developing countries like Ethiopia, energy plays an important role in socio-economic development, poverty reduction, improving the quality of life and technological innovations. However, the majority of the population in developing countries, and in Africa in particular, relies on traditional energy sources (OECD/IEA, 2014). This has been contributing to a wide variety of adverse effects, including severe health and safety effects, poisoning from ingestion, burns and deaths from fires, destroyed housing and respiratory diseases resulting from indoor air pollution (Mehlwana, 1999; Qase et al., 2001; Lloyd, 2002; Biggs & Greyling, 2001).

Indoor air pollution due to using conventional biofuel cooking stoves (including traditional three stone cooking stoves widely used in Ethiopia) causes *inter alia* severe respiratory disease. The devastating effects out of indoor wood fires has resulted in more pronounced pollutants in the form of smoke in rural households (Van Horen 1996; Spalding-Fecher et al., 2002).

An increasing demand for fuelwood, resultant deforestation spreading outwards from urban consuming centres, and land conversion to agriculture means that fuelwood supplies are constantly diminishing, resulting in increasing fuelwood scarcity in many places in the developing world (Cline-Cole et al 1990). Increasing energy consumption with fuel scarcity is challenging, especially in the African Sahel region, with vanishing woody forests. In this region, despite the low per capita fuel consumption, the pressure on the existing woody forest resources is mainly due to the increased demand by a large proportion of urban households for charcoal in the cities and towns. High dependency on wood biomass and charcoal has resulted in degradation of the surrounding woodlands and forests in the major cities of sub-Saharan Africa, for example Lusaka in Zambia, Nairobi in Kenya, Dar-es-Salaam in Tanzania and Addis Ababa in Ethiopia. High demand of urban dwellers for biofuels harvested in neighbouring rural areas has strengthened increasing pressure to clear forests and degrade land (Helberg, 2004; Edwards and Langpag, 2005). According to Gebreegziabher et al. (2010). the gap between a growing demand for fuel sources and supply scarcity has escalated fuelwood prices in urban centres resulting in extensive deforestation in Ethiopia. The dependence of urban households and other economic sectors on rural forestland has resulted in a significant negative effect on the natural environment in general (FAO, 2004; Krämer, 2002), contributing negatively to air and water pollution and greenhouse gas emissions (Malla, 2013). Environmental damage is substantial, especially in highland areas of Sub-Saharan Africa (Karekezi, 2002).

A shift from traditional fuels to renewable energy and electrification may bring environmental benefits, in particular at a micro level. Investment in clean energy technology may ensure improved, reliable, affordable, economically viable, socially acceptable and sustainable environment and development (UN, 2012). Moreover, electrification in rural areas supplied by off-grid renewable energy may provide time to schoolchildren, who are then freed from gathering fuel and tending fires, as found by Karumba and Muchapondwa (2018) in Kenya.

A rising demand with a fast-growing population, weak energy efficiency, a lack of sources for investment, and political disturbances have known as the key challenges for energy transition in sub-Saharan Africa (OECD/IEA, 2014). A more concerning issue, requiring immediate action, is that energy demand projected to increase up to 80 % by 2040 (Africa Progress Panel, 2015). In order to respond to this growing energy demand, policymakers have implemented various measures to increase the adoption of clean energy sources in sub-Saharan Africa. In line with this move, Ethiopia's National energy policy (Ministry of Water and Energy, 2013) framework has also undergone substantial changes over the last two decades and the Climate Resilient Green Growth strategy have been implemented to avoid the adverse effects of climate change and build a green economy. These strategic measures include increase the availability of cleaner energy sources such as electricity, biomass, and other renewables, such as solar and biofuels.

Despite all these efforts, a transition to cleaner fuels has only slowly progressed, and new clean sources have not satisfied the rising demand, making clean energy remain the main challenge for Ethiopia. Asfaw and Demissie (2012) found that between 1995 and 2005 the demand for a modern fuel source increased by 50 % in Addis Ababa; however, use of traditional fuel also increased by 10 % over the same period. Fuelwood as cooking energy source is being used by most of the households in Ethiopia and it satisfies more than 80 % of households' energy needs, which is noticeably challenging the natural forest stocks. However, investment in clean energy technology may ensure improved, reliable, affordable, economically viable, socially acceptable and sustainable environment and development (UN, 2012).

Low-income countries are still very dependent on traditional energy sources to meet their energy demand. In Ethiopia and elsewhere in developing countries, traditional and inefficient cooking stoves dominate residential and commercial sectors despite a substantial shift towards improved stoves in urban areas in recent years, with a much slower transition in rural areas (Barnes, 2004; Gebregizabhier at al., 2010). On the other hand, limited access, or in some cases a complete absence of clean energy sources, imperfect products and a capital market, have locked households from low-income countries into using traditional fuels. (Bhattacharyya, 2011). The World Bank Energy Access Diagnostic Report shows that about 64 % of households still depend on traditional three stone-cooking stoves, 18 % use manufactured improved stoves and only 4 % use clean electric stoves (Padam et al., 2018).

This paper contributes to scarce literature on this subject by improving the understanding of the drivers of energy source choices in Ethiopia, which is necessary to consider when designing appropriate policy interventions. Usage of different energy sources, including the explanatory factors for choosing from amongst them, is analysed across urban and suburban households living in the Hawassa City administration. We also examine the relationship between households by income groups and budget share for energy expenditure. We use a survey data, conducted between August and September 2017. The primary cooking energy choice modelled empirically using a discrete choice framework. Following this, the functional relationships between primary cooking energy decisions and explanatory factors examined using a multinomial logit procedure.

The findings of this study reveal that electricity and charcoal are primary cooking energy sources in urban areas, while fuelwood is the main source of cooking energy in semi-urban areas. The household budget share of energy expenditure is higher for households in the lowest income quartile than those in the highest income quartile. We also find that a high budget share is directly associated with electricity cooking energy choice, while a low budget share is associated with fuelwood choice for cooking. Finally, we show that income, the relative budget share of energy expenditure, education, geography, gender, family size, and knowledge of alternative fuel sources are significant factors for household primary cooking energy source choice.

The rest of the paper organized as follows: Section 2 reviews the relevant literature on household energy demand. Section 3 presents the study area and survey sampling method, population and sample size determination, while Section 4 provides a description of the socioeconomic variables in the sample data. Our empirical strategy and model presented in Section 5 and this section discusses empirical results. The last section concludes the paper with a summary of findings, and policy implications in line with the findings.

2. 2. Literature review

The available literature shows that fuel price, budget share on energy and income are the main driving forces behind household energy source decisions (Hou et al., 2018; Zhang & Hassen, 2017; Barnes et al, 2004; Heltberg, 2004;). Other factors associated with energy source decision include socio-economic characteristics of a family, environmental conditions and technological attributes (Karekezi, 2002).

For example, income and wealth-indicating assets (Hou et al., 2018) mainly drive the preference of Chinese households for clean energy sources. When consumers' income rises, it is more likely that they will move to clean fuel sources. Growth in income or assets makes the preference of rural households stronger for electricity over gas. Again in China, Zhang and Hassen (2017) show that the preference for a specific energy source is determined by the availability of local fuels, particularly in rural areas, whereas urban households' choices are affected more by fuel price, economic status, family size, gender and the education of the head of the family.

Similar results by Farsi et al. (2007) in India show that the choice of urban household's fuel source is strongly influenced by fuel price, the household's income, gender and the education level of the respondent. It was also found that affordability is the main constraint for the low-income households do not use modern energy sources. Demand for LPG is also more sensitive to its price. In Guatemala, access to credit determines the level of fuelwood consumption, especially in regions where capital resources are scarce (Edwards and Langpap, 2005). In similarity with the Indian study, the shift from fuelwood consumption to gas stoves and modern energy sources is constrained by financial affordability of households, high start-up costs and a lack of access to financial capital. Fuel price, reliability of LPG supply and household income were also found to be significant factors determining households' decisions to choose cleaner cooking stoves in Ghana (Mensah and Adu, 2015). According to World Bank research on the relationship between energy, poverty and gender in Africa, the double rate population growth in sub-Saharan Africa is the main progressive driving force for energy consumption, whilst increasing income from growing economic performance makes modern energy sources more affordable (Karekezi, 2002).

Moving to Ethiopia, Gebreegziabher et al. (2010) analysed fuel choices of urban households in Northern Ethiopia. Estimating a discrete choice model, they found that highly educated and high-income households have a greater probability of switching to modern fuel sources, thus reducing pressure by urban centres on rural forest resources and improving air quality in cities.

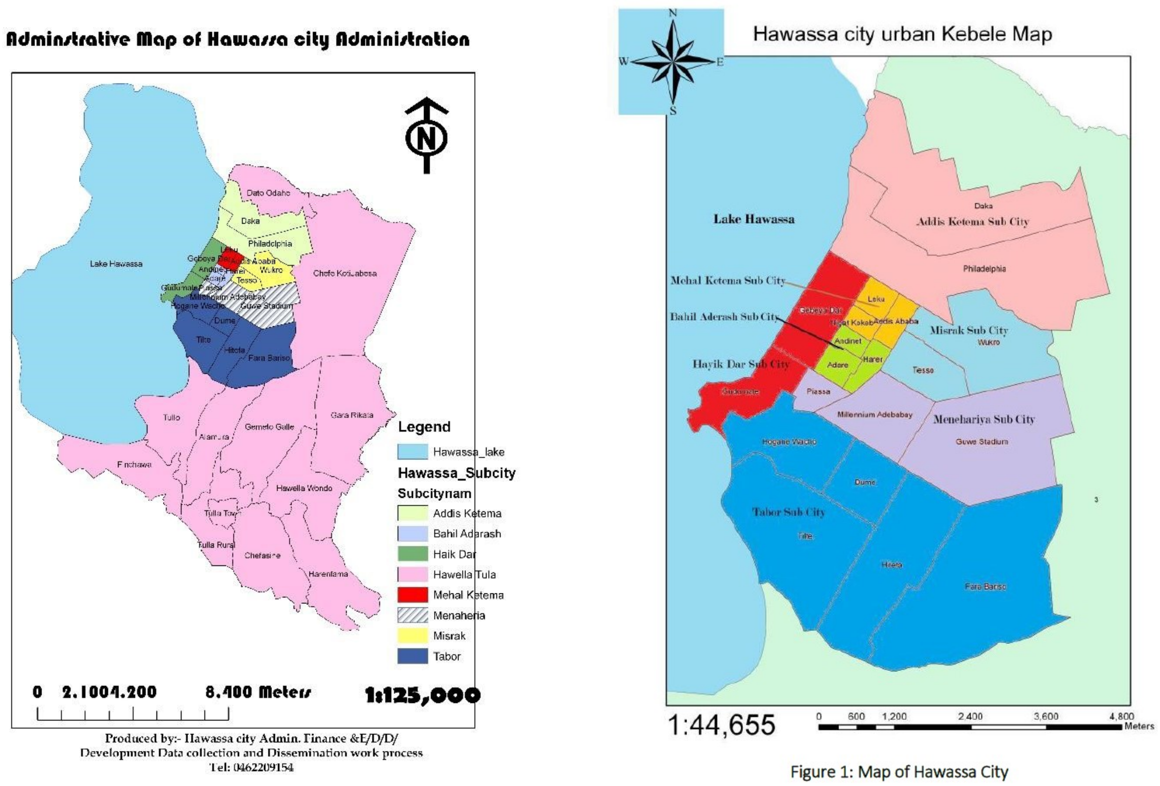
Faye (2002) analysed household energy consumption patterns in Ethiopia, estimating multivariate probit. This research suggests price and income are the key determinants of energy demand for all of its forms; charcoal and wood substituted by kerosene, and the demand for electricity increases with income. In addition, the demand for energy sources varies with household size and urbanization. Another study using a discrete choice model estimated energy demand with the aim of evaluating product specific factors in switching households' preference for fuel and stove types in Addis Ababa (Takama et al., 2012). Again, the authors found that income is a key predictor of cooking stove choice.

2.3 Data

2.3.1 Study area

Hawassa is the capital of the Sidama region of Southern Ethiopia, located on the shores of Lake Hawassa in the Great Rift Valley, 273 km south of the Ethiopian capital Addis Ababa. The population of Hawassa city is 316,842 as at 2016, with an annual growth rate of 4% . The city is broadly divided into urban and suburban districts. The urban districts include seven sub-cities or kebeles: Hayek Dar, Menaharia, Tabor, Misrak, Bahil Adarash, Addis Ketema and Mehal, while Tula is a suburban district, see Figure 1. This study analyses the energy-related behaviour of urban and suburban households living in these eight sub-cities.

Figure 1: The study site - location and administrative regions



Source: Hawassa City Administration (2016)

2.3.2 Survey design and sampling

A questionnaire that comprised three parts, with questions on socio-demographic information and energy use, including questions on fuel availability, firewood collection and fuelwood scarcity. The survey instrument was comprehensively pre-tested and its final version includes revisions based on feedback in the field.

A team of trained data collectors (enumerators) were engaged to conduct field survey in August and September 2017. The survey respondents were sampled from the seven urban sub-cities and four kebeles from the Tula suburban district in Hawassa, using quota on geographic location, as shown in Table 1, and socio-economic conditions. The final sample is representative with respect to urban and suburban areas and their kebeles.

The enumerators visited each household and filled out the questionnaire at the place and time of interviewing the respondents. The field survey was supported by a Global Positioning System to map respondent's geographic location.

Table 1: Target population and sample by geographical locations

Location	Target population [number of households]	Target population [share of households]	Sample (N=376) [share of respondents]
Urban area			
Mehal	4,324	8.0%	8.0%
Menaharia	7,236	13.3%	13.3%
Misrak	6,851	12.6%	12.5%
Addis Ketema	5,264	9.7%	9.6%
Tabor	12,868	23.7%	23.7%
Hayek Dar	5,132	9.5%	9.6%
Bahil Adarash	4,385	8.1%	8.0%
Suburban area			
Gemeto Gale	2,604	4.8%	4.8%
Chefe Kote Jebesa	2,441	4.5%	4.5%
Dato Odahe	1,580	2.9%	2.9%
Finicahwa	1,573	2.9%	2.9%
Total	**54,258**		

2.3.2 Sample description

In total, 376 people –representatives of households living in Hawassa region– were interviewed. About two thirds were living in urban areas; the remaining third were from suburban locations. The two segments differed in several socio-demographic characteristics. The last column in Table 2 reports the results of the t-test on the equality of the means for given characteristics for the two subsamples.

Table 2: Descriptive statistics

Variables	All (N=376)	Urban (N=242)	Suburban (N=134)	t test (Urban= Suburban)
Living in suburban area, %	35.6%	0.0%	100.0%	
Monthly income, in Birr	4591	5487	2972	4.729***
Budget share on energy	22.5%	26.1%	16.2%	2.312**
Self-collected or home-grown biomass	58.2%	59.9%	55.2%	0.882
Livestock ownership	35%	14%	75%	-14.924***
Family size	5.89	5.57	6.46	-3.627***
Age of family head	35.86	37.68	32.56	3.583***
Family head is male	47.9%	45.0%	53.0%	-1.477
Decision maker is male	82.2%	79.8%	86.6%	-1.655*
Education: unable to read and write	12.5%	8.3%	20.1%	-3.379***
Education: able to read and write	47.3%	50.0%	42.5%	1.388
Education: informal education	5.9%	1.7%	13.4%	-4.789***
Education: formal education	33.8%	39.3%	23.9%	3.048***

*Note: *, **, *** represent significance at 10%, 5% and 1% level, respectively.*

Descriptive statistics for the whole sample and for the subsample made from respondents living in urban and suburban areas are displayed in Table 2. The T-test of equality of the two means for the urban and suburban sub-samples is also provided in the table. Looking at the table, there are a number of points of interest. First, the average household income is 4,591 Birr a month, which is about 150 USD, and families living in urban areas are wealthier than families from suburban areas, where on average the monthly income of the former is almost twice large as the income of the latter (5,487 Birr and 2,972 Birr, respectively). Families living in urban areas also spend more on energy; on average, they spend 26% of their income on energy compared to a 16% budget share of suburban families.

Second, families from the two areas also differ in their access to natural fuels. Approximately half of the families from both places have access to biomass; however, livestock is owned by three quarters of suburban families while there are only 14% of such families in urban places.

Third, regarding the socio-economic characteristics, families living in suburban areas are larger, having 6.5 members on average (compared to 5.6 members in urban areas), are slightly younger, with a 33 year old head of the family, (38 years old in urban areas), more often have a male head of the family , and economic decisions are more frequently made by males.

Lastly, only 34% of respondents have completed a formal education, whilst 13% respondents are unable to read and write and 53% are able to read and write, but do not have a formal education. Respondents from suburban areas are also less educated than urban areas. While 20% of respondents from suburban areas are not able to read and write and only 24% have a formal education, this proportion is 8%, and 38%, respectively, in urban areas.

2.3.3. Energy expenditure and energy for cooking

Based on our survey, households in the Hawassa region spent on average 504 ETB (approx. 17 USD) a month on energy used for all purposes. This expenditure is higher in urban areas, with a mean of 604 ETB (20 USD), whilst households living in suburban areas spent on average only about a half of this amount, 323 ETB (10.5 USD). We note that the price of supplied electricity and most of the fuels did not differ between the two areas of the Hawassa region. Table 3 provides a breakdown of this expenditure by energy type and fuel source. While households from urban areas spent the most on charcoal, 205 ETB and about 34% of their total expenditure on energy, those from suburban areas spent most on fuelwood, 145 ETB and about 45%, respectively. Households from both urban and suburban areas spent, on average on fuelwood about 150 ETB. In relative terms, fuelwood represents a quarter of energy expenditure in urban areas, whilst fuelwood contributes to 45% in suburban areas. Electricity bills represent 20% of all energy expenditure in absolute terms; households from urban areas spent almost twice as much on electricity as households from suburban areas. Mean expenditure on solar energy was 103 ETB, and 35 ETB, respectively. Expenditure on other energy types, like kerosene and gasoline represented minor sources of energy.

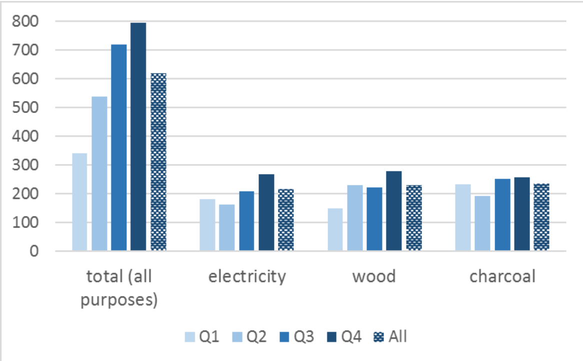
Table 3: Monthly household energy expenditure, by energy source, including households without expenditure (n=376), in ETB

Energy source	All respondents	Respondents from urban areas	Respondents from suburban areas
Electricity	97	117	61
kerosene	4.0	3.6	4.6
Gasoline	6.5	9.9	0.4
Fuelwood	153	157	145
Charcoal	157	205	70
Solar	79	103	35
Other	7	7	6
Total energy	504	604	323

The budget share on energy use, measured as total expenditure on all energy types divided by total household income, is 27.7%, and the corresponding budget shares for the income quartiles are 43%, 25%, 13%, and 8%, respectively. While the budget shares are decreasing across income quartiles, expenditure on energy is increasing with household income in absolute terms; see Figure 2 left panel. Households placed in the highest income quartile spent 769 ETB on energy, while families in the lowest income quartile spent 200 ETB. Expenditure of the two middle-income quartiles was 452 ETB, and 620 ETB, respectively.

