FACTORS DETERMINING HOUSEHOLD'S DECISION ON ADOPTION OF CLEAN TECHNOLOGY ETHANOL STOVES: THE CASE OF GULELESUB-CITY, ADDIS ABABA CITY ADMINISTRATION, ETHIOPIA

M.Sc. THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE

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REQUIREMENTS FOR THE

DEGREE OF

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APPROVAL SHEET-1

This is to certify that the thesis entitled "Factors Determining Household's Decision on Adoption of Clean Technology Ethanol Stoves: The Case of Gulele sub-city, Addis Ababa City Administration, Ethiopia" is submitted in partial fulfillment of the requirement for the degree of Master of Sciences with specialization in Renewable Energy Utilization and Management. It is a record of original research carried out by Kaleb Tadesse Tebelu Id. No. MSC/REUM/R007/09, under my supervision; and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the courses of this investigation have been duly acknowledged. Therefore, I recommended it to be accepted as fulfilling the thesis requirements.

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APPROVAL SHEET-2

We, the undersigned, members of the Board of Examiners of the final open defense by Kaleb Tadesse Tebelu have read and evaluated his thesis entitled "Factors Determining Household's Decision on Adoption of Clean Technology Ethanol Stoves: The Case of Gulele sub-city, Addis Ababa City Administration, Ethiopia" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science.

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Finally, I would like to take this opportunity to thank w/ro Etenesh the chairman of Former Women Fuel wood Carrier Association (FWFCA) for sharing information and cooperate the stuff for the data gathering.

DECLARATION

I, Kaleb Tadesse hereby declare that the thesis entitled "Factors Determining Household's Decision on Adoption of Clean Technology Ethanol Stoves: The Case of Gulele sub-city, Addis Ababa City Administration, Ethiopia" is my own work. Any scholarly matter that is included in the thesis has been given recognition through citation.

This thesis is submitted in partial fulfillment of the requirements for MSc. Renewable Energy Utilization and Management at Hawassa University Wondo Genet College of Forestry and Natural Resource. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Kaleb Tadesse________	________________________	____________________
Name of student	Signature	Date

LIST OF ACRONYMS AND ABBREVIATIONS

GACC	Global Alliance for Clean Cookstoves
HAP	Household Air Pollution
IAP	Indoor Air Pollution
IEA	International Energy Agency
LDC	Least Developed Country
SCIP	Strategic Climate Institutions Program
UNIDO	United Nations Industrial Development Organization
FWFCA	Former Women Fuel wood Carrier Association
GHG	Greenhouse Gas

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FACTORS DETERMINING HOUSEHOLD'S DECISION ON ADOPTION OF CLEAN TECHNOLOGY ETHANOL STOVES: THE CASE OF GULELE SUB-CITY, ADDIS ABABA CITY ADMINISTRATION, ETHIOPIA

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ABSTRACT

The heavy dependence on traditional biomass and fossil fuel as well as their inefficient utilization for household's energy is a concern to health and environment in the study area and elsewhere. It is believed that these problems can be prevented by adopting clean, reliable and affordable energy sources and technologies. This study investigates the current extent of use and the factors that determine household's decision on adoption of clean technology ethanol stoves in Addis Ababa city administration with the particular emphasis in Gulele sub-city. A quantitative and qualitative survey was conducted using a structured and semi-structured questionnaire with which data was collected and analyzed from a sample of 276 randomly selected households and 9 purposively selected key informants among the residents of the sub-city, respectively. Data from questionnaires were analyzed by using descriptive statistics and binary logistic regression while the data from the focus group discussions (FGD) were analyzed through data coding. The result reveals that there is heavy dependence on traditional biomass for backing among both non-adopters (85%) and adopters (62%) households. Besides, kerosene and ethanol were found to be the primary source of cooking for the households of non-adopters (55%) and adopters (100%) respectively. The econometric result shows that household's income was found to be significantly and positively correlated with ethanol stove adoption. The age, sex, family size and price of ethanol stove were found to be significantly and negatively correlated with ethanol stove adoption decision. Education was not found to be statistically significant to determine household's ethanol stove adoption decision. On the other hand, the features of the technology such as time and fuel saving (65%), cleanness and free of emission (68%) and safety (76%) of the stove were found to be positively correlated with the adoption of the stove. However, ethanol scarcity, inadequate public awareness (86%) and limited distribution infrastructure were found to be the barrier to ethanol stove adoption. To fill these knowledge gap different strategies should be planned to promote sustainably and create awareness among the community about the benefits of the stoves. Furthermore, establishing processing, modernize the distribution and the development of the ethanol should be the key issue for the government and the stakeholders.

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Keywords: *Adoption, Household, Ethanol stove, clean cookstove*

1. INTRODUCTION

1.1 Background of the Study

Access to clean forms of fuels like electricity, ethanol and natural gas is particularly limited in low income developing countries. About half of the consumption is dependent on traditional fuel sources such as firewood, charcoal, animal dung, crop straws and branches with traditional and inefficient stoves (Klasen *et al.*, 2013). The use of such fuel sources and traditional stoves is one source of health and environmental problems. Currently, utilization of solid biomass energy for cooking and lighting is one of the major factors for the decline of forests and thereby an important factor to aggravate climate change. In many developing countries particularly in sub-Saharan Africa (SSA), deforestation and degradation of forests contribute a huge amount of greenhouse gases (GHG) emission (Bruce *et al*., 2015; Johnson *et al.*, 2013; Smith *et al*., 2014; Bruce *et al.*, 2015). Accordingly, improving access to affordable, reliable and clean cookstoves such as ethanol stoves has become a priority in efforts to reduce poverty and promote economic progress (Bonjour *et al*., 2013; Lee *et al*., 2013).

Ethanol stove is non-pressurized, there is no risk of explosion. It is constructed entirely of stainless steel. It is durable and long lasting with an estimated 10-year life. It is currently available either with one or two burners. Each burner provides 1.5kW of heat output and has its own fuel canister that holds 1.2 liters of fuel sufficient for 4.5 hours of cooking. It has heating power equivalent to an LPG stove. Alcohol fires are extinguished with water. Well-designed alcohol stoves produce no harmful emissions and are powerful generators of carbon credits (Gaia, 2006).

In developing countries like Ethiopia, whose energy supply is heavily dependent on biomass fuels, searching for and adoption of clean alternative technology is critical. However, the available alternatives to biomass fuels and technologies do not offer much improvement. For example, kerosene is imported at significant expense and is not environmentally friend. Liquefied petroleum gas (LPG) burns cleanly but is expensive and cannot be produced locally. Charcoal, a processed biomass fuel, burns with less smoke but emits carbon monoxide and other pollutants as compared to ethanol fuel.

On the other hand, Ethiopia possesses all of the necessary factors for successful technology transfer of ethanol alcohol fuel. But molasses and other byproducts of industry were used to dump in Ethiopia’s rivers. However, currently two of Ethiopia’s five mills, Fincha and Matahara Sugar company adopted alternative ways for handling their waste problem by acquiring a distillery and producing ethanol. The produced ethanol fuel can be used as source of energy for modern clean cookstoves as is provided to Ethiopia through Project Gaia. Currently, Gaia Association has made the partnership with Former Women Fuelwood Carrier Association (FWFCA) to commercialize 600 stoves in low-income member households of FWFCA. Furthermore, Gaia Association had made efforts to produce ethanol stove locally and commercialization cooperating with different partners such Makobu enterprise. However, the commercialization was highly challenged by a number of reasons such as lack of awareness and ethanol supply uncertainty.

1.2 Statement of the Problem

For the first time, bioethanol stoves for household cooking were introduced to Ethiopia by Gaia association since 2004. However, the adoption is limited to only Addis Ababa city administration. The main challenges of adopting the ethanol stoves in these sub-cities are availability constraints, rising price for ethanol, inadequate public awareness, unfavorable market, limited distribution infrastructure and services (UNIDO, 2015).

In Ethiopia, different studies of clean stoves adoption have been carried out at different times. For example, Beyene and Koch (2013) examined the correlation between speed of adoption of clean stoves and different socioeconomic factor. Takama *et al*. (2012) examined household decision-making regarding clean cookstoves choices in Addis Ababa. However, the research work regarding the barriers to ethanol stoves adoption has not been done in the investigated area. Accordingly, this study may contribute to fill the gaps that hinder the adoption of bioethanol stoves and fuel by addressing two key research questions.