There are, however, a considerable number of households without expenditure on energy, 19 %, and this share sharply declines with household income. There are 41% households with zero expenditure on energy in the lowest income quartile, while there are only 3 % of such households in the highest income quartile (there are 16% and 14% of them in the 2 middle-income quartiles). Excluding these households from descriptive statistics provides information about the typical amount of energy expenditure. Naturally, the average expenditure increases when households with zero expenditure are not included. . The average expenditure appears now to be 620 ETB a month, and households appearing in the lowest income quartile spent typically 340 ETB; the average for the two middle quartiles is 537 ETB, and 717 ETB, respectively, and households in the highest quartile spent close to 800 ETB. Figure 2 also displays the average expenditure on electricity, fuelwood, and charcoal for the households with non-zero expenditure.

Figure 2: Household expenditure on energy for all purposes (left panel) and for cooking (right panel) for households with non-zero expenditure, by income quartiles, in ETB



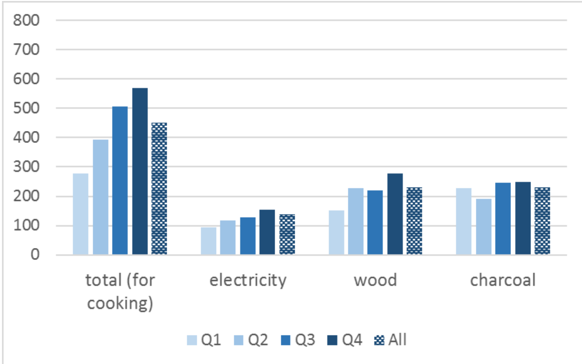
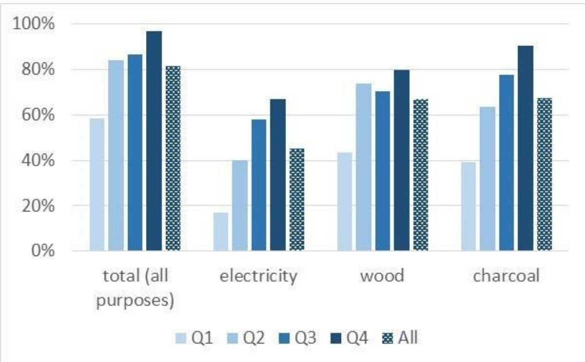
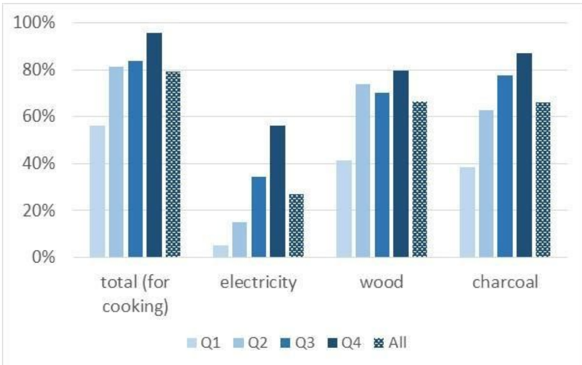


Figure 3: Share of households with non-zero energy expenditure for all purposes (left) and for cooking (right), by energy source and income quartiles





When it comes to fuel expenditure, since fuel is a basic commodity, expenditure on fuels is not increasing as much as expenditure on all sources of energy, implying that the budget share decreases sharply as income rises. A declining fuel budget share is due to affordability and accessibility.

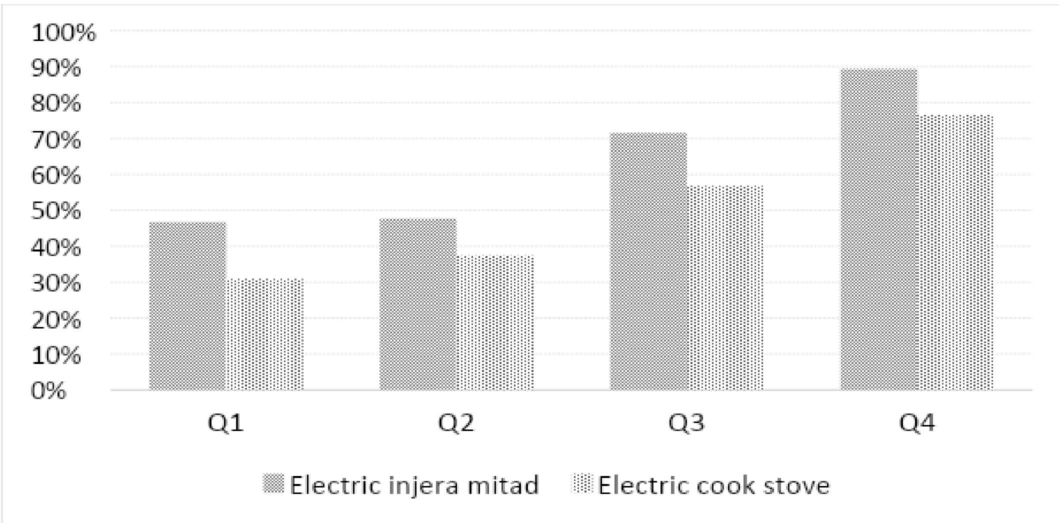
2.3.4. Household expenditure on energy for cooking

Cooking is the main activity for which households in Hawassa spent money on energy. On average, the households included in our survey spent 450 ETB (15 USD) a month on energy for cooking, which represents 89 % of their total expenditure on energy used for all purposes. If we ignore households with no expenditure on energy, we can see a typical expenditure of 451 ETB a month and a corresponding share of total energy expenditure of 73%. Energy for cooking is the dominant energy, especially in the lowest income quartile, which used 81% of energy expenditure on cooking. These households spent 277 ETB a month on energy for cooking; the second and the third quartile spent about 400 ETB and 500 ETB, respectively, and in the highest income quartile an average of 569 ETB on expenditure on energy for cooking: see right panel in Figure 2.

Poor households (the lowest quartile) use mainly fuelwood and charcoal, where approximately 40 % of them have some expenditure on these two respective cooking fuels. Electricity, which is a cleaner source for cooking compared to fuelwood and charcoal, is used by 5% and 15% of households in the lowest two income quartiles: see Figure 3, right panel.

About 63% of households own a traditional electric injera mitad and 50% can use an electric cooking stove, and ownership of these electric appliances increases with income, shown in figure 4. Despite this there are 46% and 30% of households, respectively, in the lowest income quartile which own these electric appliances for cooking, which indicates that there are more households even among poorer families able to use these electric appliances even without paying for electricity.

Figure 4: Ownership of electric appliances for cooking, by income quartile



2.3.5 Which fuel source is used for cooking?

We can now look closely at the energy used for cooking. The right panel in Figure 3 shows that there are 67% of households which use fuelwood for cooking, 65% who use charcoal and 27% that use and pay for electricity for cooking. These shares increase with income. There are about 40% of households with some expenditure on fuelwood and charcoal in the lowest income quartile, while there are 80%, and 87%, of such households respectively in the highest income quartile. Distribution is more uneven in the case of payment for electricity for cooking. There are 5% of households with some expenditure on electricity used for cooking in the lowest income quartile, while there are 56% of such households in the highest quartile.

Electricity is the most frequent energy used for cooking in urban areas, whilst it is fuelwood in suburban areas and there is no difference in this pattern during the wet and rainy season (summer) and the dry season (winter) in Hawassa, as shown in Table 4. We find that fuelwood is the main energy source for cooking in up to 90 % of households living in suburban areas in Hawassa, followed by 6 % who use mainly charcoal and 4 % who use electricity. In contrast, in urban areas, electricity is the main source for cooking used by 54 % in the wet summer and 51% in the dry winter, followed by fuelwood (24–26%) and charcoal (21%). Locally available fuelwood stock is becoming scarcer especially in the city and so the demand for charcoal and electricity is higher compared to suburban locations. In urban areas, there is a tendency to favour charcoal when fuelwood becomes hard to find, as alternative fuel sources such as solar panels are relatively expensive (Barnes et al, 2004). Nevertheless, use of biomass (fuelwood and charcoal) as a cooking fuel persists in the urban and especially in suburban areas.

Table 4: Main primary and secondary energy source for cooking, by locations

Energy source	Primary energy source for cooking		Secondary (additional) energy source for cooking	
	Urban locations	Suburban locations	Urban locations	Suburban locations
Summer				
electricity	54 %	4 %	11 %	3 %
charcoal	21 %	6 %	67 %	42 %
fuelwood	26 %	90 %	19 %	31 %
cattle dung			1 %	24 %
gas cylinder			2 %	0 %
Winter				
electricity	51 %	4 %	13 %	5 %
charcoal	22 %	6 %	63 %	46 %
fuelwood	24 %	88 %	20 %	25 %
cattle dung			0 %	23 %
gas cylinder			4 %	0 %

Note: Differences to 100% in the case of primary energy sources are covered by other sources. The two-sample t-test of the mean equality of the primary fuel source for cooking always indicates statistically significant differences in the means at a 1% level between the two locations. Means of electricity and gas cylinders used as secondary sources in winter are different at a 5% level. Gas cylinders and fuelwood used as a secondary source in summer and winter, respectively, are not statistically different at any convenient level.

It is quite typical that households in the Hawassa region also use a secondary fuel source for cooking, as an alternative or additional energy source. The percentage of households that use these fuels as the secondary source for cooking is displayed in Table 5. Charcoal and fuelwood are still used as a secondary energy source for cooking in both locations, with about two thirds of urban households using charcoal and almost a half of suburban households using fuelwood. A quarter of households living in suburban locations also use cattle dung as an additional energy source for cooking. Electricity is used as a secondary source for cooking in about 12 % of households in urban locations, while there are less than 5% of such households in suburban locations. As in the case of the primary energy sources, there are no differences in which energy sources are used as secondary sources in the wet summer and dry winter.

2.3.6 Fuelwood collection and fuelwood availability

Fuelwood is the key source of energy for cooking especially in suburban locations, where almost 90% of households use wood for cooking. Even in urban locations, fuelwood is important. A quarter of households use wood for cooking as a primary source, and another fifth use wood as a secondary source of energy for cooking. Where does this wood come from?

In suburban locations, fuelwood is mainly collected. Based on our survey; households living there collect or buy fuelwood on average 6 times a month. The responsibility for gathering fuelwood falls mainly to females: in 66 % of cases, this responsibility falls to women. Most fuelwood is purchased from either local markets (55%) or shopping centres (30%), but some respondents collect fuelwood from wood lots (7%) and natural forests (9%), see Table 6.

If we turn to time spent on collecting fuelwood, the greatest number of respondents (44%) reported that they spent on average half an hour on this activity. Seventeen % of respondents spent an hour and 27 % spent up to one and a half hours. Despite this, about 65 % of respondents believe that fuelwood is scarce and 40 % perceive the current situation as very severe, with only 4 % of them perceiving the situation as not severe at all. Among the mechanisms available to cope with fuelwood scarcity, the majority would consider using alternative energy (44%) and planting trees (39%). Relatively few think that the scarcity problem can be addressed by preventing bushfires (12%) or by producing more charcoal (5%).

Table 6: Fuelwood collection and its scarcity

Question	response options	percent
Who is responsible to avail energy supply in your household?	Wife	65.95
	Husband	20

	Children	12.7
	Other (dependant)	1.35
Where do you collect firewood?	Woodlot	6.69
	Natural forest	9.47
	Buy from market	54.32
	Buy from shop	29.53
How much time does it take to collect firewood in hours?	0.30 hour	43.37
	1 hour	17.47
	1:00-1 :30 hours	26.51
	2 hours	8.73
	More than 2hours	3.92
Do you think firewood is scarce?	Yes	64.71
How do you perceive the problem of firewood scarcity in your area?	Highly severe	40.45
	Severe	16.18
	Average	39.48
	Not severe	3.88
What is the best strategy to solve the problem of firewood scarcity?	Planting trees	39
	Charcoal production	5
	Prevent bushfires	12
	Alternative energy	44

2.3.7 Using fuelwood, charcoal, or electricity for cooking?

Next, we analyse the choice of primary energy sources for cooking and, as there are three exclusive options to choose from (fuelwood, charcoal, and electricity), multinomial logit is an appropriate model to analyse this choice (Green, 2012; Jumbe and Angelsen, 2011). Results from the maximum likelihood estimate of multinomial logit model are presented in Table 8 Panel A, with fuelwood as the reference category. The marginal effect for each explanatory variable is displayed below, in Panel B.

Table 8. MNL estimation results: probability of choosing primary energy source for cooking

Panel A – MNL coefficients

	Electricity	**Charcoal**
Income (in 1000 Birr)	0.1081*** (0.0386)	0.022 (0.0474)
Budget share on energy	0.0053 (0.0045)	0.0031 (0.0049)
Living in suburban area	-3.5323***	-2.3283***

	(0.4753)	(0.4507)
Self-collected or home-grown biomass	-0.4706 (0.353)	-0.8415** (0.3877)
Family size	-0.1083 (0.0771)	-0.2757*** (0.0895)
Age of family head	0.005 (0.0119)	0.0321** (0.0137)
Family head is male	-0.6898** (0.345)	-1.4984*** (0.4099)
Decision maker is male	0.7118 (0.4332)	1.2919*** (0.4954)
Able to read and write or without formal education	0.4516 (0.5678)	-0.1262 (0.5494)
Has formal education	1.5144** (0.5981)	1.0654* (0.587)
Constant	-0.1815 (0.8689)	-0.0983 (0.9588)
LL LR chi2 Pseudo R2 N obs.	-267.88 223.81 0.2947 371	

Panel B – Marginal Effects

	Electricity	**Charcoal**	**Fuelwood**
Income (in 1000 Birr)	0.0156*** (0.0045)	-0.0052 (0.0045)	-0.0104** (0.005)
Budget share on energy	0.0006 (0.0005)	0.000 (0.0004)	-0.0006 (0.0006)
Living in suburban area	-0.3916*** (0.0622)	-0.0287 (0.0508)	0.4203*** (0.0313)
Self-collected or home-grown biomass	-0.0133 (0.0464)	-0.0693* (0.0392)	0.0826* (0.0435)
Family size	0.0029 (0.0108)	-0.0261*** (0.0096)	0.0231** (0.0093)
Age of family head	-0.0015 (0.0016)	0.0036** (0.0014)	-0.0020 (0.0015)
Family head is male	-0.0001 (0.0462)	-0.1343*** (0.0422)	0.1344*** (0.0418)
Decision maker is male	0.0187 (0.0585)	0.1072** (0.0516)	-0.1259** (0.0528)
Able to read and write or without formal education	0.0811 (0.0808)	-0.0486 (0.0618)	-0.0325 (0.0656)

Has formal education	0.1630** (0.0812)	0.0206 (0.0626)	-0.1836*** (0.069)

Note: Standard errors in parenthesis, *, **, *** indicate the significance at 10%, 5% and 1% level, respectively.

As expected, the probability of using a cleaner source for cooking —electricity—increases with income; each 1000 Birr of household monthly income increases the probability of using electricity by 1.6%. The effect of income on using fuelwood is the opposite, and the likelihood is decreased by about 1 % for each 1000 Birr. This means that the higher the household income, the more the household is able to afford modern cooking energy sources as opposed to less expensive traditional sources. A large energy budget share does not have any effect on the choice of energy source for cooking, in contrast to Barnes et al. (2004) who found that in low-income countries larger budget shares are associated with using more traditional fuel sources, like fuelwood in Ethiopia.

Using electricity for cooking increases with urbanization; the probability of using electricity increased by 39% in the families living in urban areas. The opposite is true for families from suburban areas, who are more likely to choose fuelwood (+42% compared to two other sources). This may also indicate that in urban areas fuelwood is becoming scarce because of the increasing energy demand due to migration from rural and suburban locations to urban areas. Those families who have access to self-collected or homegrown biomass are more likely to choose fuelwood (+8%) and less likely to choose charcoal as the primary energy source for cooking (-7%), a finding that is consistent with Helberg’s 2004 study.

Large families are more likely to choose fuelwood, which costs less or can be collected free from forests and agricultural residuals. In this case, the likelihood increases by 2.3% for each family. These families also use less charcoal, which is a highly commercialized and more costly fuel source, specifically in urban areas. Each person living in a household decreases this likelihood by 2.6%.

Older families, measured by the age of the head of the family, are more likely to choose charcoal compared to electricity and fuelwood – each additional 5 years of the head of the family’s age increases the likelihood by 1.8%. We also find that female-headed households are more likely to choose charcoal for cooking, while male-headed households more likely choose fuelwood. However, if we examine who makes decisions about household purchases, we find the opposite behaviour prevails – male decision-makers more often choose charcoal, whilst female decision-makers favour fuelwood as the primary source for cooking. In other words, despite the fact that females as head of families prefer charcoal and do not choose fuelwood, if they are in a position to make economic-related decisions they are more likely to favour fuelwood. The more limited economic resources of the households may explain this different pattern where females, who are also more responsible for providing fuelwood, take decisions. It seems that female-headed households also tend to choose modern energy sources – for example electricity – than other energy sources that are more labour- and time-intensive to obtain, as has been found in similar studies carried out in Ghana and Tanzania (Barnes et al., 2004). However, in our case, this association is not significant at any convenient level.

Families with a head who is formally educated use electricity for cooking more, at 16%. On the other hand where formal education is associated negatively with using fuelwood, the likelihood decreases by 18%. Although we found a similar tendency for families whose head, has an informal education or is able to read and write their preference for choosing an energy source is not statistically different from the preference of families with an illiterate head. Formal education may therefore be the key factor in moving to cleaner electricity and act as an important trigger of health benefits due to raising awareness about the health risks associated with the use of dirty traditional energy sources.

2.4 Conclusion

Using the original survey conducted among 376 households living in urban and suburban locations in the Sidama region Southern Ethiopia, we analyse energy use in households and, in particular, the use of three energy sources (fuelwood, charcoal, and electricity) for cooking that differ in their potentially adverse health impact. Energy expenditure represents about 28 percent of total household expenditure and the budget share sharply decreases with household income. While households from the two lowest quartiles spend on average 43 and 25 percent respectively, the highest two income quartiles spend 13 and 8 percent only. Moreover, there are a considerable number of households without expenditure on energy, and this share sharply declines with household income.

Cooking is the main energy-related activity on which households in Hawassa region spend money. They spend about $15 USD a month on energy for cooking and this represents 89 percent of their total energy expenditure, used for all purposes. There are large differences in energy patterns between households living in urban and suburban locations. The former spend on average twice as much as the latter ($10.5). Expenditure on the clean energy source, electricity, represents only about a fifth of total household energy expenditure.

Fuelwood, a potentially health damaging energy source, has been the prevailing dominant form of energy among households in the Hawassa region. Usage of fuelwood, however, differs significantly between urban and suburban areas. While 90 percent of households from suburban areas still rely on fuelwood, fuelwood is the primary energy source for cooking in only a quarter of urban households. However, fuelwood is also used as a secondary fuel for cooking in another 10 percent of urban households. Most of the fuelwood is purchased in local markets and shopping centres, and 16 per cent of households still rely on wood collected in wood lots and natural forest. Dependence on fuelwood is not only associated with adverse health effects, but it may escalate the problem of wood scarcity. In fact, 65 percent of households think that fuelwood is scarce and 57 percent perceive this problem as severe or highly severe. The best mitigation strategy is considered to be planting trees (39 percent), but also investing in alternative energy (44 percent), while only 5 percent consider charcoal production to be a good strategy of coping with the scarcity problem.

Charcoal that is commercialised and more expensive than fuelwood is mainly used as the primary source for cooking in urban areas, by 21 percent of households, while there are a very small number of suburban households relying on charcoal. Still, 67 percent of households in urban locations and 42 percent in suburban locations pay at least something for charcoal, used as the secondary energy for cooking.

Electricity is typically the main primary source for cooking in urban locations. There are about 54 percent of such households, whilst there are only 4 percent of such consumers in suburban locations. It is worth mentioning that while approximately a third of households in our sample say that electricity is their primary energy source for cooking, only around a quarter of them pay to use it. . The limited affordability of the cleaner, more modern energy source of electricity is also indicated by 47 percent of households in the lowest income quartile who own an electric injera mitad —the traditional Ethiopian cooking appliance, whilst there are only 5 percent among them with some expenditure on electricity for cooking.