1.4 Objective of the study

The main objective of this study is to analyze energy status and the factors that determine the decision of households to adopt bioethanol stoves in Addis Ababa city administration, Gulele sub-city, Ethiopia**.**

- The specific objectives are:

  i.) To assess the current status of households energy use in Gulele sub-city by source and distribution.

  ii.) Stove characteristics affecting household's decision in adopting bioethanol energy technology in Gulele sub-city.

  iii.) To investigate socioeconomic factors affecting household's decision in adopting bioethanol energy technology in Gulele sub-city.

1.3 Research Questions

- What is the current status of household energy use in Gulele sub-city by source and distribution?

- What are the major socioeconomic factors and clean stove characteristics affecting household's decision to adopt bioethanol energy use in Gulele sub-city?

1.6. Scope and Limitation of the Study

Geographically, this study was purposively limited to Addis Ababa city administration due to the availability of data. Conceptually, this research was limited to identifying factors affecting adoption of ethanol stove at the household level. Theoretically, the research was based on the ideas of Energy Ladder, Energy Stacking and Diffusion of Innovation theories in identifying factors affecting households' decision to adopt or not. This research did not include the whole sub-cities of Addis Ababa city administration.

Finally, the methodology of this study was employed survey research design, mixed research methods and used cross-sectional data that was gathered through questionnaires to identify the current status of households' energy and factors influencing the adoption of the stove in the area.

1.7 Significance of the Study

Different bodies who are working on clean stove and fuels mostly take into consideration the factors influencing household's decision to adopt and work to overcome barriers to adoption. Thus from the result of this study, these groups can easily identify effectively the potential intervention areas which can play a crucial role in their success. The findings of this study are expected to contribute to efforts being made to realize Ethiopia's Green Economy Strategy.

2. LITERATURE REVIEW

2.1 Definition

Ethanol Alcohol: - Ethanol is a volatile, colorless liquid that has a slight odor. Normally, it burns with smokeless, blue flame that is not visible in normal light. Ethanol fuel is ethyl alcohol, which is similar to alcohol that is found usually in alcoholic drinks. It is most often used as motor fuel, mainly as a biofuel blending for gasoline.

Ethanol is commonly made from biomass such as corn or sugarcane. The Chemical production and the complete combustion of ethanol is given by:

$C_6H_{12}O_6$ +Zymase $\longrightarrow$ $2C_2H_5OH$ + $2CO_2$ + Energy and

$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$ respectively (Tekle, 2011).

Alcohol burns cleanly, producing only carbon dioxide and water vapor, and none of the soot or toxic chemicals like those produced by solid fuels and kerosene.

Ethanol stoves are non-pressurized alcohol cookstoves. They can burn ethanol in liquid gelled or waxy forms. Non-pressurized ethanol stoves have no risk of explosion and their fires are extinguished with water. They are constructed entirely of stainless steel. They are durable and long lasting with an estimated 10-year life. They are currently available either with one or two burners. Each burner provides 1.5kW of heat output and has its own fuel canister that holds 1.2 liters of fuel which sufficient for 4.5 hours of cooking. It has heating power equivalent to an LPG stove. Well-designed alcohol stoves produce no harmful emissions and are powerful generators of carbon credits (Gaia, 2004).

2.2 Theoretical Bases of the Study

This study depends on three theories; energy ladder theory, energy stacking theory and diffusion of innovation theory.

2.2.1 Energy Ladder Theory

The energy ladder model classifies household energies as traditional, transition and advanced energy sources. The model assumes that low-income households would use the traditional fuels until their socio-economic status improve and then they will rationally switch completely to the modern fuels. According to this theory, as households income increase, they switched to the other advanced energy sources (Osiolo and Helen H, 2009). The energy ladder model considered as classic and traditional places heavy emphasis on income (affordability) in both explaining and determining a household's energy choice (Masera, *et al.,* 2000). Furthermore, this model has been criticized heavily for its lack of consideration of the intricate interactions that characterize energy transition, demographic factors, personal preferences, etc.

2.2.2 Energy stacking theory

The alternative models that have been proposed as consequent upon the observed weaknesses of the energy ladder model is the stacking model (Masera O *et al*., 2000). This model assumes that household energy use patterns depend on several factors (not only income) which could be social, economic, cultural, or even personal preferences. Therefore, rather than transiting linearly to cleaner fuels, households tend to increase the number of fuels used without actually abandoning the old ones. The fuel stacking model has been found to be true by many researchers who found fuel stacking to be practiced more by households with higher income (Schlag and

Zuzarte, 2008; Kowsari, 2013; Puzzolo, 2013). In other words, households increased the number of fuels they used as their income increased.

2.2.3 Diffusion Theory

According to Rogers (2003) diffusion of innovations seeks to explain how innovations (an idea, behavior, or object) are taken up in a population. It originated in communication to explain how, an idea or product gains momentum and diffuses (or spreads) through a specific population or social system over time. The end result of diffusion is that people as part of a social system adopt a new idea, behavior, or product. It asserts that individuals and early adopters in a certain social system are able to influence attitude and behavior of others informally either to promote or hinder the acceptance of a new technology.

2.3 Empirical Review on Factors Determining Adoption of Bioethanol Stoves and Fuel Technology

2.3.1 Alternative Source of Energy

Currently, at a global, there are different terminologies and definitions that are being used in categorizing household cooking fuels types. These are:

i. "**Traditional", "Intermediate" and "Modern**: - Depending on the level of fuels development aspects and type of fuels used for cooking in households.

ii. "**Primary" and "Secondary" fuels**: - Based on the trends these cooking fuels are produced and extracted. Primary fuels are directly obtained from natural resources such as fuelwood, agricultural waste, animal dung, coal, solar and natural gas. Secondary fuels types, which come from the transformation of primary fuels types such as petroleum products (kerosene, LPG, dimethyl ether) from crude oil, ethanol from sugar cane, charcoal and wood pellets from fuelwood and the likes.

iii. "**Renewable" and "non-renewable**":- Based on the sources of cooking fuels types. “Renewable" (biomass, wind, solar and biogas) and “non-renewable (coal, kerosene, LPG, natural gas). A review conducted by (Sunil Malla, 2014*)* indicated, *s*everal types of cookstoves that are used by households often associated with specific fuels types. These are traditional (3-stones) stoves, simple non-traditional (e.g., clay pot-style or simple ceramic liners, chimney, rocket, charcoal and gasifier stoves) and advanced (modern cooking stoves) like, LPG, natural gas and electric are common in urban areas of both developing and developed countries

The majority of studies reported the use of existing fuel type i.e. continued the use of the old fuel and stove as the new one is adopted which is to facilitate uptake of an additional cooking technology *(*Troncoso K*.et al., 2007;* Simon*, G., 2007).*

In Ethiopia, the larger proportion of households were found using traditional biomass and clean fuels such as electricity and LPG for energy consumption (Legesse, 2016; Abate, 2016; Araya and Demissie, 2012; Gebreegziabher *et al.*, 2012).

2.3.2 Stoves Characteristics

The valuation of new stove technology was determined by a combination of different stove characteristics such as cooking time, stove size and how easy the stove was to use (Adkins *et al*., 2010; Ruiz-Mercado *et al.* 2011). Imam D. PPKT (2011) find that the distribution suitability through existing infrastructure, high efficiency, low smoke/soot level and high cleanliness compared to those fossil fuels are the most prevalent for cooking.

The nature of designs’ features of the technologies is found to be fundamental importance in relation to adoption and sustained use. Conveniences, safety, durability, the ability to provide warmth, portability in cold and rainy settings are reported as among positive features to facilitate the adoption of the stoves. These factors are thus very important for appropriate stove design and successful adoption (Takama. et al., 2012).

Studies reported that standard certification of stoves or stove components by a standards agency as a means of ensuring design specifications for fuel efficiency and emissions. Some studies have been focused on the importance of appropriate enforcement of standards for stoves and fuel storage in order to ensure quality, functionality and safety of stoves and fuels (Obueh J., 2008; Imam D. PPKT, 2011).

2.3.3 Knowledge and Perceptions

The greater awareness of the adverse effects of exposure to indoor air pollution may make cleaner fuels or stoves more attractive to adopt (Pattanayak et al., 2016; Mubarak *et al*., 2012). In the past, some "cleaner" cookstoves marketed in Ethiopia suffered dangerous explosions and caused severe burns by the improper using of the so-called K-50 stove which uses 50% ethanol and 50% kerosene. These stoves were not designed for a 100% kerosene fuel blend, but many consumers did not understand this limitation. As a result, several people were injured by improper use of the stoves (Murren and Debebe, 2006).

Lewis and Pattanayak (2012) found that education and household head decision to choose are positively correlated and statistically significant factors that determine the adoption of clean cookstoves. Potentially educated adopters are more likely to be aware of the benefits of clean cookstoves as compared to those uneducated or less educated adopters

2.3.4 Household Income, Family Size and Age

Beyene and Koch (2013) found that household income and wealth are the most important determinants of adoption of clean fuel-saving technologies. Analyses determined that for various clean stove adoption initiatives, income was positively associated with the stove adoption (Lewis, J.J. and Pattanayak, S.K., 2012).

Socio-economic measures such as income and household expenditure were important features of clean fuel (LPG) uptake (Rogers T, 2009). Bansal *et al*. (2013) in rural India and Nlom and Karimov (2014) in northern Cameroon found that household income is one of the main factors in choosing fuels for cooking.

With regard to family size, Puzzolo *et al*. (2013) found inconsistency among findings. Gebreegziabher *et al*. (2010) found that family size was positive and statistically significant to the adoption of the stove. Lewis and Pattanayak (2012) found also household head's age was indicated to be a significant negative factor that determines the adoption of clean cookstoves across studies reviewed. Conversely, Gebreegziabher *et al*. (2010) found household head's age to be positive and statistically significant determinant factor of clean stove adoption decision.

2.3.5 Stove Cost

The product-specific factors such as usage cost and stove price significantly affected stove and fuel choices (Takama, T., 2011; Alem *et al*., 2013). The same is true by the study conducted in Addis Ababa by (Obueh J.2008; Imam D. PPKT, 2011; Takama *et al.* 2012).

2.3.6 Sex and Marital Status

Miller and Mubarak (2013) found that women in rural Bangladesh, who bear disproportionate cooking costs, had a stronger preference for clean cookstoves but they lack the authority to make the purchase. Despite women's decision-making power were often limited, there was an example where women were able to pay for the clean stove using their savings which had been intended for purchasing clothes or additional food (Person B *et al*., *2012)*. Single women (female-headed households) were found more likely to adopt clean cookstoves as compared to married women male-headed counterparts (Damte and Koch, 2011).

2.4 Conceptual Frame Works

Based on the previously stated theories, the literature that the researcher has reviewed and findings of the empirical studies on factors determining the adoption of clean cookstoves, the following conceptual framework has been developed.

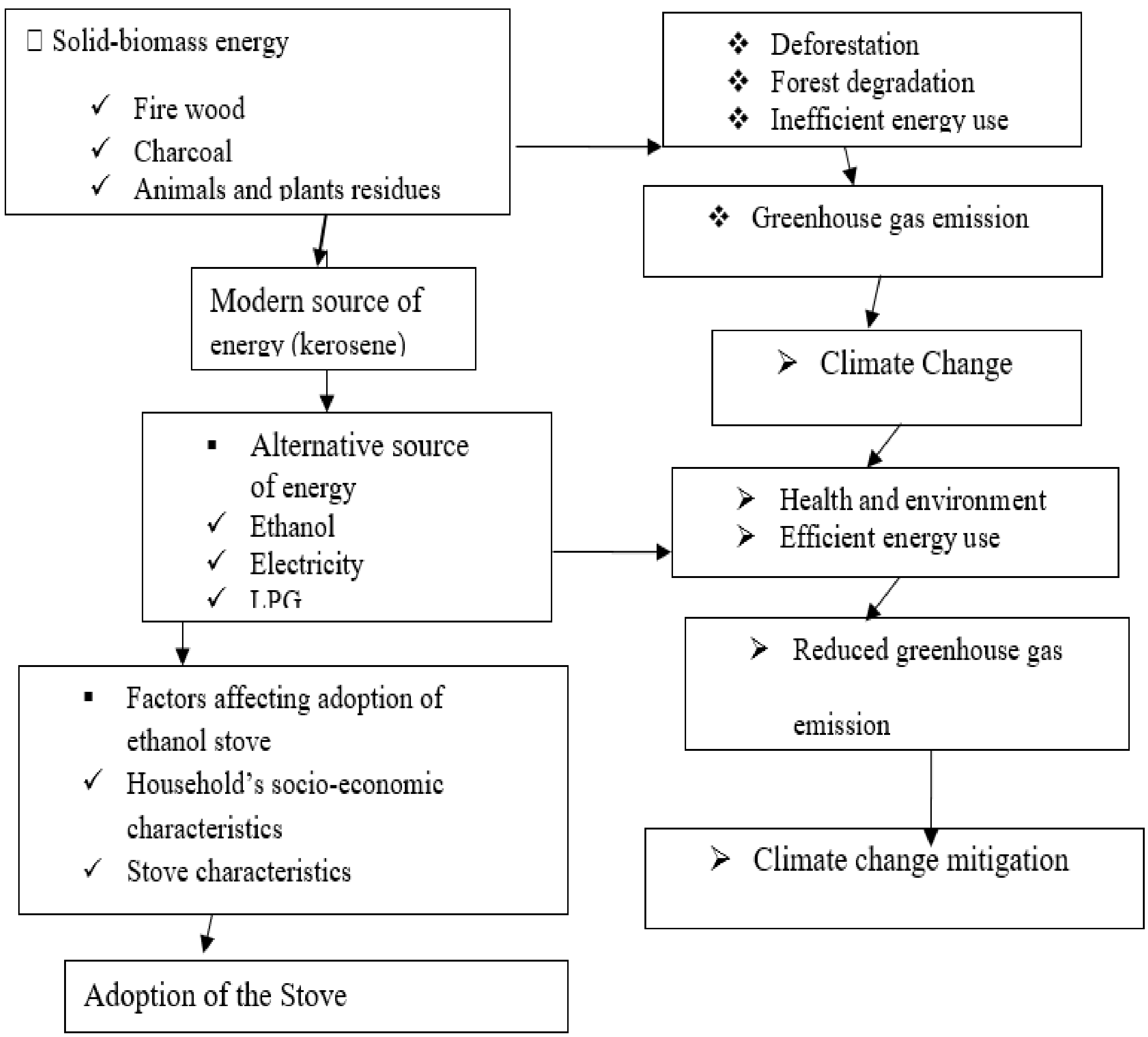

Figure 1: Conceptual framework showing the general diagrammatic representation of energy use, socio-economic factors and stove characteristics on adoption of ethanol stove

2.5 Summary of Review Literature

Several theories have been used in attempts to explain household energy preference. Among these theories is the energy ladder which heavy emphasis on income (affordability) in both explaining and determining a household's energy/fuel/stove choice. On the other hand, the stacking model assumes that household energy use patterns depend on several factors which could be social-economic and personal preferences. Besides, diffusion of innovations seeks to explain how innovations (an idea, behavior, or object) spread through a specific population or social system.

Based on the three theories, household's socio-economic measures such price and age are negatively correlated with adoption of clean stoves. On the other hand, education and household's income, as well as stove characteristics such as conveniences, safety, durability, and the ability to provide warmth, portability in cold and rainy settings are identified as positive features of the stoves to facilitate adoption.

The greater awareness of the benefits and adverse effects of cooking with traditional stove helps households to make the decision to adopt the clean cookstoves. However one of the most serious barriers mentioned by respondents is the exaggerated fear about the danger of using ethanol-based stoves in Ethiopia in the past. The gendered approach is critical for adoption and sustained use of clean cookstoves. Male-headed households were identified as barriers to stoves adoption. The assumption is that the head of the household is the primary decision maker and men have more access and control over economy including vital production resources than women due to many socio-cultural values and norms.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location and Topography

Addis Ababa the study area, is the capital city of Ethiopia. It is located between 8°49` and 9° 5` North latitude and between 38° 38` and $38^0$ 54` East longitudes. The city lies at the foot of Mount Entoto at an average 2,500 meters. It lies from the lowest point 2,114 meters above sea level in the Eastern periphery and gradually rises to over 3,000 meters in the Entoto Mountains to the North. The total area of City Administration is about 540 Km2 and sub-divided into 10 sub-cities. Gulele sub-city is one of the densely populated sub-cities situated in the Northern part of Addis Ababa.

3.1.2 Climate

Addis Ababa has a humid subtropical highland climate. The annual mean rainfall in Addis Ababa was 1025.06 mm, whereas the total rainfall has shown a declining trend of 36.45 mm in a decade. The average maximum temperature varies from 24.53°C to 22.63°C and the average minimum temperature was 11.38°C in 2017.