We find a similar pattern in Hawassa, which is commonly seen in the countries in sub-Saharan Africa. Fuelwood and charcoal are the main sources for cooking among the poorest households; fuelwood is the dominant source for cooking in suburban locations, while electricity is mainly used in urban areas and especially by richer households. We find there is no significant difference in this general pattern during the wet and rainy season (summer) and the dry season (winter).

Regarding socio-demographic characteristics, we find that electricity use for cooking increases with income, and each 1000 Birr of household income increases the probability of using electricity by 1.6 per cent. The effect of income on using fuelwood is the opposite. Large families are more likely to prefer fuelwood and are less likely to choose charcoal, which is highly commercialized and more costly, specifically in urban areas.

It is left mostly up to females in Hawassa to gather fuelwood. We also find that female-headed households are more likely to choose charcoal for cooking. However, if females make decisions about household purchases, they tend to choose fuelwood for cooking. The lower economic resources of households may explain this different pattern where decisions made by females who are also more responsible for providing fuelwood. Although our results are largely in line with the results found for other similar countries in sub-Saharan Africa, we do not support the idea that female-headed households are more likely to choose electricity for cooking as shown, for instance, in the study carried out in Ghana and Tanzania by Barnes et al. (2004). Therefore, we find a positive association between formal education and using electricity for cooking, whilst formal education reduces the likelihood of using fuelwood. Formal education is therefore one of the key triggers to move from dirty traditional energy sources like fuelwood to clean modern sources like electricity, through raising awareness about potential health risks associated with using energy in homes.

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3. Flexible Financing and Investment in Renewable Energy Sources: The Case of Biogas Energy in Sidama Region, Ethiopia[2]

Abstract: In an attempt to meeting energy demand via provision of renewable energies such as biogas technology, credit arrangements and local involvement in decision-making are key elements for low-income countries in Africa, while the link between investment cost, affordability, financing, and other socioeconomic differences may affect investment in biogas energy. In this article, a survey of 298 households is used to establish the derivers of investment in biogas energy; the findings being conditioned on credit access with flexible loan repayment options. The estimates of marginal effects from conditional (multinomial) logit model show that flexible loan repayment options might encourage a broader spectrum of households to invest in biogas energy. The key derivers of willingness to invest in short-term loan repayment options were the education and gender of household heads, access to fuelwood sources and wastewater systems, and, livestock ownership. Similarly, households' willingness to invest in biogas energy funded via medium term financing varies with the level of formal education of household heads, wastewater system, and livestock ownership. However, willingness to fund biogas energy with long-term loans was positively correlated with the area of land in use. Policy implications are that local authorities should work with financial institutions to provide credit at market rates, but with flexible loan repayment options. This will reduce the burden of the biogas market on both users and supplier's, increase functional sustainability, and promote biogas technology among low-income communities.

Keywords: Biogas Energy, Determinants, Investment Decision, Flexible Financing, Ethiopia

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3.1 Introduction

Extensive reliance on biomass as an energy source is common in Sub-Saharan Africa, where fuelwood is the dominant source of energy. In Africa, including Ethiopia, about 90 percent of rural households are dependent on fuelwood for open fire cooking and lighting despite its poor energy efficiency and high negative impact on the environment [1]. Currently, affordable clean energy services is one of the key challenges of low-income countries, and most of their populations are living in energy poverty [2].

Energy supply and demand systems have many implications for the livelihood of households, indoor environmental pollution, socio-economic outcomes and local climate change in Africa [3]. However, in attempt to meet increasing energy demand via provision of clean energy sources, credit arrangements, and local involvement in decision-making are key elements for low-income countries in Africa, while the link between investment cost, affordability, financing, and other socioeconomic differences may affect investment in biogas energy [4]. Specifically, finding new approach that may increase access to renewable energies at affordable and lower transaction costs required an effort and wise choice to mitigate the risks of indoor pollution and the resulting socioeconomic and health impacts [5].

Biogas energy technology provides low-income households with clean cooking and lighting fuel and bio-slurry fertilizer in Africa, including Ethiopia. It also benefits women and children by reducing the negative socio-economic burden (health, education, and environment) associated with traditional biomass use in Africa, where women are primarily responsible for cooking and fuel collection [6, 7].

Despite the numerous benefits of biogas, household investment in biogas energy is restricted by several factors. Economic factors are the major determinants of use and commercialization of biogas energy across low-income households in Africa. These factors include cost of material supply, land, labor, plant size, location, technology, and the substitutability benefits of other fuel sources [8]. Institutional factors also are important: Functioning and sustainable institutions with systematic marketing and commercialization strategies are important for investing in biogas energy in low-income countries [9].

Biogas energy technology was introduced in Ethiopia in the late 1970's. However, the development of biogas energy is very slow. For example, until 2007/2008, only 200 biogas energy plants were constructed across the country. In order to speed up its outreach, in 2007, the Netherlands development organization (SNV) assisted with a program to promote biogas technology on a national scale [10]. However, out of 14,000 biogas plants planned to be constructed in the five years, only 8,000 biogas plants were successfully developed in the specified project period. Currently, few biogas plants have generated from cattle dung, as several biogas energy plants were non-functional. The Netherlands Development Organization report shows 40% of constructed biogas plants were non-functional, and earned a bad reputation for biogas energy technology among some user communities [5]. For example, in Sidama and Southern Nations, Nationalities and People's Regions biogas plant inventory report revealed only 40% of the 3,345-biogas energy plants constructed between 2008 and 2016 were operating [11]. The inventory report finds reasons for non-functionality of biogas plants to be ineffective management, poor follow-up, technical complications, lack of interest in ownership, and reductions in animal holdings.

The key question is how to achieve sustainable and affordable biogas energy aligned with sustainable and flexible financing mechanisms. This requires investigating key factors driving investment in renewable energies by low-income households to assist with policy design. In this study, the main research questions include: Does access to credit help households get biogas energy? Does the term (duration) of loan repayment schedule matter? What other factors determine investment in small-scale biogas technology in suburban and urban areas? This article analyses household investment decision in biogas energy conditioned on credit access at flexible loan repayment options. To estimate factors deriving investment decision related to biogas energy at given three loan repayment options for a given household, we use a multinomial logit model.

3.2 Literature Review

Establishing affordable clean energy services is one of the key challenges of low-income countries, where the majority of people live in energy poverty [2]. Low levels of clean energy use and energy poverty are directly associated with energy demand and supply scarcity. In the demand side, the poor cannot afford modern fuels because of their low purchasing power relative to the cost of the fuels. These clean energy access problem is characterized by low electricity generation capacity, shortages of foreign exchange, inefficient service provision, imperfections in energy markets and lack of infrastructure [12]. Affordability related to investment costs required to develop biogas plants show heterogeneity across continents, specifically in Africa and Asia, where the majority of the population live in low-income categories and are involved in subsistent occupations such as small-scale farming. According to the SNV assessment report (2014), the average investment cost in Africa is more expensive than in Asian countries. The following table presents initial investment cost, per capita GDP share, and year of construction in selected African Countries.

Table 1. *Investment cost, per capita GDP share and year.*

Initial investment costPer capita GDP share Country			**(EUR)**	**(%)**
	Year 2012	**Year 2013**	**Year 2012**	**Year 2013**
Ethiopia	400	350	65%	45%
Kenya	500	530	52%	45%
Rwanda	963	673	83%	53%
Uganda	588	535	53%	49%
Tanzania	250	400	45%	39%
Burkina Faso	300	340	58%	43%

Source: SNV 2014 [5]

The investment costs of biogas technology in Table 1 show the variability of cost structures with factors such as construction materials and resource endowments such as skilled labor or technical expertise, locally available materials such as stone and cement, location and size of construction sites with available water supply and adequate livestock dung [13]. Generally, biogas performance assessment shows innovation through research and development could be fertile ground to improve construction materials for biogas development in terms of cost reduction [2, 5].

In Ethiopia, initial investment costs of small-scale biogas technology is lower than in neighboring countries such as Kenya, Uganda, and Rwanda. The reason is that the biogas development program in the study area is subsidized and this subsidy scheme was blamed for the poor reputation of biogas technology, so that reliance on high subsidies with the market failure has led to large contributions for little return in the sustainability of the constructed biogas plants. Ethiopia and Uganda constituted the highest (80%) share in investment cost comparisons in terms of per capita GDP share in 2010. Better in this context is that biogas technology construction costs have declined in Africa from 2010 to 2013. For example, African countries including Ethiopia succeeded in having on average 5.8% investment cost reduction (see table 1).

In conclusion, literature sources on affordability tell us investment costs and affordability factors for low-income households have necessitated a detailed assessment of credit access at flexible loan repayment options. Meanwhile, there strong argument on how the combined factors that drive the demand for biogas technology could benefit the low-income households as a means of ensuring the economic wellbeing and help to get clean energy via affordable cost.

Biogas technology development is moving at the very slow pace in Africa compared to developing countries in Asia. This slow development is induced by high investment costs, limited access to credit facilities, insufficient supply and the significantly low purchasing power of households [13]. On the other hand, despite abundantly available biogas and other renewable energy sources, and irrespective of high livestock potential, biogas technology utilization is very low in Africa. Such problems are associated with high initial investment costs, inadequate technical skills, and cultural factors [14]. Limited financing resources also hinders biogas technology development in Africa. This makes access to credit critical for low-income households to enable them to take advantage of poverty-reducing opportunities, and to shape economic policy and programs to their benefit [15].

The literature shows that increased income of poor households is directly associated with a preference to invest in renewable energies, including biogas energy. In Africa, for example, high-income households use more efficient energy sources (electricity and gas) while low income households use less efficient energy sources, such as fuelwood and other biomass energy [16]. In Nepal, credit access with reasonable payment period and financing through intermediaries [1] encourage renewable energy use [17].

Studies on credit financing for development of biogas energy technologies in low-income countries show that access to credit for biogas technology is the highest in Bangladesh (with 86% coverage). In Indonesia, credit access reached 84%, followed Cambodia at 54% [2]. Research in India reveals that loan repayment or payback period flexibility (short-term payback) increase adoption of small-scale biogas technology (1 to $6m^3$) [18]. The same study finds that an increase in the capacity of biogas plants decreases the payback period exponentially such that households invest in biogas plants have on average a 1.6-year payback period (loan installment). Studies also show that poor households can afford new or improved technologies such as biogas if provided with credit financing options. For example, in Nepal the loan installment terms chosen by households contains 36.7% fixed or equal loan instalment, 41.7% flexible installment, and 21.7% no installment at all [16]. Same study revealed that most users prefer to opt for biogas loans for a term of 2-3 years and repay in quarterly instalments.

Availability and substitutability of local resources such as water, bricks, materials (plastics tubes or metal), skilled labor or expertise, less intensive training, and follow up of

1 Credit options when manufacturers or rail distributors acquire loans that are returned to

consumers who adopt biogas technology, micro credit, and self-help group financing, which enables access to affordable credit with long time maturity.

Constructed biogas plants are factors that affect biogas development in low-income communities [5]. In the meantime, biogas technology for cooking requires cultural acceptance, and influenced by livestock ownership, water availability, scarcity, population density, and climate conditions [19].

Buysman & Mol conducted research on market models in biogas energy demand decisions related to sustainable self-financed strategies has little success in low-income countries except isolated example such as Cambodian National program (CNBP) started in 2006 [20].

According to Netherlands Development Organization, SNV, 2014, biogas development program was started in 2008, in Ethiopia; however, its performance has yet with little success stories [5]. This is because of the shortage of construction materials supply and maintenance personnel, little or no financing options and increased biogas construction costs, as well as inadequate market access [21, 22].

According to Sibanda et al, despite all the constraints, biogas technology has a huge benefit in solving semi-urban sanitation problems and sewer reticulation that may cause chronic epidemic, in Harare, Zimbabwe [23]. They also found that biogas energy has potential for wood savings of 6129 tons/year, paraffin savings of 2.556 tons/year and greenhouse reduction of 980 tons of CO_2 equivalent emissions/year, which would attract USD2940 from carbon credit sales per year. The Harare research also proves that combined suburb biogas technology is a feasible scenario for producing 7,378 m^3 of biogas per day with a production capacity of 384 kW. Such small-scale domestic biogas plants with their applications for cooking, lighting, and bio-slurry can contribute to the global reduction of greenhouse gases (GHG).

In Ethiopia, Gebreegziabher and others, find that biogas adoption in urban areas is a source of clean energy and a means of municipal waste minimization [24]. According to the Netherlands Development Organization, SNV, 2006 base line study, biogas energy can reduce greenhouse gas emission in three basic ways: 1) substitution of the conventional domestic energy source, 2) Modification of traditional waste management practices; and 3) substitution of chemical fertilizer [25].

In Africa the economic benefits and commercialization of biofuel, specifically biogas technology varies with investment cost estimation, and technical and non-technological barriers [26]. However, technical and non-technical factors both poses problem in biogas energy commercialization in most Sub-Saharan Africa regions [3]. In this region, investment in biogas energy also vary with standardization and quality control. As empirical studies have shown that integrated farming systems with biogas and slurry, financial support to cover initial investment cost, and promotion of multiple use biogas sources would increase widespread adoption of small-scale biogas technology [2, 7].

Empirical research in rural Ethiopia shows that biogas technology diffusion varies among households. This variation mainly associated with age of household head, household size, number of livestock (cattle), firewood collection distance, education of household head, if a household head is female, access to electricity, access to credit, and access to an all-weather road were positively correlated, but access to a marketplace is negatively associated [27].

Similar research by Mengistu et al, in Ofla district of Tigray and Mecha district of Amhara regions in Ethiopia, have reached same finding, except male-headed households were more likely to adopt biogas technology, and include the influence of the education level of the household head, household income, and number of trees planted [28]. In a study conducted by Abadi et al, in Tigray, estimate the relationship between biogas adoption and health status among 200 sample adopter and non-adopter households [29]. The results reveal that households that adopt small-scaled biogas digesters have significantly lower rates of indoor air pollution and lower expenditure on medication, and spend less time on fuel wood collection than non-adopter households spend. Similarly, in Aleta Wondo woreda of Sidama region, biogas technology installation among rural households vary with availability of water sources, access to credit, number of cattle, land size, training in masonry, and household income [30]. However, none of these studies address the effect of geographic location (semi-urban and urban context), or access to credit with a flexible repayment schedule (short, medium, and long term) as predictive covariates of investment in biogas technology.

3.3 Data

3.3.1 Study Area Description

With a total land size of 1.1 million square kilometers, Ethiopia is twice the size of France and the 10th largest country in Africa. The nation is the second most populous country in Africa after Nigeria, with a population of around 110 million a population growth rate of more than 2.3 percent per annum. The study area, Sidama region is located in Southern Ethiopia and covers a total area of 12,000 km^2. The Sidama region is one of the 10^{th} states of Ethiopia. According to the Central Statistics Agency (CSA, 2007), the Sidama region has an estimated population of 4.5 million inhabitants [31].

3.3.2 Survey Method

We prepare a questionnaire comprised of three parts; the first part includes questions on socio-demographic information. The second part comprises questions on household energy uses, available resources in the area, firewood collection, and fuelwood scarcity. The third part includes questions about investment decisions on domestic biogas plants and in a sub-section of credit access with flexible loan repayments (short, medium and long-term) and the amount of funds with respective installment periods.

Accordingly, using stratified random sampling techniques, we collected data among 298 households in Hawassa. Covering all kebeles in eight sub-cities, we assume the geographic location and socio-economic classifications as the stratifying factor. A pre-test survey was carried out and revisions were made based from feedback in the field. Finally, the enumerators visited each household and filled in the questionnaires by interviewing the household head. The field survey was supported by the Global Positioning System (GPS) to map the household's geographic location.

3.3.3 Model

In order to analyze a multiple choice response variable such as investment decisions being conditioned on three loan repayment options for a given household, we estimate a multinomial logit model [2] . The estimation of investment decisions with flexible financing options is the main approach adopted in this study.
We assume the application of the theory of Random Utility Model (RUM) to estimate the economic value of goods and services. The model underlines the consumer's subjective

preference that maximizes their satisfaction based on the perceived product or service attributes. The utility derived from investing in or choice technology options is conditional on observable attributes, if the consumer makes choice j in particular, then we assume that U_{ij} is the maximum among the J utilities [32, 33]. Then we have the utility function;

$U_{ij}=X_{ij}8 + ei$

Empirically, the model is based on the assumption that a household's investment decision related to biogas energy is conditioned on flexible financing options which are independent of one another (since the household has to decide whether they can afford or willing to invest in different longevity periods). The estimation of multiple choice response equations also allows us to account for unobservable household characteristics that may affect investment decisions concerning different loan repayment periods; we only observe the decision to invest in the three options.

These options are, first, short term financing meaning a loan repayment within two years and credit funds of 70% of initial investment costs of small-scale biogas energy. Second, medium term financing, which is a loan repayment in five years with credit funds of 50% of initial investment costs. Third, long-term financing, representing loan repayment plans in 10 years and with a 30% credit fund arrangement that cover initial investment costs. Accordingly, the probability to invest is equal: $Pr (U_{ij} > U_{ik})$ for all other $k \neq j$.

Given individual specific covariates xi, the probabilities for J choices is given by:

$$Pr (yi=j/xi) = Pr = \frac{e\,(Xi\,'\,\beta j)}{1+\sum_{k=1}^{J} e\,(Xi\,'\,\beta k)}$$

Where j=0, 1, 2, 3…..J; β0=0

The sum of the J+1 probabilities should equal to one. To avoid indeterminacy, we need only to estimate J parameters to obtain probabilities for J+1 choices.

The log-likelihood can be derived by defining for each individual d = 1 alternative j individual, d_{ij} if is chosen by individual i, and 0 if not, for the J+1 outcomes. We assume covariates of conditional investment decision in biogas energy are income, sociodemographic, and environmental factors.

3.3.4 Characteristics of Socio-economic Survey

Summary statistics in Table 2 present the sample survey. The average monthly income of the households is 4706.86 ETB and the average family size is 5.6. The majority of household heads are male (59%), and the average age of household heads is 36 years. The land size on average is 2.15 hectors. 53% of household heads have informal education while the rest have formal education. Geographically, 33% of households are semi-urban and 67% are urban households.

Table 2. *Socioeconomic survey (N=298).*

variable	Mean	St. Dev
Age	35.78	13.80
Household head gender	0.41	0.49
household size	5.62	2.21
Income	4706.86	7325.59
Land size	2.15	1.21
Semi-urban	0.33	0.47
Informal education	0.53	0.50

3.3.5 Characteristics of Household Fuel Sources

Figure 2 shows main fuel sources used for cooking in the summer and winter seasons. In summer, wood takes the main share (48%), with electricity (35.9%), and charcoal (17. 38%), while a few respondents (2.14%) use leaves in the summer season. In winter there is a nearly equivalent share (47.59%) of fuelwood, 35.03% electricity, and 17.38% charcoal and very few (0.54%) uses leaves as fuel sources.

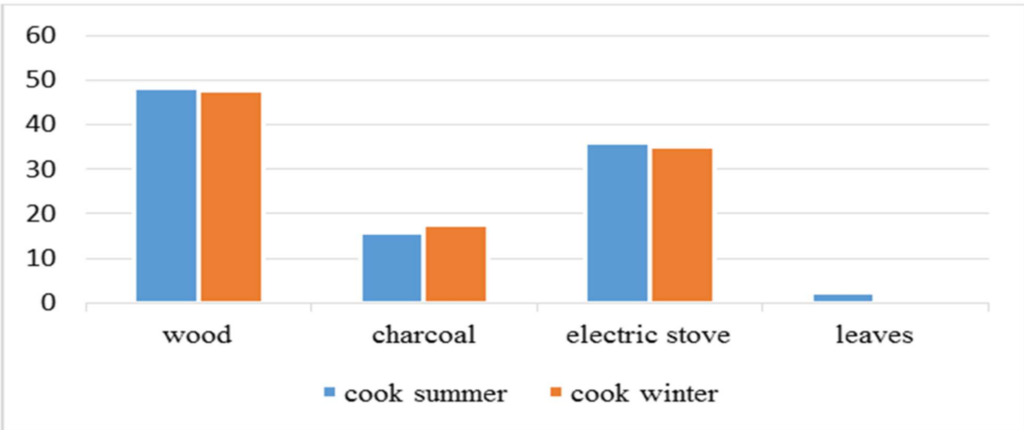

Figure 1. *Share of cooking fuel sources in summer and winter, percentage.*

3.3.5 Characteristics of lighting fuel source (summer vs winter)

Figure 2 shows main energy sources used for lighting in summer that are (89.97%) electricity, kerosene. On the other hand, kuraz (4.61%), paraffin (3.79%), candle (1.1%), and solar (0.54%). According to our survey result, the most common fuel source for lighting in winter is electricity that constitutes (86%). A small number of householders use kerosene (4.8%), paraffin (3.77%), and candles (2.16%), solar (0.81%), torch batteries (0.27%) and wood (0.27%).