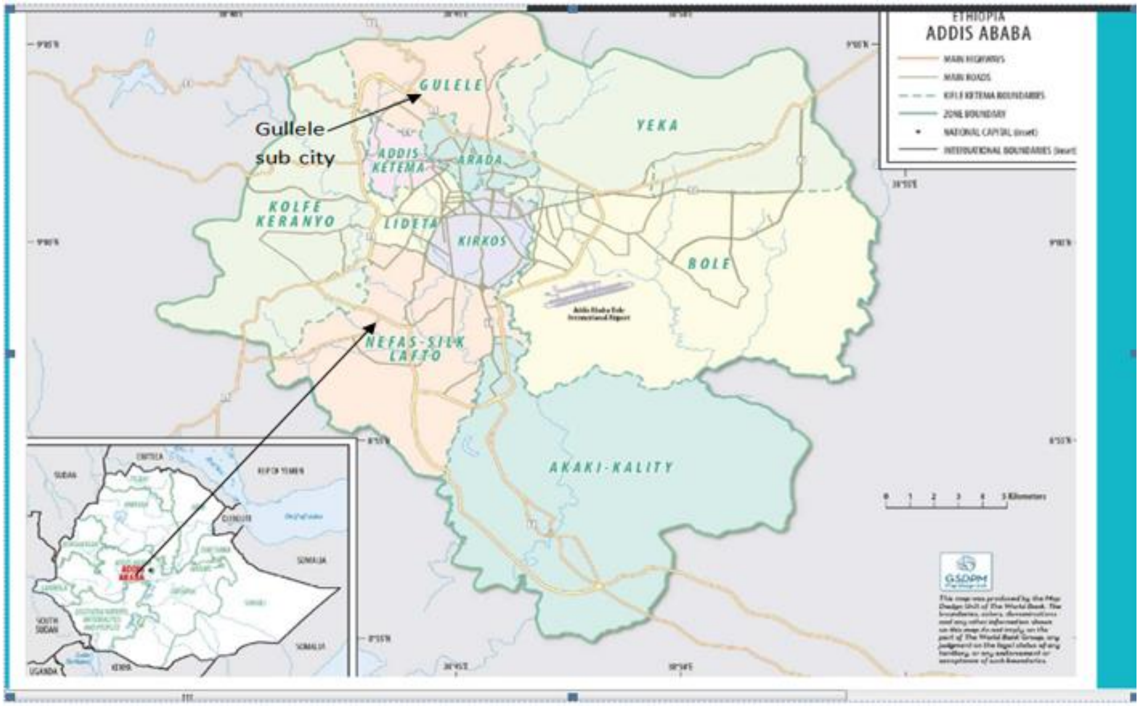

Figure 2: Map of Study Area

Source World Bank 2015

3.1.3 **Vegetation**

Addis Ababa was covered with natural forests but slow growing Juniperus, Podocarpus, and Ole forest. With an increasing population, the demand for fuelwood and construction by the inhabitants resulted in heavy deforestation. Subsequently, Menelik II the Emperor of Ethiopia introduced eucalyptus from Australia into the country in 1895 as a potential solution for fuelwood shortages threatened the very existence of the city. The introduction was a success and at the turn of the twentieth century, the practice of growing eucalyptus for fuel expanded into the area surrounding the city. Hence, if the dramatic success of eucalyptus were not succeed, Addis Ababa would not have come to exist as the Emperor would have been forced to move elsewhere to look for fuelwood(Demisse *et al*.,2017).

3.1.4 Population

Addis Ababa has a total population of about 3,195,000 and an annual growth rate of 3.8 % according to the 2014 population projection. The same report shows that 47.4% of the City‘s populations is male and the rest 52.6% is female.

3.2. Research Design

According to Mouton (1996) research design is the framework that has been created to seek answers to research questions. It serves to "plan, structure and executes" the research to maximize the "validity of the findings". Therefore, the researcher believes that the research design provides him with a clear research framework, guides the methods, decisions and sets the basis for interpretation in seeking answers to research questions. Thus, the cross-sectional survey research design was structured before data collection or analysis started. It was planned according to tasks and activities that had to be done to complete the project.

3.3 Research Methods

In this study, the quantitative and qualitative method was used because the purpose of the researcher was to collect, analyze and conclude about the cross-sectional data. In addition, the researcher made a general conclusion about the whole population based on the data which were collected from only sample respondents and key informants. Thus based on the scope and complexity of the research problem, the researcher decided quantitative and qualitative methods to conduct this research.

3.4 Sample Size Determination

The samples of the study were selected from the two broad categories of households and key informants using the following techniques.

(A) **Probability sampling**:-For this study, stratified random sampling was applied for data collection due to the heterogeneity of the population. In this method, the entire heterogeneous population was divided into homogeneous groups (non-adopters and adopters) and then units were sampled at random from each of these stratum. Strata are purposively formed based on past experience and personal judgment of the researcher as adopters versus non-adopters households for the convenience of analysis, precision, availability and cost of investigations. After stratification, sampling was conducted separately in each stratum. To determine the appropriate sample size, the criteria for good sample size were employed. These were the level of precision, the level of confidence or risk and the degree of variability in the attributes (Glenn 1992; Cochran 1963). A simplified formula by Yamane (1967) was used to determine a sample size of 276. The systematic sampling was used for the selection of the 276 individual households from 5260 households of woreda 6 in Gulele sub-city. The categories of households as adopters and non-adopters as well as key informants from different sectors were the most relevant in terms of the aims of this research filtering relevant samples from relevant groups of communities and organizations/individuals acting in the field.

Accordingly, to determine sample size n, a simplified formula Yamane (1967) was used.

$n= \frac{N}{1+N(e)2}$ eq. --1

Where n is the sample size, N is the population size, e is the level of precision.

A 95% confidence level and P = .5 were assumed

Accordingly:

The households sample size**:**

$$n = \frac{5260}{1+5260(.0585)2} = 276 \quad \text{eq. ---2}$$

Once the sample size determined, samples were selected from each Stratum of adopters and non-adopters households as follows.

Table 1 Proportional Sample Size Determination

Categories	HHs no.	How to compute	Sample size
Adopters	1753	1753 x total sample / total HH=1753x276/ 5260	92
Non-adopters	3507	3507 x total sample / total HH=3507x276/ 5260	≈184
Total	5260	1753x276/ 5260 +3507x276/ 5260	276

Source: Own computation (2018)

3.4.1 Households Sample Drawing

The systematic random sample drawing was applied for every k^{th} unit (1-3507 and 1-1753 for those non-adopters and adopters respectively) from sequentially arranged units within the N population. K runs from 1-172 non-adopters whereas 1-92 for those adopters based on the determined interval. The intervals (I) were determined the by dividing the number of population by the sample size. i.e. I=N/S, where I is interval or skip, N is Population size, and S is sample size. Accordingly, the intervals for non-adopters households=3507/236=15 whereas for adopter households =1753/92 =19

The selection of the first k unit was done randomly and then every k^{th} unit (15 and 19) thereafter for non-adopters and adopters households respectively.

(B). **Purposive sampling**: - For this study, non-probability sampling procedure was used for the selection of knowledgeable and experienced key informants from NGOes and state functions based on their involvement. Accordingly experienced groups promoting and implementing ethanol projects/initiatives (e.g. association and enterprises, fuel distributors, stove manufacturers, experts etc.) that could provide the views on issues they faced in practice, including specific barriers and enablers to ethanol uptake and stove adoption were selected. A sufficient number of participants were selected and enough information was provided to enable the researcher to compile the report of the study.

Accordingly, 3 women from the users, 2 experts from Ministry of Mine, Petroleum and Natural gas,2 experts from Ministry of Water, Irrigation and Electric, 1 expert from Gaia Association,1 expert from Sugar Corporation and 1 expert from Clean Stove Producers. Totally 10 experts were selected from these sectors.

3.5 Data Source and Method of Data Collection

In order to achieve the desired objective, both primary and secondary data were used in the research area. The primary sources of this study were households and the key informants from the users, local clean stove producers, ethanol fuel distributors, experts of NGOs and state functions. The secondary sources were the reports of experts of NGOs and state functions.

3.5.1 Data Collection Method for Specific Objective 1

The specific objective 1 was to assess the current status of energy by source and distribution of Woreda 6 communities in Gulele sub-city. The numerical data were collected quantitatively through structured questionnaires that were developed to include responses to general information. The responses were in relation to the views and experience in accordance with the diverse effects of households' energy consumption trends in the study area. Thus the questionnaires covered a wide range of clean cookstoves relevant to the central issue of the interest. The main energy sources assessed were traditional biomass (firewood, charcoal, animals and plants residues), kerosene, and clean energies (ethanol, LPG, and electric) as well as the households' energy consumption patterns (cooking, heating and backing) were identified.

Using the questionnaire as research instrument has its own limitations (Muijs, 2011). Therefore, to maximize the validity of the data collected by the questionnaires, the following activities were taken into consideration. These were the careful design of each and every question, the clear layout of the questionnaire format, Clear explanation of the objective of the questionnaires and Pilot testing was applied (Wilkinson and Birmingham (2003). Furthermore, in relation to this study, a questionnaire was constructed in relation to the literature review and the theoretical frameworks. In order to avoid language barriers and to facilitate easy understanding of the respondents, the questionnaires were first constructed in English, later translated into Amharic. Before the execution of the formal survey, the household questionnaire was first pre-tested with six households from 276 households that randomly selected among 5260 households.

After the test, any limitations in the measurement process such as ambiguous instructions, inadequate time limits and unclear formulated items were identified and some modifications were made. This was made the questionnaires as a clear way to collect data in a survey that people respond directly to the questionnaire form itself without the aid of an enumerator.

3.2.2 Data Collection Method for Specific Objective2 and 3

The specific objective 2 addressed socio-economic and stove-fuel characteristics that affect adoption of the clean cookstoves. Since barriers and facilitators of clean fuel uptake are highly interconnected, mutually interdependent and in most cases difficult to measure, the quantitative approach alone would have been sufficient to answer the entire proposed research question. Therefore, the researcher decided to employ qualitative and quantitative method for this objective to get data about a wider range of interests, enhance the significance of interpretation by generating deeper and broader insights and describe more fully the research picture.

i. **Quantitative data**

The contents of the questions were to determine features and characteristics of clean cookstoves that is important to households in the Ethiopian context. Besides they were to identify what kinds of socio-economic level of households are more likely to prefer this new technology. Accordingly, to enhance the significance of interpretation, the Likert scale as category-partition method was adopted. This was as recording technique for the responses to the questionnaire to capture the incidence, potency and intensity to what extent factors determine household's decision to adopt the technology. Empirical studies promote that the Likert rating scale is particularly useful for the purpose of evaluation of data as part of a research survey. In this study, a five-point Likert scale (strongly disagree, disagree, neutral, agree, strongly agree) was used to enable scores of either low or high values to represent the extent of the knowledge, opinion, judgment and experience of the respondents with regard to adopting the technology.

Table 2 Five Likert Scale with respect rate

strongly disagree	disagree	neutral	agree	strongly agree
1	2	3	4	5

ii. Qualitative Data

To yield data for the qualitative investigation the unstructured/ open-ended questionnaires were administered to stakeholders and state function experts. The researcher believed that experts working on ethanol stove production and fuel distribution can contribute specific and an in-depth information to the objective than household samples. It is believed that they could provide the technical explanation on views of specific barriers and enablers they faced in practice (experienced) in ethanol stove adoption. To conduct the discussion about institutional and the stove adoption barriers two focus group discussions were held with the presence of the users, the key informants of the clean stove producers, and the clean stove and ethanol fuel distributors, and experts of NGOs and state functions. On both the first and the second discussions ten key informants participated. The key informants' response was found to be similar to the second discussions and then the researcher understood that holding extra discussions would not add value and finalized the investigation.

3.6 Organizing Data and Analysis

To reduce incompleteness and make them useful in the analysis, the raw data were filtered before analysis. This was to solve the problems related to inappropriate responses, incomplete answers and other fictitious responses. Then the data was edited, coded, grouped, tabulated and summarized with the help of SPSS software version 20 and R-software.

3.6.1 Methods of Data Analysis for Specific Objective1

The supportive tools to analyze data were the excel sheet that simple to use for tables and graphs and spss software. These statistics were the percentage, frequency distributions and X^2 (chi-square) test.

3.6.2 Methods of Data Analysis for Specific Objective2 and 3

In this section, the descriptive statistic of data: frequency, a percentage, mean, standard deviation and Chi^2-square test, as well as econometric analysis, were done by SPSS 20. The qualitative data were analyzed by the use of intensive textual analysis.

3.7 Model Specification: - when the dependent variable is dichotomous, taking 0 or 1 values, there is a need for a probability model that has these two features: (1) as Xi increases, Pi = E(Y = 1 | X) increases but never steps outside the 0–1 interval, and (2) the relationship between Pi and Xi is nonlinear; thus, one can easily use cumulative distribution function (Gujarati, 2004). Both Logit and Probit regression models satisfy the above two requirements. But, even though there is no bias in statistical theory for preferring one over the other, there are two practical advantages of the binary model over probit model (Fox, 2010). The first one is its simplicity: the equation of the logistic CDF is very simple. The second is its interpretability: the inverse linearizing transformation for the binary model is directly interpretable as log-odds, while the inverse transformation for probit does not have a direct interpretation. By taking into consideration these advantages, the researcher preferred to use a binary logistic regression model to predict the effects of independents variables on the dependent variables. The logit model of adoption for the sample respondent households was expressed as follows; with intercept term (βo) and Xi independent variables can be equated as:

Ethanol stove adoption (Esa) = β0+β1age+β2fsize+β3edulev+β4 sex+β price+β6 income.

3.8 Econometric Model

3.8.1 Operational Definitions and Descriptions of Variables

This study included variables of ethanol stove adoption: household socio-economic and stove characteristics. These variables are defined and described as follows.

Dependent variable: Ethanol stove adoption (Esa) was given a value of '1' to the ethanol stove adopters while '0' was assigned to non-adopter to direct measure of the binary dependent variable in determining the adoption practice of ethanol stove.

Independent variables: The independent variables were selected based on the existing theories and empirical studies (Rogers, 2003; Puzzolo et al, 2013). The definitions of these selected explanatory variables are given below.

Age (age): Here refers to the age of the household head is a continuous variable measured in years. It was expected that the younger families could participate in ethanol stove adoption and use clean technologies than the older generation due to their challenging behavior to accept the new technology easily (Damte & Koch, 2011).

Educational status of household head: In this study a dummy which refers to whether the respondent is literate (can read and write) or illiterate (cannot read and write). A value of '1' was assigned for literate and '0' for illiterate. It was expected that literate-headed households have better chance to participate in ethanol stove and to use clean technologies than illiterate-headed household in the study area (Puzzolo et al, 2013).

Sex of household head: It is a dummy variable with a value of ‘1’ for male-headed household, and ‘0’ otherwise. It was expected that relatively female-headed households could adopt ethanol stoves (Damte & Koch, 2011).

Household income: It is a continuous variable measured in Ethiopian Birr. It was expected that households with higher income could have access and benefit from ethanol stove than those with lower income in the study area (Rogers, 2003).

Price: Here price refers the end users cost to buy ethanol stove in Ethiopia Birr.

Family size: In this study, it is a continuous variable; the number person living in the same household affects household energy consumption patterns and was expected that the larger family size could participate in ethanol stove and use clean technologies than smaller family size in the study area (Rogers, 2003).

Table 3 Summary of Variable Definition and Hypothesis

Variables	Type	Expected effect	Description
Age	Continuous	-ve	Households number of years
Sex	Dummy	-ve	if married = ‘1’and ‘0’ otherwise
Education level	Dummy	+ve	1’ if the respondent is literate and ‘0’ if illiterate
Family size	Continuous	-ve	Total number of the person in the households
Price	Continuous	-ve	Price of a clean stove in Ethiopia Birr
Income	Continuous	+ve	The annual income of the household in Eth. Birr

4. RESULTS AND DISCUSSION

4.1 Data Analysis and Discussion

For econometric analyses, the binary logistic model was employed. The explanatory variables included and analyzed in the model are summarized in Table 5 of section 3.7.1. The variables that have significant explanatory power in determining the clean stove adoption decision are interpreted in this section. The odds ratio and p-value effect of these explanatory variables were interpreted.

Further, to understand the extent to which these factors affect ethanol stove adoption decision, Statistical descriptive will be employed to identify factors affecting households' decision to adopt. 264 questionnaires (response rate 96%) collected and analyzed. However, the rest 12 questionnaires were incomplete and unreturned.