In both seasons, many households use electricity as a primary lighting source. The differences in lighting fuel sources in terms of electricity was about 3% lower in the winter.

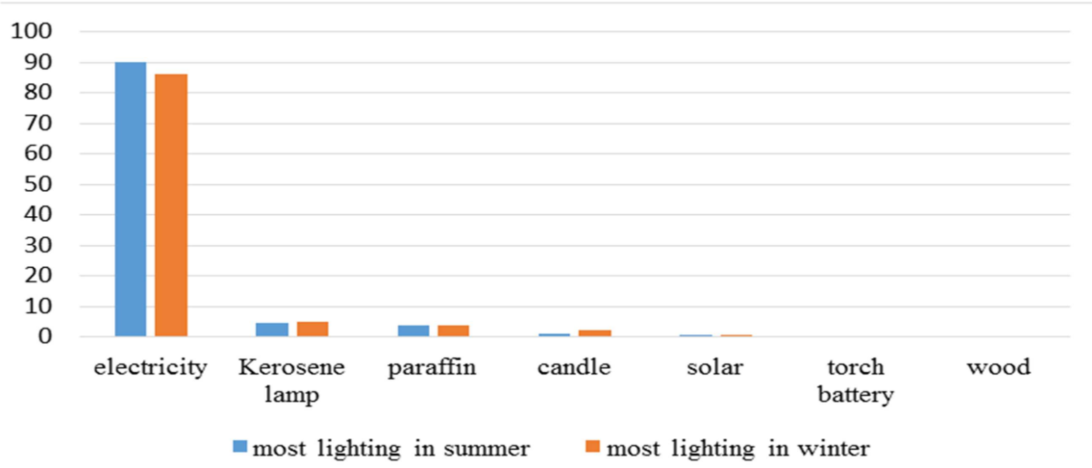

Figure 2. *Share of lighting fuel sources in summer and winter, percentage.*

3.3.7 Household Perception on Biogas Technology

The survey results on biogas technology are presented in table 3, which indicates that 72% of sample respondents have heard about the biogas technology, while the rest had not. Based on the result, the mass media (television and radio) is found to be the major sources of information (74.81%) followed by spillover effect or previous users (10.74%). However, the role of extension workers (5.93%), researchers (4.4%), biogas promotion programs (2.93), and schools (1.11) was small. The findings show that most households (82.83%) perceived biogas as alternative source. The findings show that 30.82% of households strongly agreed that biogas technology should be promoted, while half (49.85%) agreed with this statement and 15.41% disagreed with biogas technology promotion.

Table 3. *Description of households' perception of biogas technology.*

Questions	response options	Percent (%)
Have you ever heard about the biogas technology?	yes	72.16
	biogas promotion	2.96
	extension workers	5.93
How did you get information on biogas technology	mass-media	74.81
for the 1st time?	previous users	10.74
	researchers	4.44
	school	1.11
What do you think about biogas technology as	appropriate	82.73
alternative energy source?	not appropriate	17.27
	strongly agree	30.82
	agree	49.85
Do you agree biogas technology to be promoted?	neutral	3.02

disagree	15.41
strongly disagree	0.91

3.3.8 Wastewater Systems

Figure 3 presents household characteristics in terms of wastewater management systems. Our survey results show that householders connected to a home sewage system or who had their own septic tank constituted 21%. The simple majority (37%) of householder's discharge wastewater directly to a drainage ditch or land, while 36% of householders discharge wastewater directly to prepared pits within a compound. Very few respondents (4.8%) use other means to discharge wastewater from the house.

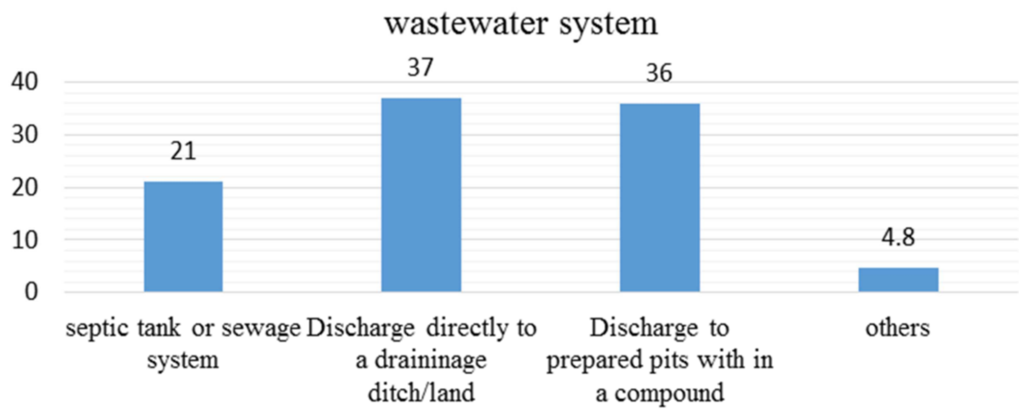

Figure 3. *Percentage distribution of respondent's wastewater system.*

3.3.9 Availability of Water and Fuelwood Sources

Availability and access to domestic water resources, firewood for cooking, and grazing land for fodder are the most important external factors determining household fuel choices. Three response options were available to respondents; (1) Readily available (2) available in short distance (3) Not available.

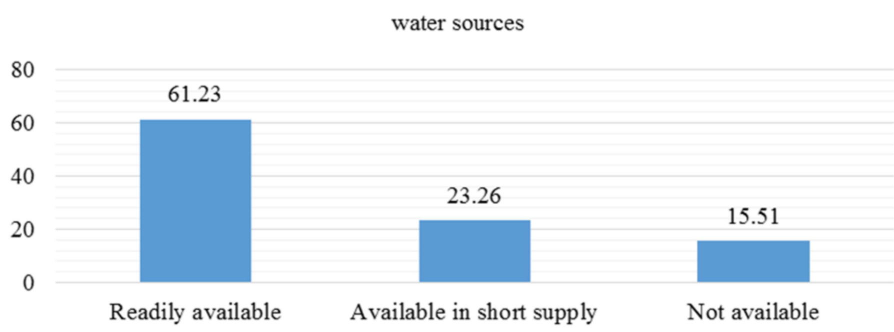

Figure 4. *Percentage distribution of water sources.*

Figure 4 shows, 61.23% of respondent's have readily available domestic water sources, 23.26% have domestic water sources available in short distance, and 15.51% of respondents do not have domestic water sources in their area.

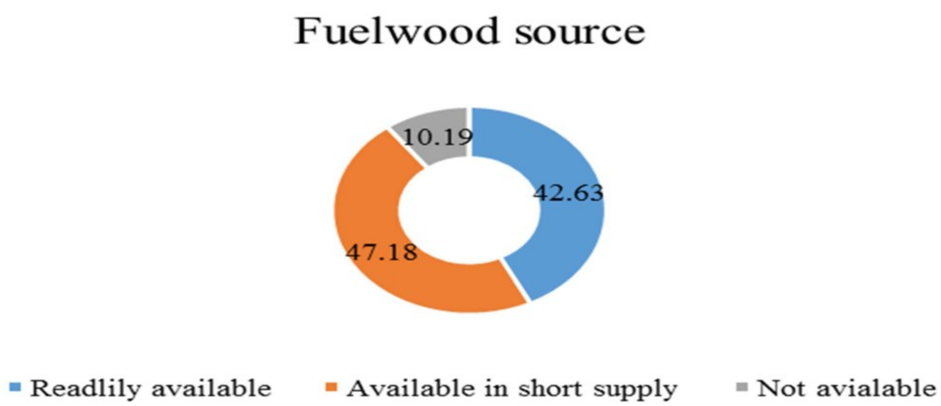

Figure 5. *Percentage distribution of fuelwood sources.*

Figure 5 shows 42.63% of households in the study area have a readily available fuelwood source, 47.18% have available fuelwood in short supply and 10.19% of them have no available fuelwood source.

3.3.10 Willingness to Invest in Biogas Energy with Credit Access at Flexible Financing

Household's willingness to invest in biogas energy with credit access with flexible loan repayment options is presented in the following table.

Table 4. *Investment in biogas energy with credit access in flexible financing.*

Time	Loan repayment options	Credit amount	Initial investment cost (Birr)	percentage of respondents
2 years	Short-term	70%	14000	14.1
5 years	Medium-term	50%	14000	24.47
10 years	Long-term	30%	1400	61.44

Table 4 shows the demand for biogas energy accompanied by credit access with flexible loan installments. 14.1% of households were willing to invest with short-term loan repayment plans at the corresponding outstanding amount of 70% of initial investment cost. 24.47% of households were willing to invest with medium term loan installments with credit funds of 50% of initial investment costs. The majority of households (61.4%) were willing to invest with a long-term loan installment plan with the funding option 30% of initial investment cost.

3.4 Results

3.4.1 Independent variable, definition, and expected sign.

Table 5 Table, Independent variable, definition, and expected sign.

Variable	Definition	Expected sign
livestock	Livestock =1 if f household own at least 4 cows 0 otherwise	+
Land size	Household Land holdings in square meter	+
Waste water system	Household water system connected to waste disposal	+
Male	male=1 if gender of respondent's head 0 otherwise	+/-
Alternative fuel source	Knowledge of alternative fuel source other than biomass	+/-
Informal education	Informal education of household head	+/-
Formal education	Formal education of household head	+/-

The econometric results of conditional covariates explains investment in biogas technology is shown in Table 6. We have conducted diagnosis tests using post-estimation tools that can be used to help interpret model results. We did likelihood ratio tests that provide an alternative method in testing sets of coefficients, and marginal predictions for multiple variables (responses).

Table 6. *Econometric results from multinomial logit estimates (n=298).*

Variables	Loan repayment options	
	Short-term	**Medium-term**
livestock	0.629 (0.456)	0.581 (0.358)
Land size	-0.339** (0.166)	0.101 (0.152)
Waste water system	1.110** (0536)	0.152** (0.421)
Male is household head	-0.965** (0.454)	-0.563* (0.332)
Alternative fuel source	-1.741** (0.467)	-0.344 (0.356)
Informal education	2.338** (0.685)	1.100 (0.759)
Formal education	1.041** (0.461)	1.040*** (0.349)
_cons	-0.850*(0.506)	-1.846*** (0.525)

Notes: SE values in parentheses. $*\ P < 0.10$, $**\ p < 0.05$, $***\ p < 0.01$ represent significance at 10%, 5% and 1% level, respectively.

Among the socio-economic variables, male household head and investment in biogas are indirectly correlated and significant at a 5 percent significance level in relation to the short and medium term repayment schedule relative to long term. Informal education has a positive and direct effect on decision to invest in biogas energy with the short-term loan repayment schedule at a 5 percent significance level. However, formal education has an indirect effect on investment with a short or medium term repayment schedule relative to a long-term repayment schedule, at a 5 percent significance level. The coefficient estimate of a waste water system has a positive and significant association with investment in biogas energy, at 5 percent significant level, while access to alternative fuel sources and land size are negatively associated with investment in biogas energy conditioned on a shorter loan repayment schedule. (See table 7)

In contrast, the difference in household size, age of household head, marital status, family relationship, occupation, geographic location (semi-urban vs urban), ethnicity, and religion were not statistically significant and not included in the interpretation of estimation results.

Table 7. *Marginal effects from multinomial logit model (n=298).*

variable |	**Loan repayment options**		
	Short term	**Medium term**	**Long term**
Livestock	.0002 (.029)	.062 (.050)	-.062 (.057)
Land size	-. 0267** (.012)	.018 (.023)	008 (.026)
Waste water system	.049 (.047)	.207** (.083)	-.256*** (.087)
Male is household head	-.055 (.030)	-.062 (.049)	.117 *** (.0562)
Alternative fuel source	-.148** (.045)	-.022 (.055)	.170*** (.065)
Informal education	.280** (.137)	.097 (.143)	-.378*** (.133)
Formal education	.061 (.042)	.149*** (.065)	. -.210*** (.070)

Notes: SE values in parentheses. ∗ $P < 0.10$, ∗∗ $p < 0.05$, ∗∗∗ $p < 0.01$.

The marginal effect of a male household head increases the probability of investing in biogas energy with a long-term loan repayment plan by 0.11, relative to short and medium term plans. This is in line with the results from the literature on the role of gender in investment in biogas technology that shows heterogeneity across regions in Ethiopia. For example, in Tigray region of Ethiopia, female-headed households are more likely to invest in biogas technology [27]. In contrast, in Amhara region, male-headed households are more likely to invest in biogas energy [28]. It is also consistent with the study result in Uganda that female-headed respondents are less likely to invest in biogas technology than their male counterparts [32].

A household head having informal education increases the probability of investing in biogas energy with a short-term loan repayment schedule by a factor 0.28. However, with the long-term repayment, a household head having informal education reduces their willingness to invest in biogas energy by a factor 0.37. The marginal effect of formal education is more likely increase the household's willingness to invest in biogas energy with the medium term loan repayment schedule by 0.149 compared to short and long-term options. However, the marginal effect of a household head having formal education in the long-term repayment option reduces the probability of the household investing in biogas energy by 0.21 compared to the short and medium options. This is consistent with previous study results that show a positive association between education and investment in biogas technology [27].

The marginal effect of the economic variable land size reduces the probability of investing in biogas energy in the short-term loan repayment period, relative to medium and long-term options. This means a one-unit increase in land size in hectares is associated with a 0.026 decrease in the relative marginal effects of being willing to invest in biogas technology with the short-term repayment plan than the long-term option. Many empirical studies in related regions agreed that increasing land holdings had a decreasing effect on investment in biogas energy [30, 32].

The relative marginal effect of household's being connected to a waste water system increases the probability of investing in biogas energy in the medium-term loan repayment schedule by a factor of 0.2, compared to short and long terms. However, the effect of a waste water system reduces the probability of investing in biogas energy by 0.25 in the long-term loan repayment option compared to the short and medium schedules. The result is consistent with findings from Ghana that a novel septic tank design (up flow domestic septic tank) can help to recover biogas as energy and treat domestic sewage [34]. Connecting waste water systems to biogas digester also shown to be a feasible sanitation solution in urban slums in Bwaise III, Uganda [35].

The marginal estimates of alternative fuel source (access to fuelwood and other biomass) reduce the probability of households investing in biogas energy by 0.14 in the short-term repayment option, relative to long and medium term options. In this regard, previous study results [27] reveal access to fuelwood in the nearest market is negatively associated with the adoption of biogas energy in rural Tigray, North Ethiopia. However, the effect of access to alternative fuel is more likely to increase the probability to invest in biogas energy in the long term by 0.17 compared to the short and medium term options. Thus, the association between long-term repayment options and access to other fuel sources is also consistent with the result of a positive net present value from investing in biogas technology compared to householders collecting their own energy sources. This is in line with the study findings of Oromia and South region of Ethiopia that reveal the benefits of biogas energy such as bio-slurry use for agriculture production, time and energy saved by women and children [36].

3.5 Discussion

This paper, examines driving factors of investment in small-scale biogas energy, conditioned on credit access with flexible loan repayment options. The covariates that have a significant effect on investment decision were discussed as follows. Our results reveal that, with short-term loan repayment options with high credit rate (70% of investment cost) women are more likely to invest in biogas technology. Practically, in the study area, women's participation in investment in biogas technology and the share of a loan extended to them is low (only 10%) in Ethiopia [2]. This is the lowest of the regional loan share for women in African countries. For example, the loan share of women in Rwanda is 25-30%, and in Kenya, the loan share of women reaches to 90%. The implication is that if the loan share of women increases significantly there will be a high probability of investment in biogas technology or renewable sources. If they can afford to pay the required investment cost and have autonomous decision-making powers women will benefit from biogas technology in terms of reduced health risks, and time and energy saved. Biogas technology use also increase convenience and reduces hardships related to fuelwood collection by women and children [37]. Household landholding (size) does not affect investment in biogas energy with short-term loan instalments. It holds for medium and long-term loan instalments. In the short-term credit option, those households that own a large area of land can simply get fuel for cooking from their own land and therefore do not want to invest in biogas energy. Instead, they invest in biogas energy in the long-term credit option, as they are not certain about future fuel sources. Moreover, the inverse relationship between the probability of investing in biogas technology with short-term loan repayment options and large land holdings may indicate the minimal effort of promotion and awareness creation about biogas energy. Households were informed on the benefits of improved fuel sources, such as the role of bio-slurry as a fertilizer source (biogas digester bi-product) that could increase agricultural efficiency and ensure clean production of agricultural outputs. The result is consistent with other findings that land size and adoption of biogas energy are inversely related among rural households [30]. The research findings regarding livestock ownership reveal that households that possess more cattle and other livestock are more likely to invest in biogas energy since they will have enough substrate for plant operation. An increase in the number of livestock, particularly, cattle has the same magnitude of increasing the probability of investing in biogas energy. However, livestock ownership may not be the only determinant, as there is the presence of other wastes that might generate biogas energy, specifically in semi-urban areas. The relationship between formal education and investment in biogas energy is more influential in the short and medium-term loan instalment scenarios than the long-term option, while informal education has a modest influence for biogas energy in the medium-term instalment option relative to the long-term option.

The covariate waste water system (septic tank) connected to a biogas reactor is beneficial to produce clean biogas energy. Thus, planning for direct conversion of domestic waste water systems or septic tanks to a biogas digester is simple and can be a potentially feasible and sustainable sanitation solution in urban or semi-urban areas. Both short and medium term credit financing options will increase investment in biogas energy among households connected to a waste water system.

The biogas demand with credit access with a short-term repayment option has less effect than in the long-term option if abundant alternative fuelwood sources are available in the locality. In the short-run option, householders have no experience of fuelwood scarcity, and it is not an immediate subject that needs to be dealt with. Nevertheless, investment in biogas energy in the long–run option depends on the expected present value of initial and operating costs with competitive borrowings (loans) if there is uncertainty about the availability of fuelwood in the future. This is consistent with the demand theory applied to long-run demand for electricity consumption conditioned on appliance holdings [38] that the association between investments in improved technology and competitive borrowings with expectations with discount rate assumptions.

3.6 Conclusion

The main findings of this study reveals that women household heads are more likely willing to invest in biogas technology in a short-term loan repayment options with credit funds of 70% initial investment costs. Another finding is that households with large land holdings and that have alternative fuel sources prefer long-term loan repayment options with lower credit funds of 30% initial investment cost. Further, education has a direct effect on investment decision. Households with a head with informal education were more likely to invest in biogas technology at medium-term loan option with credit funds amounting to 50% of initial investment cost. On the other hand, households with heads with formal education were more likely to invest in biogas technology at short-term and medium-term loan options of 70% and 50% respectively. An increasing number of livestock owners were more likely to invest in biogas technology with short-term loan options with credit funds of 70% of initial investment costs. For urban households connected to home sewage systems, investment in biogas varies with short and medium loan financing options, given 70% and 50% of credit funding respectively.