4.2 Results and discussion on Objective 1

4.2.1 Energy Sources and Distribution

The energy use status by source and distribution among non-adopters were (Electricity 32%, Kerosene19%, Charcoal 17% Firewood 17% Animal and Plant Residues 11%, LPG2%, Solar 2%) whereas (Electricity 32%, Ethanol 32%, Firewood 10% Animal and Plant Residues 11%, Solar 5%, Charcoal 4%, Kerosene 4% and LPG2%) were found to be distributed among the adopters. Figure 4 shows the energy source and distribution among the sampled households. This study has shown that households in the study area do not switch completely from biomass to modern fuels, but rather increase the number of fuels used as their total income rises. However, the identified energies are not equally dominant by source and distribution among household categories.

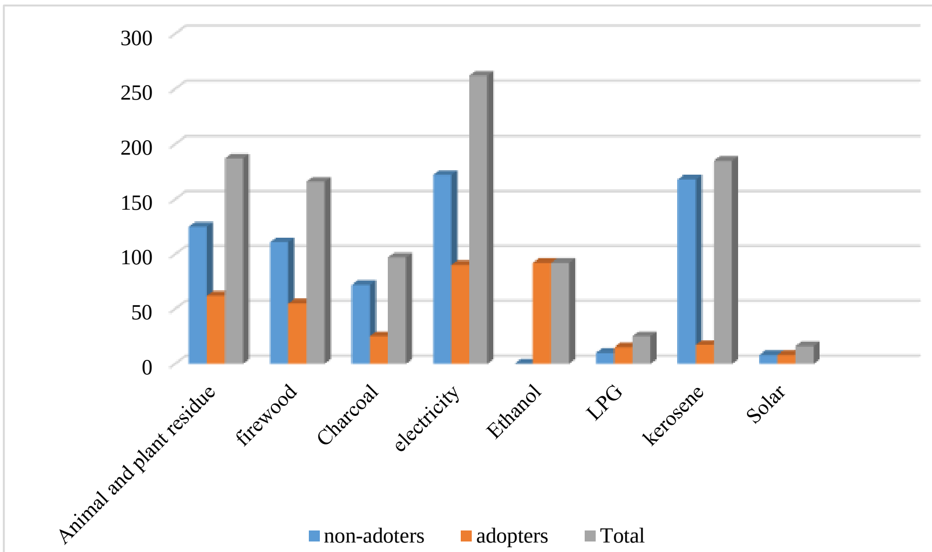

Figure 3: Energy Sources and Distribution among Non-Adopters and Adopters

Own survey data (2018).

4.2.2 Type of Fuel and Energy Consumption Pattern in Households

As table 6 below presents, the main energy source for cooking and heating in non-adopters households were kerosene55%, charcoal 27% and electricity 18% respectively. This indicated kerosene was the predominant energy source for cooking and heating which was the second household energy consuming practice in the study area (table 5). Conversely, 100 % of adopters used ethanol. This shows that ethanol can displace polluted and environmental risk full biomass and kerosene. On the other hand, 79.5% and 87.5% non-adopters and adopters respectively, agreed that backing needs a large amount of fuel and thus it is the most energy consuming practices. About 85.2% non-adopters and 62.5% adopter households used biomass sources and 14.8% non-adopters and 37.5% adopters used electricity for backing 'injera' and bread (table 5).

To feed household members, 'injera' may be made frequently which leads to consumption of much biomass fuel as compared to other cookings. This finding is similar to the studies conducted by (Beyene and Koch, 2013; *W. Legesse, et al., 2015)*.

Table 4 Types of fuel and Energy Consumption patters

Household energy	Categories	Non-adopter		Adopter		Total		χ2	p-value
		F	%	F	%	F	%		
Sources of energy for cooking and heating	Kerosene	95	55	0	0	111	51.6	255	.000*
	Charcoal	46	27	0	0	64	29.8		
	Electricity	31	18	0	0	40	18.6		
	Ethanol	0	0	92	100	40	100		
	Total	172	100	92	100	264	100		
More energy consuming practice	Cooking	36	20.5	12	12.5	49	92	1.38	.24NS
	Backing	136	79.5	80	87.5	206	100		
	Heating	0	0	0	0	0	0		
	Total	172	100	92	100	264	100		
The energy source for More energy consuming practice	Firewood	88	51.2	28	30	122	82	12.54	.002*
	Anima land plants residues	58	34	30	32.5	86	67		
	Electric	26	14.9	34	37.5	47	51		
	Total	172	100	92	100	264	100		

*Source: Own survey data (2018). NB: * indicates 1% level of significance, NS=not significant and F=frequency*

4.2.3 Estimate Types of Fuel and Energy Consumption Pattern in Household

To estimate the amount of energy consumption for the households in study area:-

1. The annual total energy used among the non-adopters (Table 5) = 547Mj*34%*172 +3650Mj*172*51% + 11242Mj*27%*172 +11753Mj*55%*172 +66Mj*14%*172= 2Tj

2. The annual total energy used among the adopters (table 5) = 547Mj*32.5%*92 +3650Mj*92*30% + 7701Mj*92 +66Mj*37%*92= 0.9Tj. Accordingly, the annual total energy used among the non-adopters and adopters is (1 and 2) is about 2.9Tj. The estimated energy for households in woreda 6 of Gullele sub-city was about 5260*2.9Tj/264 =57.8Tj. From this result one can conclude that if all households were adopted the ethanol stove, the current per year production of ethanol (700Tj) could have replaced the kerosene and charcoal (6.3Tj) which the households used for cooking and heating in the area. Furthermore, beyond the public health and environmental issues, adoption of ethanol stove can save foreign exchange which takes lion share of foreign currency (Nigatu, 2017).

Table 5 Estimate Types of Fuel and Energy Consumption pattern in Households

	Animal and plants residues in kg	Firewood in kg	Charcoal in kg	Kerosene in litter	Ethanol in litter	Electricity in kwh
Average daily used energy	1.5	0.5	1.05	1.2	2.2	.05kwh
The equivalent caloric value in joule	1500kj	10Mj	30.8Mj	32.2Mj	23.1Mj	0.18Mj
Annually used energy	547Mj	3650Mj	11242Mj	11753Mj	7701Mj	66Mj

Source: Own survey data 2018

4.3 Results and discussion on stove characteristics influencing household's adoption decision (Objective 2)

4.3.1 Household Adoption and Ethanol Fuel

As can be seen from the table 6 the majority (52%) of non-adopters and 75% of adopters agreed that the scarcity of ethanol fuel on the market hinders the stove adoption. From the witness of key informants, this is because of the current knowledge on the status of ethanol production and dissemination for the household fuel market, as well as on ethanol stoves initiatives, is quite limited. For instance, there is only one supply outlet for this big city. So users have to travel a lot of distance to find the ethanol. The key informants added that the existing ethanol distributors have very limited in distribution capacity both financially and physically. Existing distributors of ethanol for cooking are essentially few small enterprises for whom ethanol distribution is a secondary business. Private potential large-scale distributors (such as petroleum companies) have not yet to enter the market because of supply uncertainties.

Table 6 Household Adoption and Ethanol Fuel

Factors affecting adoption	Categories	Non-adopter		Adopter		Total		$\chi 2$	p-value
		F	%	F	%	F	%		
The shortage of ethanol fuel hinders the adoption	Neutral	15	8.9	2	2.5	25	9.5	7.6	.043**
	Agreed	89	52.2	69	75	143	54.2		
	Strongly agree	68	38.8	21	22.5	96	36.4		

Source own 2018, ***NB****: ** indicate 5% level of significance*

4.3.2 Household Adoption and Ethanol Stove Characteristics

As can be seen from the table 7 the majority (55%) of non-adopters and 75% of adopters agreed that the scarcity of the stove on the market hinders the fuel adoption.

From table 7 regarding the effect of the design of the stove in transportation and to serve for different cooking purposes hinder the adoption, 58% non-adopters and 55% adopters was disagreed. This implies there is a similar perception of the design of the stove between the two group of households and the chi-test did not indicate the significance. Both of the households groups assumed it was not the design that affected the adoption. But there were other issues such as lack of awareness and undeveloped market system.

About 54% of non-adopters strongly agreed and 75% of adopters agreed about the absence of the guarantee of the stove affected the adoption of ethanol stoves (table 7). This result is similar to the studies conducted by (Imam D. PPKT, 2011; Takama et al., 2012).

About 56% non-adopters agreed and 60% adopters strongly agreed that the size and quantity of the food be cooked the stoves for the large family affect the adoption of the stove. As key informants explained this is because the stove was not sufficient to prepare meals such as 'dorowat' on larger pots for those who have large family size and this was a limiting factor for adoption and sustained use of a new cooking technology. This is in line with the findings of (Troncoso K et al., 2007; Person, B et al., 2012; Barnes et al., 2014). The Chi^2-test showed significance at 5% level (table 7).