To sum up, the study findings suggest that flexible credit financing access should take into account gender balanced credit shares, specifically, measures for women may increase adoption of sustainable, clean and biogas energy technologies among low-income households. Education and training related to the benefits of biogas technology should prioritize access bio-slurry as a natural fertilizer, and sanitary solution in urban and semi-urban areas. Policymakers can also create demand for biogas from households with large land holdings and that have alternative fuel sources through offering credit funding with flexible financing along with user-centred benefit valuation and further promotions.

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4. Residential Water Saving Behaviour and Water Use. Evidence from Hawassa, Ethiopia[3]

4.1 Introduction

Increasing water demand is one of the key challenges cities in developing countries have to face. This challenge has been emerged especially in low-income sub-Saharan Africa, where high water scarcity goes hand-to-hand with inefficient use of water sources. The fact that despite effort made by local authorities and other public actors, demand for water has been growing with increasing population and economic growth, growing expectations of a growing middle class for better quality water service, leading to increased pressure to improved and sustainable allocation of clean water supply in African cities (Jacobsen et al., 2012).

Africa secondary cities are already facing water challenges and characterized by high population growth rate, less financial resources, and larger vulnerability to pollution and less managerial capability (CLOSAS et al, 2012). While as water consumption increases, water sources are becoming scarcer, the ground water table is dropping, and rainfall is declining in many regions in Africa, including Ethiopia (UNEP, 2010).

The current water scarcity, expected climate change impacts, and projected water demand require collaboration among all actors (household, industry, agriculture and services) to adopt effective and sustainable socioeconomic, technological, environmental and institutional interventions (Howe et al., 2011). One such example in water demand management is 'fit for purpose' action that promoted water saving while used for various purposes (Global Water Partnership, 2010; Maheepala et al., 2010; Vairavamoorthy et al., 2008). 'Fit for purpose' is typically used to fill a gap between growing demand and supply scarcity caused by competitive uses when investment capital is insufficient. In addition, water scarcity and a growing demand requires critical understanding of the value of safe water and the way households perceive how scarce it is, while residential water efficiency

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increases with investment decision on water using devices (MacKenzie, 2003; Lee et al, 2011). This implies that household's efficient water equipment choices or preferences and affordability matters water use behaviour at home. Such water management option is not only save money by reducing wasteful water consumption but also keep a cleaner environment (Martin et al., 2015). On the other hand, optimum water use with the existing supply scarcity in the residential sector necessitates a change in the water demand management approach i.e. decentralized decision-making (Arbués et al., 2003; Arbués et al., 2016; Dean et al., 2016; Ethiopian Ministry of water & energy, 2001). As water demand management option, this approach help to understand the drivers of water consumption and saving behaviour, specifically, in low-income community can also lead to taking steps to avoid wasteful use and increasing distributional efficiency to provide access to a large proportion of people without clean water sources (CLOSAS et al., 2012). All these need to design and implement effective policies for sustainable demand management options in the region where scarce investment capital.

In Ethiopia, a range of water demand management instruments have been implemented such as water conservation activities along with economic and non-economic measures (Ministry of Water & Energy, 2001). These demand management options are aimed to address the water scarcity problem, and promote efficient use at home and for agriculture. Therefore, examining how these tools are effective and affordable requires clear understanding of water use and saving behaviour along with key driving factors. In more details, our analysis was focused on two basic research questions across survey households in Hawassa i.e. what main factors affecting household water saving behaviour conditioned on water using devices and which factors most affect household water consumption? The details of analysis were made on the relationship between water consumption and socio-demographic factors, estimate income elasticity, quantify what water-using devices were on stock/used, how much water was saved while showering/using water from taps or in a kitchen sink?

4.2 Literature review

Literatures in the field of water management in terms of water savings and water use behaviour are uncovering important findings in the face of socio economic dynamics and consequential urbanization in developing countries (UNESCO, 2012).

Many studies have current publications in urban water savings in developed countries, specifically in Northern America, Europe and Australia (Willis et al., 2011; Nancarrow & Syme, 1989). Relatively small number of water efficiency studies have been published in developing countries where access to clean, reliable water source, and not affordable investment cost remain critical rather than water conservation issues (Saurí, 2013). However, this study has reviewed some more results that have shaded light on driving factors of water efficiency at home, mainly focusing on developing countries. In this regard, a research in the Wei river basin china (Fan et al., 2014) confirm that a negative relationship between high education level and water conservation behaviour, and knowledge gap among residents is a constraint to water conservation activities in Blagoevgrad, Bulgaria (Clark & Finley, 2007).

In India found that higher incomes, longer water-supply durations, and the belief on droughts prevention are positively associated with willingness to adoption of water-conservation behaviours and technology (Ramsey et al., 2017).

The size of the city, the education of the reference person and the climatic location of the city determines water savings behaviour at home, in Spain (Arbués et al., 2016).

Study across the member countries of the organization for economic cooperation (OECD) reveal that household component of water conservation achieved through installation of water efficient devices, if supplemented by water savings behaviour (Grafton et al., 2011). Using ordered probit analysis they estimated two models, forming a water demand equation with respect to the water use at price, income, water saving appliances ownership and family structure. Some more studies have also shown that installation and use of water efficient appliances (toilet, shower, tap and washing machine, etc.) change household water use characteristics accustomed with water conservation education program (Willis et al., 2011; Unity water, 2019).

According to Fidar et al.(2010) water efficient devices are the primary water conservation tools before regulatory measures such as tariff adjustments (Fidar et al., 2010), while more household's stock efficiency increase up to 25 percent water savings by reducing consumption. It is a low cost demand side alternative approach to measure individual consumption. Similarly, the four years longitudinal study underlines households with extra water savings technologies are more likely to have water savings behaviour at home (Lee et al., 2011). Mayer et al (1999) reported that water metering, water restrictions, and installation of water savings devices determine water saving habits at home. A relatively small number of studies investigate household water savings behaviour conditional on the stock of water using devices to evaluate how water saving habits and environment behaviour are related (Renwick & Archibald, 1998). They studied two-stage joint factor analyses in low flow toilets, showerhead, and new irrigation methods and the structure of households in water use. The covariates (both price and non-price) of policy measures that reduce water consumption were the relative effects of family size and income.

A household survey analysis in OECD countries (Millock & Nauges, 2010) predict factors that affecting adoption of household water using devices in relation to water conservation behaviour. They investigate drivers of the adoption of four water use devices (the washing machine, flush toilets, and low flow showerhead and rainwater collection tanks). The authors identified the drivers of adoption or an investment decision on water-using devices associated with socio-economic characteristics (age, education and income), attitudinal and behavioural variables (perception of environmental threats), price and non-price policy variables (money savings, water conservation habits, metering and labelling). According to them the environmental attitude and ownership status strongly predict the adoption of water efficient-equipment. Policy-related variables, metered and individually charged ones, have higher probability to invest in water efficient-equipment.

In Africa, (MacKenzie, 2003) examined the impact of water-efficient technologies in reducing water use for toilets at three basic measures such as low-volume toilet cisterns, dual flush toilet cisterns, and toilet retrofit devices.

An environmental attitude has a strong and significant effect on water savings behaviour and technology choices of householders (Willis et al., 2011; Heinrich, 2007; Gilg & Barr, 2006). The study findings indicate a positive environmental attitude and water conservation motive drives water savings behaviour. Ecological beliefs of an environmental attitude and water conservation behaviours are directly related (Corral-Verdugo et al., 2003) and soft policy options are also important tools since raising awareness by comparing the quantity of water-use among peers can stimulate water savings behaviour (Datta et al., 2015). In contrast, the argument rising because except the increase in specific water savings practices, less evidence in effect of environmental attitude on water conservation performance and overall water use (Grafton et al., 2009; Nancarrow et al., 1997)

On the other hand, policy instruments such as economic measures i.e water pricing and income determines household water demand, while non- economic measures include education, attitude, water using devices also determines water use efficiency (Bich-Ngoc & Teller, 2018; Ethiopian Water Sector strategy, 2001).

A book of water savings at desert cities has pointed that political battles determine the real water demand decision (Martin et al., 2015). As to several scholarly findings water pricing (tariff) policy as an economic tool encourage regulatory actions such as imposing additional water price to increase water efficiency and reduce wasteful use. In this regard, most results demonstrate that the water demand is a negative function of price in developed countries (Arbués et al., 2016; Dalhuisen et al., 2003; Espey et al., 1997). Conversely, some more studies reported water demand is price inelastic in developing countries. Meta-analysis (Arbués et al., 2016), household survey in Sri Lanka (Dharmaratna & Parasnis, 2010), and in Czech Republic (Hortová & Krištoufek, 2014).

Many researchers estimated income elasticity of water demand ranging from 0.051-7.29. Billings and Day (Billings & Day, 1989) estimated income elasticity at + 0.36. Billings (1982) estimated income elasticity at +1.68–2.14, Kulshreshtha (1996) at +0.051–0.123, Nieświadomy and Molina (1989) at +0.10–0.14, Hewitt and Hanemann (1995) at + 0.15, Agthe and Billings (1980) at +1.33–7.829, Renwick and Green (2000) at −0.01 0.25. Empirically, scholars estimated water demand with income as an economic factor reported interesting results. Hortova and Krištoufek (2014) estimated income elasticity for Czech households at +0.10 (2000-2011). Similarly, Havranek et al. (2018) in their recent meta-analysis research estimated the mean income elasticity at 0.15 and less for Czech residential water demand. Katzman in Penang Island, Malaysia (Katzman, 1977) estimated income elasticity of residential water demand at 0 for low per capita income householders (with less than 300 US dollar) and for high-per capita income householders at +0.2-0.4. Aisa and Larramona (2012) find that high-income households have less commitment for water saving habits in Spanish households and high-income underestimate actual water consumption in Wei river basin, China (Fan et al., 2014).

Some more literature sources indicated that non-price demand measures are water saving activities, socio-demographic factors, the use and ownership of water efficient devices and public regulations (Dessalegn, 2012; Adams, 2014; Willis et al., 2011; Inman and Jeffrey, 2006; Neiswediomy, 1992). As non-price instruments of water demand management options, public education and conservation activities have a significant impact on household water use patterns (Adams, 2014). Inman & Jeffrey (2006) have also pointed out the need for home water savings because of the increasing global water consumption, population size along with high growth rate of urbanization in developing countries. In Ethiopia, for example, efficient allocation of water resources assume the use of regulations to control water demand, promoting public awareness on importance of water, reduction of reticulation and other losses of water production, and efficient and sustainable water source use (Ministry of water & energy, 2001). However, in rural Ethiopia, these measures (pricing and non-pricing) may not be applicable in its full capacity, for the reason that large segment of the residents use non-piped water sources. In urban areas, there exists relative applicability of pricing policy to help promote distributional efficiency in residential water uses. Notwithstanding, few comparative studies analyse residential water demand in urban households in Ethiopia. Three decades ago, the analytical study in the same study area, in economic sectors containing residential sector indicates peak hours derives household water consumption (Mesfin Tegegn, 1988).

Socioeconomic and demographic variables, household expenditure, primary water source, retail business affects household water demand, in Northern Ethiopia (Dessalegn, 2012). Similarly, case study in Mekelle City, North Ethiopia revealed family size, education, and water source and distance from water sources determine household water demand (HIKMA, 2012). Case study in Addis Ababa, the Capital of Ethiopia reported that Management efficiency, effectiveness and institutional functionality of water utility affect the residential water demand (Berihanu, 2009). The novelty of this paper is an attempt to characterize water savings and consumption behaviour conditioned on owned water using devices along with main driving factors in the particular study area.

There have been significant variations in water use among the community because of the presence of water appliances for pipe-connected households. The estimated household per capita water consumption (lpcd) in developing countries for pipe-connected householders varies across regions. For example, in Cambodia 72 litres per capita per day (lpcd) in a group of provincial towns (Basan et al., 2008). In Fianarantsoa, Madagascar 88 lpcd (Larson et al., 2006), in Buon Ma Thuot, Vietnam 120 lpcd (Cheesman et al, 2008), in Salatiga City, Indonesia 130 lpcd (Rietveld et al, 2000), and in urban areas of medium cities from three districts in Southwest Sri Lanka, Gampaha, Kalutara, and Galle 135 lpcd (Nauges & van den Berg, 2007). In East Africa region on average 64 percent, piped households have a flush toilet and they use 19.2 litres per capita (Thompson, J. and Porras, 2001). This is the lowest per capita consumption compared to developing countries.

4.3 Data description and Methods

4.3.1 Residential water sources of Hawassa

Water scarcity and access to potable sources are the basic administrative challenges of Hawassa city administration. The growing income and annual growth rate of 4.02 population along with fast growing urbanization and socio-economic dynamics cause increase in water consumption. Despite tremendous efforts and measures taken by the city municipality, the optimum allocation and water access to the majority of residents in the study area was not adequate. The total water system connection was 29,789 with a pipe network length of 272 kilometres in 2016. The city water access coverage was 64.86% with 36 litters of average per capita consumption. The residential customers connected to a pipe water system were 23,043 people (58 percent) and the rest were non-connected residents who use different water sources (Annual statistical report, 2014).

The total annual water use from the pipe connection as of 2014 is 3,406,893 m3 and in the study area, on the other hand, non- efficient use of this scarce water supply result in water loss up to 15 percent from annual water production, which could have been used for needy households (South Ethiopia water Bureau inventory report, 2015). According to the inventory assessment report, it has been the most felt challenge to the municipality and necessitates more attention to design demand management strategy to reduce wasteful use of scarce domestic water supply.

The water tariff structure applied in Hawassa is increasing block rates, for which, the large city category with a population of above 100 thousand inhabitants apply. Note that in Ethiopia IBR vary with the size of the city or towns (Ministry of Water & Energy, 2013). The five residential Increasing Block water Tariff (IBR) applied for the respective water consumption in litres presented as follows. The first block 3.00 Birr (5,000 litres), the second block 3.50 Birr (5,000- 10,000 litres), third block 4.50 Birr (10,000-15,000 litres), fourth block 5.00 Birr (15,000-12,000 litres), fifth block 5.50 Birr (>20,000 litres).

4.3.2 Sample design

The purpose of the survey was to conduct an empirical research on household monthly water use (in litres) and savings behaviour measured in terms of performed water saving habits among the study households. We collected the required research data by asking questions about how they would behave in water-use practices in line with (Tingyi Lu, 2007; Whittington et al, 1990; World Bank Water Demand Research Team, 1993). The research data comes from a cross-section household survey conducted in April 2014 by the authors in collaboration with Southern Ethiopia Water Resources Bureau.

Our research in this part of dissertation use two stage-sampling procedures for the selection of observation units. Firstly, seven administrative sub-cities were selected using purposive sampling techniques (Menehariya, Bahile Adarash, Tabore, Hayk dare, Addis Ketema, Misrak k. Ketema and Mehal Ketema). Secondly, we purposively selected 14 kebeles (two kebeles per sub-city) as there are connected households in all kebeles. We calculated the proportion of the number of households in each kebele to the total number of households in the kebele and we used this proportion to determine the number of sample households to be included in the sample. Finally, we randomly drew a sample of 200 adult respondents from 14 kebeles. We excluded households using additional water sources, non-pipe connected households and other primary source users. We also excluded the seasonal variable due to limited time and resources. Data collectors carried out the mapping of the survey households, and randomly visited selected sample houses and made contact with the reference person mostly the head of the household, either male or female.

4.3.3 Definition of variables in the model

Household water consumption: The quantity of household water use in litres/cubic meters is a key dependent variable in this study. This variable measured by the combination of monthly water consumption obtained from the information on water meter (Birr/m3). For all connected households the consumer pays monthly service charges. The price per unit consumed is considered to quantify the volume of water used in a monthly tariff rate and the water bill is given by the quantity of water used multiplied by the unit tariff rate set by the water utility or provider.

Water-using devices: owned or installed flush toilet, a flow tap, a shower, a dishwasher, a bath and washing machine

Water savings behaviour conditioned by frequency use of owned water-use devices: The dependent variable in this case are the three indoor water saving performances. These are: **tap water saving** (actions taken to avoid unnecessary tap water flow during hygienic use; brushing teeth, face and hand washing, if unnecessary), **shower saving**(avoid water overflow when taking a shower or taking a short shower), **saving kitchen sink** (control extra water use when washing the dishes in the kitchen before food preparation and after).

Socioeconomic variables: age, family size, occupation, income, water consumption, water expenditure

Environmental attitude variable: Agreement on household responsibility to conserve water, agreement on water scarcity, and agreement on the willingness to pay in cash for water protection, joint agreement on water source protection with the municipality, awareness of the environment pollution protection.

4.3.3 Model specification

First, to estimate the drivers of water savings behaviour, we use logistic regression, also called a logit model, for dichotomous outcome variables. Using the logistic regression model, the log odds of the outcome estimated as a linear combination of the predictor variables. Empirically, our data set for the dependent variables had ordinal responses for water saving indexes with never, occasional, often and very often categories. Nevertheless, using ordered logistic or multinomial logit estimation result does not achieve convergence, because of small sample ordinal data. To overcome this limitation, we used a simple binary logit model by creating dummy dependent variables in order to achieve convergence for the estimated results (Datta et al., 2015; Opitz, et al., 1999). The three dummy dependent variables of water savings behaviour with binary discrete outcome coded with the value 1 if respondents performed water saving activities often and very often, 0 if respondent never and occasionally performed).

We use a Maximum Likelihood (ML) estimation to find the parameter value that gives the distribution that maximizes the probability of observing data. Secondly, using multiple regression analysis we estimated the household water consumption with more than two explanatory variables or covariates (Renwick & Green, 2000; Renwick & Archibald, 1998). In this analysis, we have estimated the variation in water consumption as the dependent variable in the left hand side of the equation. Income, socio-demographic, the number of water-use devices owned and the environmental variables were factors or covariates of the demand model. We use the log-log demand model specification

$Q = f(P, X, Y)$

Where, Q - Quantity of water demand, Y - household income, X – other socio-economic characteristics with the parameter estimate for Y interpreted as income elasticity

4.4 Results

4.4.1 Two sample t test of the respondent's socio economic profile

Table 26 present the summary statistics of the sample survey and a two-sample t-test for two group comparisons (water system connected vs non-connected) across households in Hawassa. According the survey result, the average monthly income of the household that connected to a water system was 4075 ETB and non-connected householders earn 1777 ETB given an average family size of five and four respectively. This gives a monthly per capita income to be 815 ETB and 419 ETB for connected and non-connected households respectively. The simple majority of the respondents (52 percent) were male for connected and (60) percent for non-connected ones. Both groups did not significantly differ in age category with 38 being the average age. Monthly household water consumption varies between 350 and 66700 litres. The mean comparison between connected and non-connected respondent's average monthly water consumption exhibits a significant variation. Water-system connected households use more water than non-connected ones. The education variable has a significant variation between the two sample groups. Regarding the education variable, 84 percent of connected households completed secondary school and higher than secondary school education while only 37 percent of non –connected respondents completed secondary and higher than secondary school education level. See table 1 for the two-sample t-test with equal variances for continuous and dummy variables. The mean comparison of the two groups in terms of the average water consumption per capita per day in person was 54 and 22.5 litres for connected and unconnected[4] households respectively (exhibits a significant variation).

As to the budget share of the two groups, the report indicated 1.14 and 0.88 percent for connected and non-connected ones respectively. This implies that on average a household spends only 1 percent of its monthly income on water supply. This is the lowest water expenditure rate compared to the World Bank's, which describes affordable tariffs if a monthly bill based on subsistence consumption absorbs no more than 5 percent of the household's budget (Opitz et al, 1999). The households in the study area can thus afford to spend more if they provided with improved water access. We know that the water supply in developing countries is highly subsidized and the subsidy meant to cover operation and maintenance costs. Non-connected respondents spent a slightly lower proportion of their income than connected respondents do. This output, therefore, proves that high-income groups spend more share of their income on water supply compared to their counterparts. As to respondent's living home, non-connected respondents were more likely to live in a rental house (government rental home[5]) (17 percent) compared to connected respondents (7.1 percent). Nearly 34 percent of connected respondents employed in private business activities, while 26 percent of non-connected households employed in private business activities.

[4] Non-connected households failed to comply with the United Nations recommendation that a human being needs 50 litres of water per day in order to prepare meals and to have enough for personal hygiene. 50 litres of water per day are necessary in order to avoid diseases and to retain efficiency(source: Institute water for Africa; http://www.water-for-africa.org)

[5] Government providing rental homes are mostly for low income group of people or households

Table 26: Two sample t test of respondent's socio economic profile

	Connected			*Non-connected*			*Two-sample t test*	
Variable	Ob	Mean	St.Dev	Ob	Mean	Std. Dev.	t test	P value
age	168	38.41	9.50	32	38.94	10.19	0.28	0.777
Male is head	168	0.65	0.48	32	0.75	0.44	1.11	0.269
respondent is male	168	0.52	0.50	32	0.59	0.50	0.72	0.470
Household size	168	5.18	2.26	32	4.38	2.31	-1.85	0.066
Education	168	0.84	0.37	32	0.60	0.49	-3.25	0.001
income(Birr)	168	4075.05	2392.09	32	1777.63	879.75	-5.36	0.000
Budget share	168	1.14	1.07	32	0.88	0.69	-1.36	0.175
Private business	168	0.34	0.47	32	0.22	0.42	-1.34	0.182
Rental agent	168	0.07	0.26	32	0.13	0.34	1.02	0.308
Joint responsibility	168	0.74	0.43	32	0.65	0.48	-1.02	0.300
water consumption	168	8558.67	8955.43	32	2964.68	3562.85	-3.47	0.000

Note: Description of variables[6]

As we can see in table 26 the environmental perception variable (joint responsibility) indicated by agreement between householders and water utility to ensure a sustainable water supply to the community in the study area. Both householders perceived comparably that 74 percent of connected households agreed and strongly agreed for joint source protection, while 65 percent non-connected respondents agreed and strongly agreed to do so. The mean comparison from the two sample T-test in this case shows that there is no statistically significant variation between connected and non-connected respondents. In Table 21, we can see the output of the two-sample t-test with equal variances for continuous and dummy variables provides useful descriptive statistics for the two groups (connected vs non-connected respondents) that we compared, including the mean, standard deviation as well as the actual results from the independent t-test. We can see that the group means are

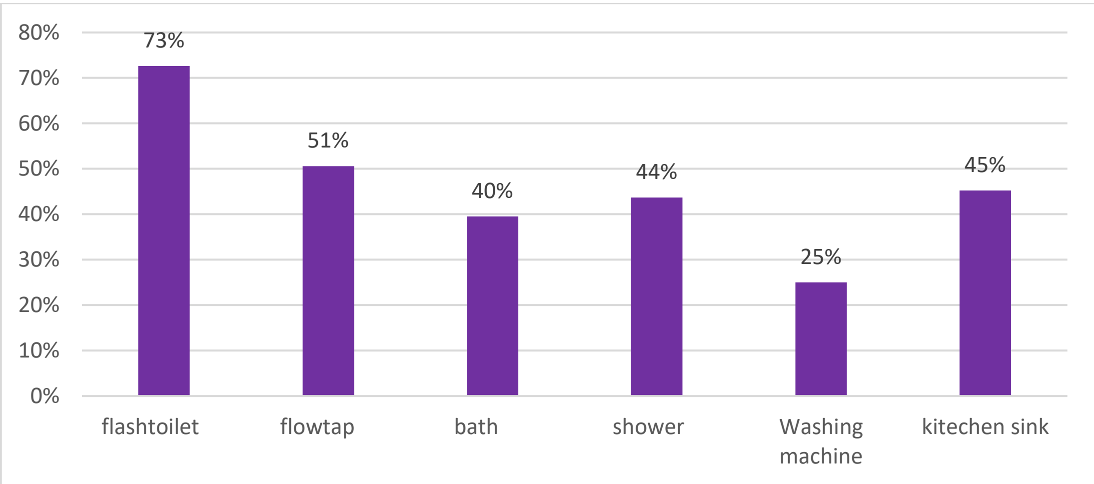
[6] Dummy variable male is head represent the decision maker of the respondent's household (head= 1 if the respondent is male, 0 if the respondent is female). Dummy variable respondent is male indicates the gender of the respondent head (if male=one and zero=female). A continuous variable household size meant a total number of people living in the respondent ́s household. Education variable coded as (1 if the respondent's level of education is secondary and college education and 0 if the respondent has primary education and can read and write). Respondent's occupation for living is coded as private business (dummy variable =one if respondent ́s occupation is private or he/she owns a business, zero=otherwise), and housing variable coded as rental agent (dummy =one if the respondent lives in a governmental rental home, zero=otherwise). Budget share is a proxy variable for household expenditure (monthly percentage ratio of water expenditure to respondent's household income).

significantly different as the p value in the Pr (T > t) row (under Ha: diff! =0) is less than 0.05 (based on the two-tailed significance level). Looking at the mean column, we can see that those people who do not connected to the pipe water supply had lower income, education, family size, private business participation and less water consumption.

4.4.2 Percentage distribution of water-using devices

Figure 27 presents the stock of water-using devices by the survey householders. The majority of the respondents own a flush toilet[7] and half of them were equipped with a flow tap. Respondents were almost equally equipped with a kitchen sink and shower-water devices while less than half of the sample respondents owned a bath-water device. Fewer respondents were equipped with a washing machine.

Figure 27: Percentage distribution of water-using devices



Source: household survey (2014)

4.4.3 Count and each water-using devices by income quarters

Each and count water-using devices by income quarters presented in Table 28. The results show that 25 percent of households in the highest income quarters (Q4) owned twice as many flush toilets as those in the lowest income quarter and a quarter more kitchen sinks than those in the lowest income quarter (Q1).

[7]Note: Of all water use devices; flush toilet, the necessity device owned three times higher percentage distribution than all other devices.

Table 28: Water- devices each, total count and by income quarters

Water device	*Q1(0-25)*	*Q2(25-50)*	*Q3(50-75)*	*Q4(75-100)*	*ALL*
Flush toilet	45	76	81	89	73
Flow tap	21	52	57	73	51
Bathing	4	16	25	21	45
Showering	5	20	25	21	40
Washing machine	4	12	12	14	25
Kitchen sink	12	18	25	21	45
Total count devices	1.26	2.84	3.23	3.76	2.77

Source: household survey (2014)

We can also see that total count water-using devices at home with count means by income quarters in table 28. Households connected to water system who were own at least one of the six water-using devices vary with income classes. The comparison of income and total devices exhibits a significant variation between poor and rich householders while 25 percent of households with the highest income quarter (Q4) own twice the amount of water devices compared to the 25 percent lowest income quarters.

4.4.4. Weekly frequency use of water-using devices

Water use frequency of each water-using device illustrated with the mean, standard deviation, minimum and maximum values in table 29. Flush toilets and tap water used on average three times a day whereas households took a bath, a shower, or washed clothes only twice a week. The survey result shows that some water appliances such as flush toilets, kitchen sinks, and flow taps used very frequently each day. The frequency use of these water-using devices added on a weekly basis per respondent household. However, washing machines, showers and baths do not used each day in the study areas.

Table 29: Weekly frequency use of water-using devices, N=168

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
Flush toilet	25.6	5.3	15	35
Using a flow tap	19.1	7.4	1	35
Bathing	1.3	0.6	1	3
Showering	2.3	0.9	1	5
Washing-machine	1.6	3.1	1	21
Kitchen sink	15.6	6.5	1	30

4.4.5 Frequency distribution weekly water-using activities by income quarters

Table 30 present an immense variation in water use frequency across survey householders against income quarters. The result clearly shows higher-income quarters exhibits a higher water use frequency among equipped households in comparison with low-income groups.

Table 30: Weekly frequency use of water-using activities by income[8] quarters

Frequency use	*Q1(0-25)*	*Q2(25-50)*	*Q3(50-75)*	*Q4(75-100)*	*ALL*
Flush toilet	10.50	18.00	21.00	20.80	25.60
Flow tap	5.19	9.64	10.89	14.00	19.10
Bathing	0.14	0.42	0.84	0.75	1.30
Showering	0.26	0.97	1.31	1.48	2.30
Washing machine	0.14	0.31	0.27	0.91	1.60
Kitchen sink	4.70	6.20	8.2	9.40	15.60

Fourth quarter income category householders (Q4) have a double water use frequency of flush toilets, flow taps and kitchen sinks than those in the first quarter (Q1). A shower-taking and bathing frequency by 25 percent of the highest income quarter (Q4) is five times more frequently than the 25 percent of the lowest income quarter (Q1) while the washing machine water use frequency in the highest income quarter (Q4) is six times larger than in the lowest income quarter (Q1). Total weekly water use frequency presented in the table 3 again proves that 25 percent of the highest income group is twice the mean of the 25 percent lowest income quarters.

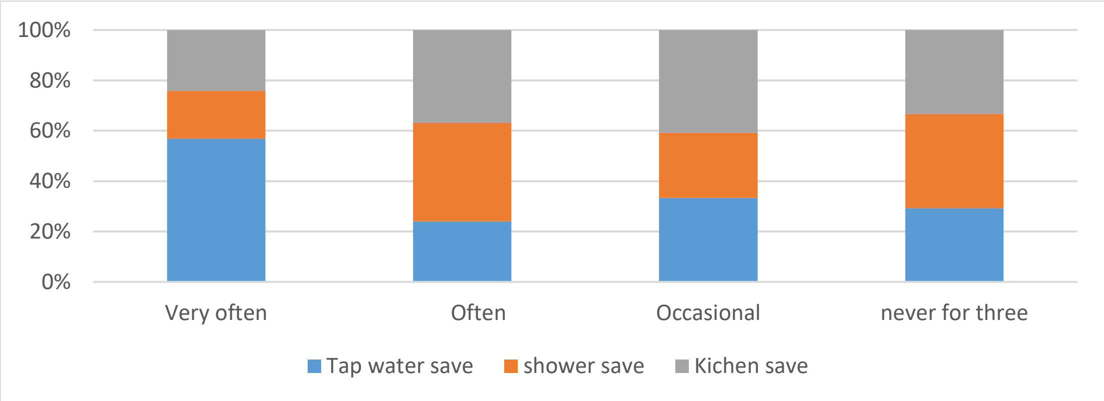
4.4.7 Water savings behavior based on owned water-using devices

Household water savings habits are the main dependent variables used in this study. The water savings behaviour measured in terms of three indexes present the percentage distribution of water saving performance conditioned on water-using devices.

[8] Note: Income inequality has a significant impact on the water-use frequency and the use of luxurious water devices such as baths, showers and washing machines.

Figure 28 present accordingly the answer to the performance index[9] question; turning off the tap while brushing one's teeth and for hygienic use was reported to never be performed by 48.5 percent, occasionally to be performed by 13.1 percent, often to be performed by 11.31 percent and very often to be performed by 26.79 percent. The second performance index question was whether the households avoid unnecessary water flow while soaping in the shower or taking a short shower. In this regard, 62.5 percent of respondents said they never do it, 10.12 percent occasionally, 18.45 percent often and 8.93 percent of them do it very often. As to water saving in the kitchen sink, 55.36 percent responded never to turn off the tap, 16.07 percent to occasionally do so, 17.26 percent to do so often and 11.31 percent did so very often.

Figure 28: Descriptive statistics of respondent's water saving performance at home



Source: Household survey, 2014

4.5 Estimate of water savings behavior and water use

We use two econometric water-modelling approaches in this study. Firstly, using the logit model we estimated the relationship between the explanatory variables and the water savings behaviour. The models estimated the relationship between the covariates and the dependent variables where each of the dependent variable is on the logit scale.

The binary dependent variable coded as **save tap (**Model 1**):** turning off the tap to avoid wasteful water use in the hygienic interval (brushing the teeth, face and hand washing). Saving water while showering**, save taking shower (**Model 2**)**: avoiding unnecessary water

[9] Note: Tap water save ; represent water savings activities while brushing teeth, washing face and hands, shower save denote avoiding unnecessary water flow while soaping in the shower or taking short showers, and kitchen save designate avoiding running water in the sink when washing dishes before and after cooking meals to save water

flow while taking a shower to save water, and **save Kitchen -sink (**Model 3**)**: saving water while washing dishes and cooking food in the kitchen.

Table 30: Models and Estimated coefficients from logit models-survey data.

Covariates	*save- tap*		*save- taking shower*		*save-kitchen sink*	
	Coef.	Std.Er.	Coef.	Std.Er.	Coef.	Std.Er.
age	-0.09	0.019	0.02	0.019	0.013	0.018
Head is male	-0.35	0.356	-0.40	0.351	-0.39	0.340
Household size	0.07	0.081	0.08	0.0798	0.16^{***}	0.080
income	0.22^{***}	0.086	0.15^{***}	0.07	0.046	0.072
Budget-share	0.24	0.182	0.10	0.159	0.15	0.159
Higher education	0.91^{**}	0.532	0.60	0.539	0.62	0.482
Joint responsibility	0.73^{**}	0.394	0.69^{**}	0.415	0.23	0.381
_cons	-2.23	1.036	-2.53	1.059	-2.37	1.006
Likelihood ratio test Chi-square (1)	26.48		15.58		13.33	
	[0.000]		0.029		0.064	
Prob> Chi-square	51.4		36.2		44.3	
Number of cases 'correctly predicted'(percent)						

Note: * P≤0.05, ** P≤0.01, *** P≤0.001 represent significance at 10, 5 and 1 percent level, respectively.

The logistic regression results in these three models estimated coefficients, and the standard error and p-values of the t-test if coefficients were significantly different from zero. In addition, we run model diagnosis tests; the likelihood test, number of cases predicted, and multicolinrarity using the Variance inflation factors (VIF).

The results in Table 30 shows the drivers of water savings at home in the three models conditioned on water-using devices. In this part, we have the dependent variables with binary outcomes. The estimated results from marginal effect exhibits kitchen water saving increase with large family size. The estimated coefficient for average monthly income indicated an increase in tap and showering water savings. Similarly, the parameter estimate of the budget share variable, proxy to monthly expenditure indicates a rise in water saving habits as more budget share spent on water but not statistically significant.

The coefficient estimate of the factor variable of higher education shows a positive effect on tap water savings behaviour. Secondary and college education has a significant effect on tape water savings and non-significant but positive effect on showering and kitchen water savings as well. The factor variable environmental attitude (joint responsibility) has a positive and significant effect on tap and shower savings. The parameter estimate of variable age has a positive sign for showering and kitchen water savings while a negative coefficient for tape water savings. The estimated coefficient for a dummy variable household head type (head is male) with a negative sign indicate that male-headed households are lower water saviours than female. However, the variable age, household type, and budget-share variable in all models exhibited a statistically insignificant result.

4.5.1 Marginal effects of water savings

We estimate the marginal effects of logit models to analyse the variations in more details; we calculated the marginal effect value of each significant covariate or explanatory variables in the three indoor water savings behaviour. These estimations measured in terms of the increase in the predicted marginal effect. In each indoor water savings behaviour designated by value 1 is the probability of prediction by a unit increase in the predictor, holding all other predictors constant. We considered the covariates that are not significantly different from zero when interpreting the coefficients. The result in the parameter estimate of marginal effect predicts that the probability of water savings habit increase by 4 percent if the respondent's family has one additional person in the household**.** Thus, the water saving performance in the kitchen exhibit statistically significant result.

Table 31 Estimated marginal effects-survey data.

Variable	*Save tap water*		*save shower water*		*Save kitchen water*	
	dy/dx	Std.Err.	dy/dx	Std.Err.	dy/dx	Std.Err.
Age of respondent	-.00216	00481	.00037	00445	.003121	.00452
head	-.08772	.08783	-.09427	.08297	-.0983212	.08412
Household size	.01725	.02036	.018608	.01842	.0412616**	.01986
Income	.000554**	.00002	000034**	.00002	.0000115	.00002
Budget-share	0604699	.04556	.0236979	.03692	.0366412	.0394
Higher education	.2274023*	.1332	.1308507	.10591	.1465838	.10773
Joint responsibility	.1830383*	.09402	.1505725*	.08364	.0573202	.09243

The econometric result predicts the differences in monthly income of the respondents. The water saving performance in tap water and showering increases by 1 percent and 3 percent for 1 birr or 0.03$ change in income respectively. The coefficient for the variable income show a positive and statistical significance at the 5 percent level in both cases (tap water saving and shower saving). Higher education, a factor variable coded with value 1 if the respondent (household) had secondary school and college education zero for primary education and read and write. Higher education showed a positive coefficient and significant at 10 percent significance level in the tap water savings. The estimated marginal effect result revealed tap water savings increased by 0.227 for the reference person having secondary and college education.

Agreement on the joint responsibility with coded value 1 if the respondent strongly agreed, and a 0 if the respondent do not agree as a factor variable whether to predict water savings performances. The econometric result revealed that estimated marginal effect predict the probability of tap water savings and showering to rise by 0.18 if the respondents have agreed on joint responsibility (with water provider or municipality) to protect the community water sources.

4.5.2 Estimated results of water use

To estimate household water consumption variation, we used multiple regression (Ordinary least square estimator) controlling income elasticity and other socio-demographic variables, water using devices, and daily water saving frequencies. Table 26 presents the estimates of water consumption factors controlling for age, household head type, household size, income, education, number of water devices, and water saving frequency (saving once and saving twice a day).

Collinearity test: The generalized variance inflation factors (GVIFs) checked for each regressor. The GVIFs ranging from 1.0 to 2.0 for all explanatory variables in the model indicates that multicolinrarity is not a problem. We also run Lawley chi2 test and the result shows the correlation matrix is compound symmetric (all correlations equal). Lawley chi2 (20) = 70.80 with Prob > chi2 = 0.0000. The test result indicating that none of the explanatory variables interacts with each other. The overall model significance is estimated to be (R^2=0.2978) 29.78 percent variation in water consumption across survey households and is explained by independent factors.

Table 31: OLS estimates of water consumption (n=168)

lnQ10*	***Coef.***	***Std. Err.***	***t***	***P>t***	***[95 percent Conf. Interval]***	
age[11]	-0.014	0.006	-2.210	0.028	-0.026	-0.001
Head is Male[12]	-0.098	0.119	-0.820	0.414	-0.334	0.138
Household size	0.091	0.027	3.310	0.001	0.037	0.145
Lninc*13	0.235	0.123	1.910	0.058	-0.008	0.478
Higher education	0.205	0.180	1.140	0.257	-0.151	0.561
Save once(very often)	-0.118	0.153	-0.770	0.442	-0.420	0.184
Save twice(very often)	-0.228	0.237	-0.960	0.338	-0.697	0.240
Number of water devices	0.139	0.042	3.290	0.001	0.056	0.223
_constant	6.411	0.956	6.710	0.000	4.524	8.298

Source: Authors estimation based on household survey (2014)

The socio-demographic variables (age and household size) were statistically significant predictors of monthly water use across survey households in Hawassa. Water use is negatively correlated with age, while household size with a positive sign. Old people uses less water than younger people and a large family size led to additional litres of water use. The coefficient estimate for count water-using devices indicate a positive and statistically significant result, while more stocks of owned devices increased water use in the house. Income was an important factor of water consumption in this analysis, where we found as a key predictor with the income elasticity of water demand at +0.235 showing wealthy families use more water than their counterparts do. The result is similar to other reports for example in Dar es Salam, Tanzania high-income people 15 times more per capita water use than low-income people do (UNDP, 2006). Similar findings on a positive income effect has cited from (Havranek et al., 2018; Dalhuisen et al., 2003).

In our analysis, we found statistically insignificant but interesting variables in water consumption model with their coefficients. These are water saving indicator variables (saving once and saving twice[14]), household head type, and education. If householders

[10] Note: The dependent variable **lnQ** represent log of monthly quantity of water consumption in litres.

[11] Variable **age** stand for respondents year of age,

[12] Dummy variable head is **male** represent respondent's household type coded as male=one, if household head type is male and zero otherwise.