From table 7 the majority of non-adopters households (60%) agreed and about 75% adopters disagreed that the traditional beliefs such as household preferences, food tastes, cooking practices by the stove hinder the adoption. From witness of key informants**,** the inconvenience of fuel consumption for cooking 'shirowot' at simmering time and for the coffee ceremony was found to be enabling limiting factor for adoption and sustained use of the stoves. This result in line with studies conducted by (Christoff, 2010; Barnes, 2014)

As indicated in table 7, the majority of non-adopters households (80%) and about 53% adopters agreed that the fear of stove accident hinders stove adoption. As key informants explained one of the most serious fear is the dangers of using ethanol-based stoves in the past. The most familiar example is the so-called K-50 stoves. These stoves were not designed for a 100% kerosene fuel blend, but many consumers did not understand this limitation. As a result, several people were injured by improper use of the stoves. There was the strong fear from the non-adopters side rather than adopters. The perception from the adopters’ side is being progressed due to the absence of the accident from the current users of the stove and the chi-test declared the significance.

Table 7 Household Adoption and Ethanol Stove Characteristics

Factors affecting adoption	Categories	Non-adopter		Adopter		Total		χ2	p-value
		F	%	F	%	F	%		
The shortage of the stove hinders the adoption	disagree	21	12.5	11	7.5	33	12.5	13.6	0.003***
	Agreed	84	54.7	51	75	131	49.6		
	Strongly agree	67	33.8	32	17.5	100	37.9		
Unsuitability of the design hinder the adoption	strongly disagree	83	58	41	45	125	47	0.59	0.28NS
	disagreed	89	42	51	55	139	53		
	agree	0	0	0	0		0		
The absence of guarantee of the stove hinder the adoption	Disagree	26	15.5	0	0	34	15.2	10.6	.0014***
	Agree	86	53.9	69	75	144	54.5		
	Strongly agree	60	30.5	23	25	85	32.2		
The inability of the stove to prepare food for the large household size	Disagree	69	44	32	35	103	40	.57	.46NS
	Agree	7	4	5	5	11	40		
	Strongly agree	96	52	55	60	150	57		
Traditional beliefs about the stove such as food taste, cooking practice hinder the adoption	Disagree	17	10	69	75	28	6	10.4	0.001***
	Agreed	109	60.4	23	25	159	60.2		
	Strongly agree	46	29.6	0	0	59	28		
Effect of fear of stove accident	Disagree	3	2	9	10	19	7.2	15	0.001***
	Agreed	146	80	51	53	17 5	66.3		
	Strongly agree	23	18	32	37	70	70		

Source: Own survey data (2018). ***NB****: *** indicate 1% level of significance, NS=not significant, F=frequency,*

4.3.3 Reasons to Adopt Ethanol Stove:

To investigate the most important reasons for the adoption of ethanol stove, only ethanol stove adopters (92 respondents) were asked. As the table (8) shows, the perceived relative benefits of ethanol stove over solid biomass and kerosene were found to be the most important reasons to adopt this clean cooking technology. Accordingly, out of the surveyed 40 adopters of ethanol stove (67.5%) strongly agreed that perception of the stove's clean and free of emissions was one important justification to purchase ethanol stove.

Out of the surveyed 92 adopters of ethanol stove (67.5%) strongly agreed that perception of safer to use was one important justification to purchase ethanol stove, (62.5%) strongly agreed that due to time and fuel saving property of the stove was the reason to adopt. This finding is similar to some previous studies (Imam D. PPKT, 201; Takama, Ta et al., 2012).

Table 8 Reason to Adopt Ethanol Stove

Statements/ Reasons		DA	A	SA	Mean	St.dev
		22.5	15	62.5		
The stove is clean and free of emissions	**fr**	**-**	30	62	4.67	.47
	%	**-**	32.5	67.5		
The stove is safe to use	**fr**	**-**	22	70	4.67	.47
	%	**-**	24	76		
Time and fuel saving property	**fr**	22	14	56	4.4	.84
	%	22.5	15	62.5		

Source: Own survey data (2018), DA= disagree, A= agree, SA=strongly agree

4.4 Results and Discussion on factors affecting households decision to adopt the ethanol stove (Objective 3)

4.4.1 Awareness and Attitude of Households towards Ethanol Cookstoves

As the result shows that majority of (86%) of non- adopters were found to be unaware adverse effects of health cooking with traditional biomass fuel and kerosene whereas 100% adopters were awared about the relative benefits of ethanol stove (Table 9). From the result, one can deduce that the lack of consumer awareness about the negative effects of cooking with traditional and fossil fuels on health and environment was one of the barriers to ethanol stove and fuel adoption. The finding of this study is similar to previous works (Pattanayak et al., 2016; Mubarak et al., 2012) in terms of that the greater awareness of the adverse effects of exposure to indoor air pollution may make cleaner fuels or stoves more attractive to adopt. Moreover, the ethanol stove adopter households are found more advantages in terms of saving time and fuel of cooking and heating, improve their health and contribution to reducing environmental burden as compared to non-adopters. However, the penetration rate of adoption ethanol stove too low in the study area. To improve these knowledge gap different strategies should be planned to promote sustainably and create awareness among the population about the health and environmental benefits of the technology via demonstrations, posters, and radio or TV advertisements.

With regard to sources of information, as shown in (table 9) the main source of information (67%) for non-adopters and 87% for adopters were ethanol fuel distributors while the minority of 6.7% and 12.5% non-adopters and adopters respectively claim that stove producers were more accessible source of information.

From table 9 the majority of non-adopters (77.7%) had negative attitude towards ethanol cookstove. This may be from the fact that some clean cookstoves marketed in Ethiopia had suffered dangerous explosions and caused severe burns in the past. Conversely, 100% of the adopters had positive attitudes towards ethanol cooking stove technology. The key informants stated that they perceived that cooking with ethanol stove could substantially contribute towards solving environmental and health problems of fossil fuel and biomass as well as reducing time spent to prepare food especially for households having students.

Table 9 Awareness and Attitude of Households towards Ethanol Stove

Awareness and Attitude	Categories	Non-adopter F	Non-adopter %	Adopter F	Adopter %	Total F	Total %	χ2	p-value
About time and fuel saving benefit of Ethanol stove	Yes	9	4	92	100	49	18.6	206.8	.000***
	No	163	86	0	0	215	81.4		
	Total	172	100	92	100	264	100		
About adverse effects of biomass and kerosene on health	Yes	9	4	92	100	49	18.6	206.8	.000***
	No	163	86	0	0	215	81.4		
	Total	172	100	92	100	264	100		
Sources of information	stove producers	115	67	80	87	185	70.1	6.8	.005**
	fuel distributors	57	33	12	13	79	29.9		
	Total	172	100	92	100	264	100		
Attitude towards ethanol stove	positive	40	22.3	92	100	90	33.7		
	negative	132	77.7	0	0	174	66.3	6.8	.009**
	Total	172	100	92	100	264	100		

*Source: Own survey data (2018), *** and ** Significance at the level of 1% and 5%*

4.4.2 Ethanol Stove Adoption and Other Related Issues for adopters

Table 10 shows that about 90% of adopter faced problem of fuel shortage and 10% of them faced problem of maintenance in using ethanol stoves. In this study no problem of ethanol stove accident was reported. This is in line with empirical studies conducted by Takama, T., Tsephel, S. & Johnson, F.X., (2012) that reported the safety of the stove is one of the most desirable positive features of stoves to facilitate adoption. On the other hand, there were only 12.2% sampled households who had access to technical support services. The key informants added that very few households use ethanol for cooking, therefore, few have firsthand knowledge of ethanol as cooking fuel and they do not operate well (households using the stove learned how to operate from each other or seeing others use the fuel). The majority of adopters (62.5%) and 37.5% replied that the immediate energy sources used during the shortage of ethanol were kerosene and electricity respectively. This indicated that energy supply was heavily dependent on kerosene which is polluted sources of energy and hence searching clean alternative source of energy and adoption of clean stoves is essential. As can be seen from table 10 the majority of adopters (90%) get the stove by subsidy. According to results from key informants, the current stove supply has become mainly market-based in which the full costs of stoves had to be paid by users. With removal of subsidy, the cost would be the key barrier to purchasing the technology. They suggested that subsidy or access to financial support services and flexible stove pricing policies can enable the individuals to adopt ethanol stove technology. However, it must be managed carefully to avoid adverse effects on markets and the perceived value of the technology. This result is in line with the findings conducted by (Barnes DF et al., (2012); Person B et al., 2012; Sesan TA., 2012), in the aspect that subsidies are likely to be important for equity of access (for the poorer households) especially to higher performing and more expensive clean cookstoves.