[13] Monthly log income of the household designated by code **linc.**

[14] Save once and save twice; denotes the average daily water savings frequency with most relevant responses (often and very often) using three devices(tap, water and kitchen sink)

performed water saving activities very often once and twice a day, they use less water. If women is the family head or decision maker, less likely water use at home while highly educated people use more water than low educated ones. There was no effect of other covariates such as the reference person's occupation for living, house-ownership and gender differences.

4.6 Discussion

In this paper, we examined the drivers of residential water savings behaviour and water use based on the household cross-section survey in Hawassa. As to the outcome variable water savings behaviour, the differences in water budget share and socio-economic characteristics show a significant effect. From the economic variables, the differences in budget share has a positive effect on water savings performance but not significant. Our results confirm that household expenditure on water has a positive effect on the probability of the water saving performance. The differences across survey household's income capture a positive and significant effect on household water savings consistent with (Arbués, et al., 2016). In contrary to this finding, the income impact of water savings empirically argued that higher income leads to less commitment on water savings at home (Adams, 2014; Aisa and Larramona, 2012).

The differences in family size has a positive and significant effect on water saving habits. Specifically, the more family members in the household, the more likely is the kitchen sink water saving performance. A previous study in this regard has pointed that the increase in population size necessitates water conservation habits in developing countries (Inman & Jeffrey, 2006). The variation in the respondent's education level has a positive and significant effect on water savings behaviour. In the study area, we expected that education would create job opportunities and then people earn income to purchase water efficient devices. People that are more educated can understand water scarcity problems better and use water wisely thereby increase water efficiency. The result is consistent with other studies indicating a positive effect of education on water conservation choices and investment decisions on water efficient devices (Lam, 2006; Millock & Nauges, 2010). In contrast to these results, others argue that higher education level does not prove a significant change in water savings behaviour and underestimate the actual water consumption (Adams, 2014; Fan et al, 2014).

If household and the municipality agree on joint responsibility to ensure sustainable water source protection, there is a positive and significant variation in water saving performance at home. This is consistent with other studies result that motives drives direct and significant pro environmental behaviour (Willis et al., 2011; Corral-Verdugo et al., 2002) that environmental attitude performs better in areas where high water scarcity. Conversely, some more studies favoured to have a negative and indirect relationship between the environmental attitude and water conservation habits (Ramsey et al., 2017).

The results from the water use model indicate that the socioeconomic differences, the total stock owned water-using devices and water conservation activities were identified as the main driving factors of household water use and the demographic variable age and household water use were inversely related while previous studies found the same result (Lman, 1992; Nauges and Thomas, 2000).

For a household head type is being a female was negatively associated i.e female head or decision maker less likely household water use. In the study area, men were believed to be less careful than women in water consumption were and women use less water than men do, since women are responsible for availing water in the household.

The study results indicated that the reference person's high education level led to more water consumption. People with higher levels of education usually believed to keep personal and environmental hygiene at home leading to more water use. Household water use may vary with the number of people living in the household. The increase in family size will increase water use and it is consistent with similar studies (Dessalegn, 2012). This implies that, the probability of per capita water use decreases. Income and water consumption variability has a direct relationship. High-income families consume more water than low-income families. This is consistent with the sub-Saharan African city, Dar es Salam, Tanzania where high-income householders use fifteen times higher per capita than poor householders (UNDP, 2006). Water saving performance induces reduction in quantity of home water use. Householders having positive perception with very often water saving activities at least once a day or twice a day was associated with less water use. This is consistent with other studies finding by Heinrich (2007).

4.7 Conclusion

Household water use and savings behaviour are important policy variables when meeting the growing water demand and to promote distributional efficiency in countries where large segments of population are under low-income category. In this study, the drivers of urban water use and savings performance from estimated data captured the variation in socio demographic and economic characteristics (age, income, education, and family size, water-using devices) and environmental attitude variable(joint responsibility). From the predicted marginal effect, we conclude that large family size increases 4 percent kitchen water saving performances, and a positive and significant income effect on tap water and shower savings performances. The marginal effect of education on tap water savings performance was positive and significant, while joint agreement between the householders and the municipality contribute to a sustainable water supply, which affects both the tap and the shower water savings at home positively. As to the drivers of water use, large family size, number of count stock of water-using devices, and wealth at income elasticity +0.235 drives positive and significant variation in household water use in Hawassa, while demographic variable age significantly affect water use at home with a negative sign.

Lastly, the study result implies that policy instruments should rely on quantified characteristics and driving factors of household water use and savings behaviour based on generated information from cross-section survey. The findings will contribute as secondary source document to promoting sustainable and efficient water management options in cities of low-income countries.

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5. Summary of study results

The objective of this dissertation is to contribute to the better understanding of household's energy choice decision, water use patterns and water savings habit along with environmental changes.

The key approach followed in this thesis is modelling household survey data based on stratification of socio-demographic variances, income, geographic location (urban vs peri-urban), and environmental dimensions.

The main energy related data are generated from household survey to identify the patterns of energy choice based on the three main energy sources; electricity, charcoal and fuelwood along with driving factors. Using multinomial logit estimation the key drivers of fuel source choice or substitution were household income, fuel budget share, education, geographic stratification, level of education, gender, family size, information or knowledge on alternative fuel sources. Specifically, the demand for electricity source is directly associated with the variation in budget share for fuel expenditure across households; reflecting the increase in modern energy source use while low energy budget share is associated with fuelwood consumption.

Electricity as cooking source is rising with increasing income. Households in the high-income class afford to purchase and own modern energy cook appliances while low-income households yet rely on inefficient fuel sources; fuelwood and other biomass (leaves, agricultural residues, etc.)

Our study finding clearly indicates electric source for cooking is more likely increasing in urban areas than peri-urban ones. Solid fuel substitution is partially progressing and fuelwood consumption is predominantly cooking source for peri-urban households. This indicates climate mitigation scenario is relatively better improvement in urban areas than peri-urban areas. Large family size in contrast, found to have inversely related to electric cook source; instead, they more likely depend on multiple fuel sources mainly fuelwood. In this regard related study by Heltberg (2004) stated that household energy choice describe with family size, composition and diversification in the context of developing countries.

Unexpectedly, information or knowledge about alternative energy source has indirect impact on modern fuel consumption. This may indicate modern fuel source need more investment capital. Gender relationship with electric cook source mainly goes with male headed is negative. Male-headed households do have less electric cook sources than women headed do. As to the relationship between family decision-making and cook energy sources, electric cook source has positively associated with men decision making, while men decision-making has direct effect on charcoal use for cooking.

The relationship between gender and charcoal fuel source is significant. Female-headed households use less charcoal than male-headed ones. This variation could be because in the study area household decision-making is mainly the responsibility of men, while women are economically dependent on others decision and cannot afford or make purchase decision for commercial fuel source.

The demographic variable age and charcoal use for cooking are directly related and significant. Mostly old people use charcoal for cooking compared to young people.

In urban areas, it is clear that the share of household's charcoal choice increases relative to peri-urban areas. This suggests that in urban areas fuelwood source is becoming scarce because of the increased demand associated with migration or population movement from peri urban to urban.

Our results show that a large number of family size less likely rely on charcoal sources for cooking demand. Here, an important factor is affordability related to household purchase decision. In the study area, charcoal is highly commercialized fuel sources, specifically in the urban areas. In contrast, fuelwood source dominates household cook fuel demand in peri-urban areas. In Peri-urban areas, a decrease in demand for charcoal may be associated with access to self-collected or home-grown biomass fuel sources.

Knowledge and information on alternative fuel sources other than biomass energy lead to less demand effect on charcoal sources for cooking. The consumer's awareness is positively associated with environmental pollution protection or reducing a negative health effect of using charcoal fuel source.

The findings related to key factors affecting the patterns of household energy consumption include among others, significant were income, budget share on fuel expenditure, count electric appliances, and energy saving cooking methods.

Ordinary least square (OLS) with log forms were used to estimate the relationship between energy use and the driving forces. Our study result shows positive and increasing relationships between income and electricity consumption with income elasticity at +0.246. This is clearly suggests when income of households increase, more likely electricity use for various purposes. In the cases when people spending more budget share on energy supply, it does not affect the increasing consumption because the fuel expenditure is not the main issues rather clean energy supply matters.

Our research result is in line with the economic theory, the rise in prices of a commodity the quantity demanded for that commodity decreases if other things remain unchanged. This shows that the demand for necessity goods does not vary too much with price changes. However, an increasing stock of count electric appliances will lead to consume more electricity. If householders own or purchase electric appliances, for example, electric stove, Injera mitad, refrigerator, television, etc. increase the intensity of electric supply consumption. Consumer behaviour related to knowing energy save cook methods determine electric consumption as expected while people's positive perception on energy savings in terms of using energy saving cook methods encourage reducing electric consumption thereby increasing household energy efficiency.

The results revealed that charcoal consumption significantly vary with household income. Income is one of the strongest and significant determinants of charcoal consumption in the study area at income elasticity of +0.124, while high-income households consume more quantity of purchased charcoal in kilograms compared to low-income households. Age of household heads turned out to be significant, where old people use more charcoal for cooking along with (complemented) space heating to warm their house.

The results also clearly indicated that the effect of budget share on charcoal consumption; whereas low-income households spend a high proportion of their budget on energy supply will lead to a reduction in charcoal use substantially. Nevertheless, like electricity demand, budget share on charcoal expenditure does not affect its consumption. This can be justified for charcoal is competitive substitute fuel type, where electric interruption is the most common problem in urban areas, specifically in the study region. The controversial effect of charcoal expenditure (price change) in low-income countries may be associated with the

competitive nature as a modern fuel source such that its consumption continue with increasing income.
As established from the survey data the main drivers of fuelwood use in the study area were age of household head, marital status of household head, income, and budget share on fuel expenditure. Likewise, in charcoal does, age structure determine fuelwood consumption at the household level.
Fuelwood use and family relationships have important and significant correlations. Married people consume less per capita fuelwood than other family relationships. Demand for fuelwood consumption vary with household income at income elasticity +0.278. Rich people still dominate energy consumption either modern or traditional sources. In economic theory, demand for energy at the household level is a function of income and access.

The effect of budget share on fuel expenditure exhibits direct relationship with fuelwood consumption. Increasing budget share on energy will lead to households to purchase different fuel sources including fuelwood. It also suggests whatsoever increase the cost of fuel sources rich households spend more income to satisfy the increasing household energy demand.

In paper three, we examined household preferences for biogas energy, whereas the relationship between investment decision, credit financing and driving factors are estimated in the model. In this part, we examined the key covariates of investment decision conditioned on three credit-financing options: In the short term, medium and long term loan repayment options. The credit financing options offered were believed to be a possible solution to avoid affordability problem related to income sources. Multinomial logit model was used to analyse a household decision on biogas energy supply with a given credit financing.
Investment decision on biogas energy conditioned on credit financing options is significantly determined by gender balanced and extended credit share with flexible loan repayment options, home water sewage system connectivity, availability of local resources (water, land, livestock and alternative fuelwood sources), and education level. The finding suggests that policy implications in terms of promoting and developing biogas energy as a renewable source should consider these variables to wider and sustainable biogas technology use and subscriptions among low-income households. Overall, the success of energy related policies depend on capacity building, the removal of financial barriers, strategy to increased access

to modern fuel sources, education and training on raising awareness and pro environmental consumption behaviour and reforestation actions.

In the area of household water savings and water use, the main driving forces of water use were increasing income and the resulting life style, high education achievement, large number of family size and increased count water using devices are more water intense. On the other hand, information and environmental awareness encourage responsible water use behaviour and reduce water use at home.

To sum up; household characteristics, preferences and decisions moving from traditional fuel sources such as fuelwood, charcoal and other biomass sources to modern fuel sources (electricity and biogas energy), residential water savings and water use practices at home increase efficiency and will have a significant contribution in formulating optimum allocation of scarcer environmental resources locally.

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Appendices A

HOUSEHOLD ENERGY SOURCE CHOICE AND CONSUMPTION MANAGEMENT SURVEY QUESTIONNAIRE

1 INTRODUCTION

This questionnaire intends to collect some socio-economic information related to the household. The information collected, as part of this questionnaire will be used for PhD studies aimed to assessing household energy source choice, and consumption in Hawassa. The information provided by the household head for this survey will no ways deprive any household head or member of any existing benefit that it receives, or entitle any household member to any benefit. Honest cooperation in this process is solicited for this purpose.

2 IDENTIFICATION

(N.B. Respondent should be either farmer/spouse/adult child – someone with sufficient knowledge)

Name of interviewer					
Name of respondent					
GPS	X		Y	Z	
Address of respondent	Kebele________________________________				
Gender of respondent	Male		Female		
Gender of the household head	Male		Female		
Age of respondent					
Level of Education of the respondent	1 *unable to read and write*	2 *Read and write*	3 *Informal educations*		4 *Highest grade completed*
Occupation of HH heads	1 *Employed*	2 *Own private business*	3*Unemployed*	4 *Farmer*	5 *other*
Marital status	1 *Married*	2 *Single*	3 *Widowed*	4 *Divorced*	
Relation to the family	1 *Head*	2 *Spouse*	3 *child*	4 *House help*	5 *Other relative*
Family size	Male		Female		

3 CHARACTERIZATION OF ENERGY

3.1 Energy consumed by the household

3.1.1 What is the source of energy in your household for cooking?
1 Electricity
2 Kerosene (butagas)
3. Charcoal
4. Biomass (wood, leaves, grass, plants products)
5. Dung
6. Gas cylinders
7. Others (specify...)

3.1.2 What type of fuel do you use most for cooking, lighting, (if any) and water heating?

What is the fuel or energy source used for	Type of fuel/ energy source used			
	Summer (Bega)		Winter (kiremt)	
	Most used	Other fuels	Most used	Other fuels
Cooking				
Lighting				
Water heating				
Space heating				

3.1.2 What else do you use as energy for (traditional feasts, ceremony and entertainment)?
____
____
____

3.1.3 What type of appliance in the household are you using?

A Enjera mitad
B Stove
C Fridge
D TV, radio tape
E Other specify____

3.2 **Household energy sources**

3.2.1 What resources are available in your area?

Resource	Availability (use key)	Distance to the resource (Kms)
Water for domestic use		
Firewood for cooking		
Grazing land/fodder		

Notes: (1) Readily available (2) available in short supply (3) Not available

3.2.2 How often does someone collect firewood for your house in summer (bega) and in winter (kiremt)?

Summer (Bega)____
Winter (Kiremt) ____

3.2.3 Who is responsible for energy availability in your household?

(i) Wife ( )
(ii) Husband ( )
(iii) Children ( )
(iv) Other specify_______________

3. 3 Fire wood collection

3.3.1 Where do you collect firewood?

1 Woodlot 2. Natural forest 3. Buy from market. 4 buy from shops

How far is it in km?___________________________________

3.3.2 How long does it take to collect firewood time in hr.?

1. Half hour 2. Hour 3. Hour and a half 4. Two hours 5. More than two hours

3.3.3 If you buy, how much do you buy? At what price? How often (interviewer to standardize answer in days per week)? Where? How far is the source?

Amount	**Price in Birr**	**Frequency of collection days/week**	**Place of buying**	**Distance in kilometre**
Head Load				
Truck Load				
Donkey cart				
Donkey				
Wheelbarrow				
Other				

4. **THE KITCHEN UTENSILS AND COOKING PROFILES**

4.1 What cooking method do you use for most of your food ?
1.Frying 2. Boiling 3. Injera Backing 4. others_________________________________

4.2 What type of stove(s) do you use for question number 5.1 activities?

1. Frying ________ 2. Boiling___________________3. Injera backing_________________

4.3 When do you cook your main meal? 1. Morning 2. Afternoon 3. Evening

4.4 How many times do you cook per day? ______________

5 COPING WITH FUEL WOOD SCARCITY

5.1 Do you find that firewood is scarce? 1.Yes 2.No

5.2 How do you rank the problem of firewood shortage in your area?
(i) Highly sever ( ) (ii) sever (iii) Moderate ( ) (iv) Not sever ( )

5.3 If yes for Question 6.2, what do you think is the best strategy towards solving the problem of firewood scarcity?
(i) Plant trees ( )
(ii) Encourage charcoal making ( )
(iii) Prevent bush fires ( )
(iv) Looking for alternative sources of energy ( )
(v) Others (specify). ……………………………………………...…

5.4 Do you know of any specific cooking techniques (ways) that you could apply to save firewood?
1. Yes 2. No

5.5 If yes for question 6.4 above, what techniques? _________________________________
____

5.6 Do you know any alternative energy other than Biomass (firewood etc.)?
(i) Yes ( ) (ii) No ( )

5.7 If Yes, mention them;
(i) ……………………………….….……………………………..........
(ii) …………………….………………..………………………….........

5.8 For the alternative energy sources, you mentioned above, which ones do you use?
(i) ……........
(ii)…

5.9 What are the advantages and disadvantages of the alternative fuels?

Alternative fuel	Advantages	Disadvantages

5.9 If No for Ques. 6.2 above, do you think firewood might become scarce in the future?
1. Yes 2. No

5.10 If yes, for ques. 6.10 above, what would you do if firewood becomes scarce in future?
____

6 **Have you ever heard about the biogas technology**? If no skip to question 18.
(i) Yes ( ) (ii) No ( )

6.1 If yes, who gave you information about biogas technology for the 1st time?

a. Biogas researcher ( )
b. Extension officers ( )
c. Politician ( )
d. Neighbour, Relative, friend who adopted BT ( )
e. Biogas Project staff ( )
f. Others (Specify) ……………………………………………………………

6.2 **What is your comment concerning biogas technology as alternative energy source?**

a. Appropriate technology ( )
b. Not appropriate technology ( )
Do you agree that biogas technology shall be promoted?
i. Strongly agree ( )
ii. Agree ( )
iii. Neutral ( )
iv. Disagree ( )
iii. Strongly disagree ( )
Give reason for your answer above (Question 6.17) …..................

6.3 Willingness to pay (WTP) for biogas energy supply

6.3.1 What is the amount of energy consumed in the household for lighting, cooking and other uses?

Fuel /energy sources	Qty./unit	cost in birr /month for cooking	cost in birr /month for lighting	cost in birr /month for other uses	Total expenditure/ month
Electricity					
Kerosene					
Gas Cylinder					
Biomass / Wood					
Charcoal					
Solar					
Other					
Total					

6.3.2 If it is possible to have biogas energy supply from organic waste recycling that can save on fuel wood, increase the quality of environment, save time and energy, bio slurry use for soil fertility, zero or minimum greenhouse gas emission, what percentage are you willing to pay for each attributes?

Attributes	0-10%	10-20%	20-30%	30-40%
Save woody biomass				

Clean environment/ health benefit				
Reduce fuel source collection time				
Bio slurry use for soil fertility				
Zero greenhouse gas emission				

6.3.3 Are you willing to pay/ adopt biogas plant with average initial investment cost ranging 14,000 Birr and negligible running cost compared to conventional sources (electric, biomass, etc) for lighting, cooking and bio slurry-for compost use?

1. Yes [ ] No [ ]

6.3.4 If your answer for the above Question is NO, why don't you adopt biogas technology?

a. Do not have enough substrate (up to 20kg dung, other organic matter) ( )
b. limited space for biogas construction ( )
b. Shortage of household labour to manage the plant ( )
c. Plenty of fuel wood in the area I am living ( )
d. High Technology costs ( )
e. Not know how to use the technology ( )
f. I find it not appropriate for me ( )
g. Others (specify)……..

6.3.5 Would you like to adopt/willing to pay for biogas energy supply if you have provided with subsidy funds from the government or credit scheme in the following loan repayment schedule

a) Short term(1-2 years) 70% of investment capital yes [ ] No [ ]
b) Medium term (five years) 50% investment capital yes [ ] No [ ]
c) Long term(10 years) less than 30% investment capital yes [ ] No [ ]

6.3.6 If it is possible to provide the alternative biogas energy supply by the third party or business firm, are you willing to pay with the following options?

1= Equivalent to monthly electricity bill/fee [ ]		1= Equivalent to biomass fuel expenditure [ ]
2= 10% greater than electricity bill [ ]		2=10% greater than biomass fuel expenditure [ ]
3= 15% greater than electricity [ ]		3=15% greater than biomass fuel expenditure [ ]
4= 20% greater than electricity [ ]		4= 20% greater than biomass fuel expenditure [ ]

7 HOUSEHOLD INCOME

7.1 What is the source of monthly income of the household?

a) Income from monthly salary______________
b) Income from Own business_______________
c) Income from crop --------------
d) Income from livestock--------------
e) Income from labour--------------
f) Remittances--------------
g) Any other--------------

7.2 What is the total monthly income of the household?

<2000 ETB
2,001-3,000 ETB

3,001- 4,000 ETB
. 4,001-5,000 ETB
5,001- 6,000 ETB
6,001- 7,000 ETB
7,001- 8,000 ETB
8,001- 9,000 ETB
9,001- 10,000 ETB
10,001-15,000 ETB
15,001-20,000 ETB
>20,000 ETB

8 PROPERTY OWNERSHIP AND STANDARDS

8.1 Ownership of house

1- Private
2- Own condominium
3- Rented from individuals
4- Rented from kebele
5- Other *(specify)*: ________

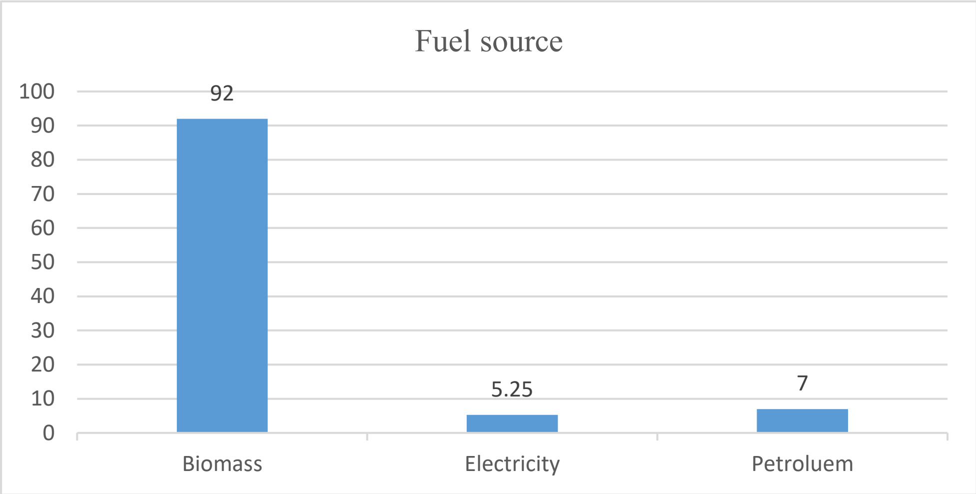
8.2 What is the standard of Kitchen facility? (RECORD OBSERVATION!)

1. Modern (Inbuilt water line, sink and cooking facility)
2. Traditional (private)
3. Traditional (communal)
4. Traditional improved (private)
5. Traditional improved (communal)
6. Other (specify)____

Appendices B

Residential Energy Land scape in the study area

Figure 6: Share of total final energy demand based on different sources in Ethiopia.



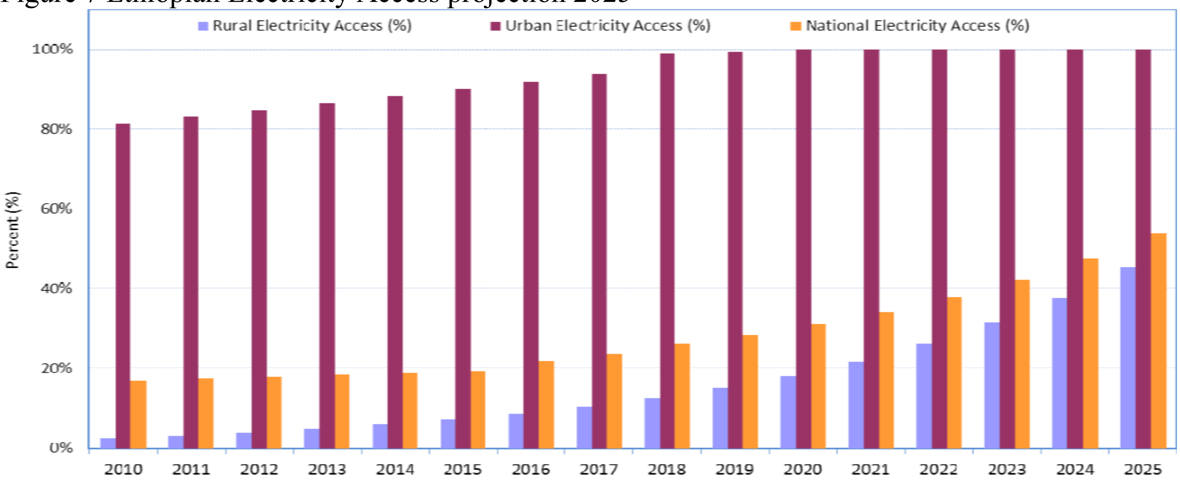
Source: Welfare monitoring survey, 2016

Table 6: Energy demand from 1996 to 2010 and Projected demand at 2030

Energy source	1996	2010	2030
Biomass	96.6	92	71.6
Petroleum	4.8	6	22.6
Electricity	0.6	2	5.8

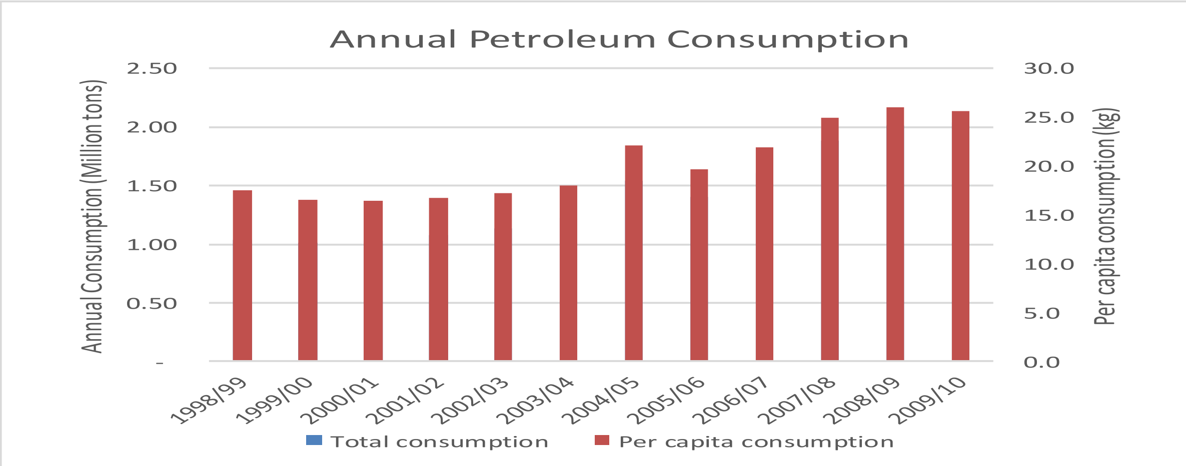
Source: ESMAD, 2011

Figure 7 Ethiopian Electricity Access projection 2025



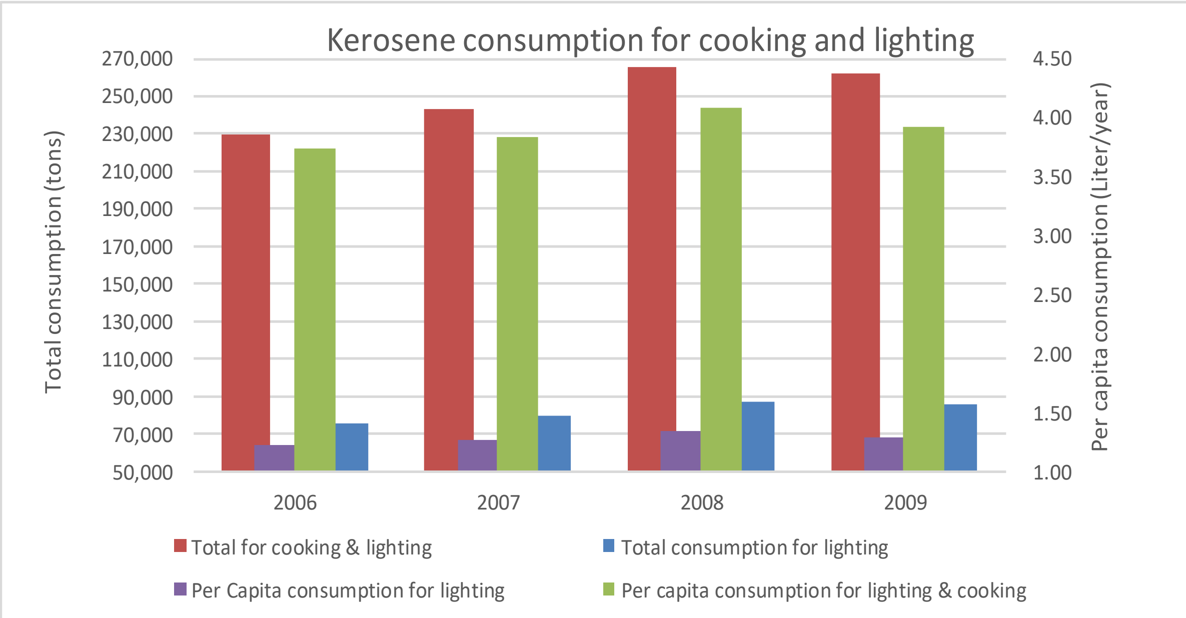
Source: Lighting Africa

Figure 8: Trend of annual Petroleum Consumption



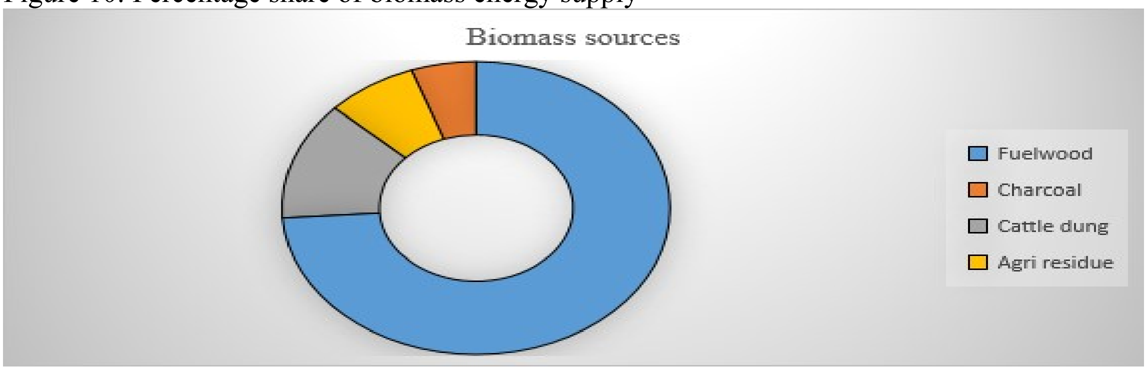
Source: ESMAP, 2011

Figure 9: Kerosene Consumption for Cooking and Lighting



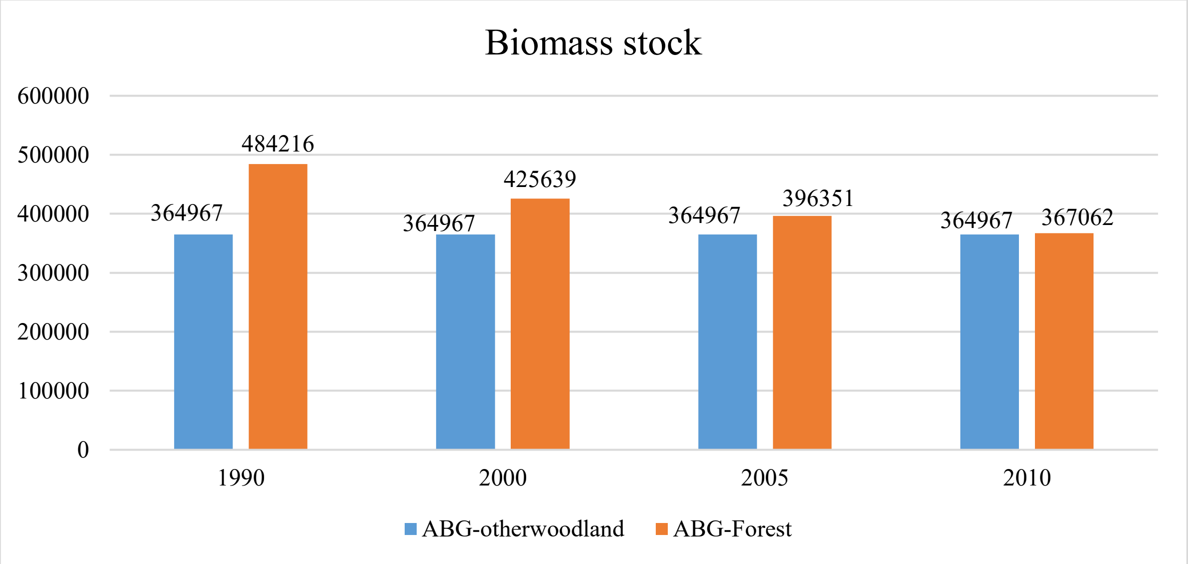
Source: ESAMAP, 2011

Figure 10: Percentage share of biomass energy supply



Source: FAO, 2010

Figure 12: Biomass stock in 000, tones, Above Ground Biomass (AGB)



Source: FAO, 2010

Table 7: Percentage share energy source for cooking 1996-2016

Place of Residence	1996	1998	2000	2004	2011	2016
Country						
Collected firewood	65.4	66.1	67.8	70.5	72.61	69.47
Purchased firewood	8.0	9.9	8.0	10.9	12.37	12.24
Charcoal	0.7	0.8	1.2	1.3	3.91	4.24
Leaves, dung cakes, etc.	17.4	18.0	15.6	11.5	7.24	6.91
Kerosene	3.0	2.6	3.3	2.4	1.18	0.38
LPG(butane gas)	0.2	0.4	0.2	0.5	.25	0.21
Electricity	0.4	0.5	0.4	0.4	1.32	5.25
Others	5.0	1.7	3.4	2.1	1.11	1.15
Rural						
Collected firewood	74.1	74.7	76.4	80.7	87.23	86.32
Purchased firewood	1.4	3.5	2.4	3.7	3.62	4.10
Charcoal	0.1	0.1	-	0.2	0.23	0.28
Leaves, dung cakes, etc.	19.1	20.1	17.2	12.7	8.37	8.63
Kerosene	0.2	0.2	0.3	0.2	0.17	0.11
LPG	-	0.1	0.1	0.1	0.04	0.09
Electricity	-	-	0.1	0.1	0.01	0.13
Others	5.2	1.4	3.6	2.3	0.34	0.25
Urban						
Collected firewood	17.2	13.8	16.6	16.0	18.59	16.21
Purchased firewood	44.5	49.1	41.3	49.4	44.72	37.97
Charcoal	4.3	5.0	8.3	7.7	17.54	16.73
Leaves, dung cakes, etc.	7.6	5.3	6.3	5.3	3.04	1.47
Kerosene	18.9	17.2	21.5	13.8	4.93	1.25
LPG	1.0	2.5	1.4	2.7	1.05	0.56
Electricity	2.7	3.8	2.2	2.4	6.18	21.42
Others	3.8	3.2	2.4	0.8	3.95	4.21

Source: Central Statistical Agency (1996- 2016)

Figure 13: The percentage share lighting energy by rural households 1996-2016

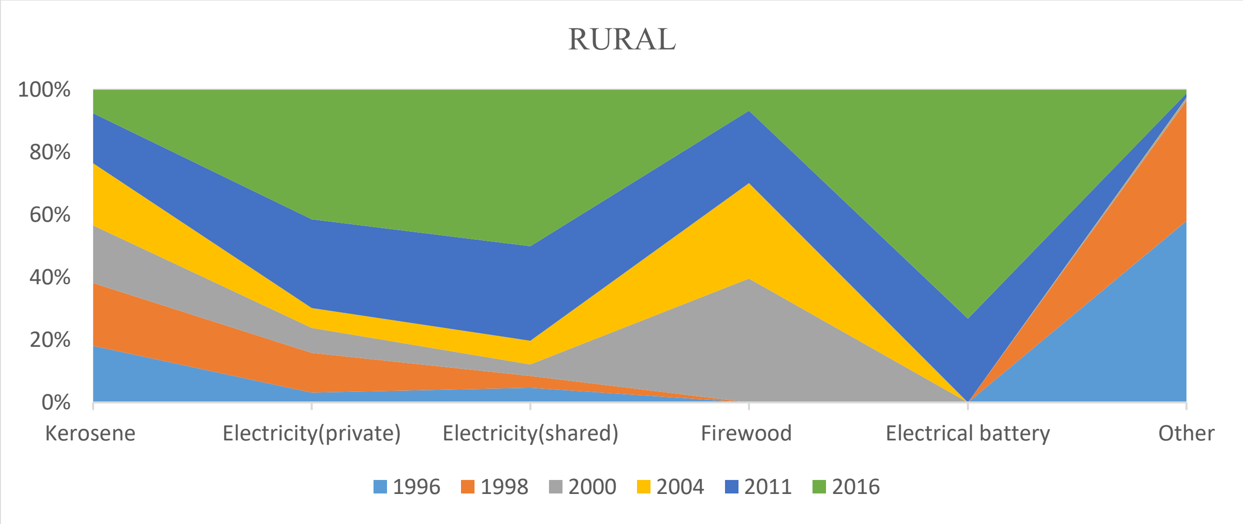
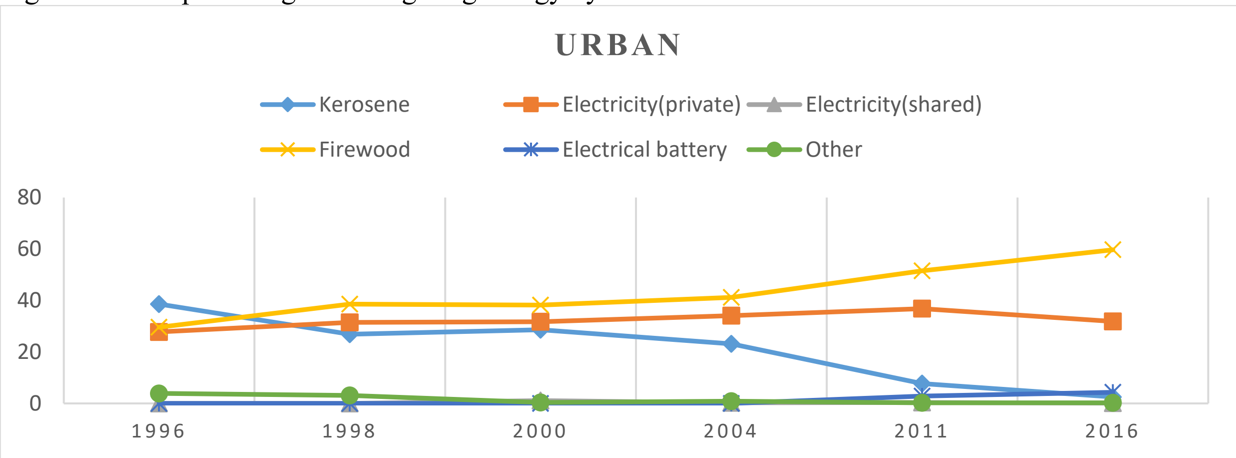


Figure 14: The percentage share lighting energy by urban households 1996-2016



Source: Central Statistical Agency (1996-2016)