Table 10 Ethanol Stove Adoption and Other Relate Issues to Adopters

Problems and technical support	Categories	F	%
Any problem associated with the use of ethanol stove	Yes	83	90
	No	9	10
	Total	92	100
Types of the problem associated with use of ethanol stove	Shortage of fuel	83	90
	Maintenance problem	9	10
	Accidents	0	0
	Total	92	100
Technical support services to adopt ethanol stove	Yes	12	12.5
	No	80	87.5
	Total	92	100
The ways the adopters get the stove	subsidy	83	90
	Full payment	9	10
	Total	92	100
The source of energy when the ethanol stove fails	kerosene	60	62.5
	Electric Stove	32	37.5
	Total	92	100

Source: Own survey data (2018),

4.4.3 Binary Logit Model to Identify Determinants of Ethanol Stove Adoption

In the previous section, factors affecting households' ethanol stove adoption decision were analyzed using descriptive statistics. Further, to understand the extent to which these factors affect ethanol stove adoption decision, the binary logistic model was employed. The explanatory variables included and analyzed in the model are summarized in Table 5 of section 3.7.1. The variables that have significant explanatory power in determining the clean stove adoption decision are interpreted in this section. The odds ratio and p-value effect of these explanatory variables are interpreted below.

Table 11 Logit Regression Estimation Result

Variables	B	S.E	Wald	p-value	Exp(B)
age	-.270	.052	26.893	.000***	.764
sex(1)	-4.191	1.835	5.216	.022**	.015
Fsize	-.598	.268	4.976	.026**	.550
Educ(1)	.806	1.387	.338	.561	2.239
income	.005	.002	4.192	.041*	1.005
price	-.002	.001	6.202	.013**	.998
Constant	9.963	3.259	9.346	.002	21226.13

*Source: Own survey data (2018). NB: ***and ** indicates 1% and 5% level of significance respectively*

4.4.4 Regression Result Interpretation

Sex: The odds ratio indicates that the probability of ethanol stove adoption is 0.015 times higher for female-headed as compared to male-headed households. As it was expected, this finding reveals that male-headed households were found more unlikely to adopt ethanol stove than female-headed of their counterparts. This might be because of female of female-headed households may have greater power in the household to make economic decisions (in this case the economic decision to purchase ethanol stove) than the male-headed households. The result of this study is consistent with empirical studies of Damte and Koch (2011) that found single women (female-headed households) are more likely to adopt fuel efficient new technologies as compared to married women.

Age: This variable had a negative significant effect on a households' ethanol stove adoption decision with ($p<0.01$).

The odds ratio indicated that the probability of the clean stove adoption decreased by 0.764 as the age of household head increase by one year.

Family size: This variable had a negative significant effect on a households' ethanol stove adoption decision with p-value 0.026. The odds ratio 0.55 indicated that the probability of the clean stove adoption decreased by 0.55 as the number of household increase by one person.

Price: As it was expected the price of ethanol stove was found to have a negative significant effect on a households' ethanol stove adoption decision. This variable has p-value and odds ratio 0.013 and 0.998 respectively. The odds ratio of 0.998 for price shows that the probability of clean stove adoption decreased by 0.998 times for one birr increment in the price of the clean stove. This finding confirms household energy ladder theory which asserts that a household's socio-economic status (i.e. the ability to pay the price of clean stove) determines the adoption decision. This study is consistent with the findings of Gebreegziabher et al. (2010) and Puzzolo et al. (2013) that found price as one determinant factor that affects clean cookstoves adoption decision.

Income: As it was expected, the income level of the household was found to have a significant positive effect on urban household's ethanol stove adoption decision with a p-value of 0.041 and odds ratio of 1.005. The odds ratio of 1.005 for income shows that the probability of clean stove adoption increased by one birr increment in the household annual income. This finding is supported by household energy stacking theory that rather than transiting linearly to advanced fuels (electricity and LPG), households tend to increase the number of fuels used without actually leaving out the old (the traditional) ones. The finding of this study is similar to previous works (Gebreegziabher *et al*. (2010) and Puzzolo *et al.* (2013) that found higher income level of households to have a significant positive effect on household's clean cookstoves adoption.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Summary

In the study area, the traditional biomass and kerosene are identified as the major source of cooking and heating energy. The identified energies were not equally dominant by source and distribution among households. Electricity was accessed to every household. However, the majority of households used the electricity for lighting home. Firewood, animals and plants residues were used by both households' categories for backing. However, for cooking and heating, ethanol was dominated among the adopters whereas kerosene and charcoal were among the non-adopters households. On the other hand ethanol has potential to replace totally the imported kerosene for house hold energy and charcoal for cooking in the investigated area. There was already familiarity with using more than one type of fuel/ energy in the investigated area. The continuity of using the traditional fuel and stove as the new one adopted appeared to facilitate uptake of an additional cookstove.

Household head's age and family size were found to be statistically significant and negative to the household's decision to adopt ethanol stoves. Households of Small family were found to be more ethanol stove adopter than households of the larger family. Education was found to be statistically insignificant to determine households' clean stove adoption.

The nature of design features of technology such as cleanness, conveniences and safety are found to be fundamental importance in relation to adoption and sustained use. There is inadequate public awareness about the dangers of using ethanol-based stoves. This was due to improper use of the stoves by the users in the past. Some cleaner cookstoves marketed in Ethiopia suffered dangerous explosions and caused severe burns in the past.

Moreover, ethanol availability constraints was found to be the barrier to ethanol stove adoption. Besides, the current stove supply situation is market-based approaches in which the full costs of stoves had to be paid by the users; the cost would be the key barrier to purchasing the stoves. .

5.2 Recommendation

Based on the study conducted and major findings, the following recommendations has been forwarded.

- ✓ The government should encourage the strategies of access to clean, affordable and sustainable energy services through adoption and promotion of ethanol cook stoves and fuels in the area.
- ✓ The government should encourage the introduction of ethanol as a domestic, renewable cooking fuel to reduce the financial risks to the economy of dependence on import fuel.
- ✓ The penetration rate of adoption of ethanol stove has been low in the study area. To improve these knowledge gap different strategies should be planned to promote sustainably and create awareness among the population about stoves benefits via demonstrations, posters, and radio or TV advertisements.
- ✓ The government and other development partners need to assist stove producers, fuels distributors and users technically and financially through training and access to credit provision schemes.

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Appendices

Appendix A: Household Survey Questionnaire

Hawassa University, Wondo Genet College of Forestry And Natural Resources School of Natural Resource and Environment Study.

Objective:

Dear respondents, the purpose of this questionnaire is to gather primary data about factors determine household' decision on adoption of clean technology ethanol stoves adoption. The study is for partial fulfillment of the requirements for Master's Degree in renewable energy utilization and management at Hawassa University Wondo Genet College of forestry and natural resource. I confirm you that all data will be used for academic purpose and your responses will be kept confidential.

Instructions:

- No need of writing name
- Where boxes are available please tick (√) in the box.
- Where boxes are unavailable write the letter(s) and/or answers on the spaces provided.

Instructions to Enumerators:-

- Make brief introduction before starting any question,
- Introduce yourself to the respondents, greet them in local ways and make clear the objective of the study.
- Please fill the interview schedule according to the respondents reply or follow the respondents to fill the space provided properly (do not put your own feeling).
- Please ask each question clearly and patiently until the respondents get your points.
- Please do not use technical terms and do not forget local units.

Thank you for your cooperation

SECTION I*:* Socio-economic and demographic characteristics of households

1. Age__________ (in years)

2. Who is the head of this house hold? Male ☐ Female ☐

3. Literacy level: Illiterate (cannot read and write) ☐ Literate (can read and write) ☐

4. Religion 1. Orthodox. 2. Muslim. 3. Catholic. 4. Protestant 5. Others (specify

5. Who is more responsible to fulfill cooking appliances in your family? Females ☐ Males ☐

6. Who is more responsible to prepare food in your family? Females ☐ Male ☐

7. Who are more responsible for fuel supply in your family? Females ☐ Males ☐

8. Total family size: ________ (in number)

9. Your monthly income in Birr _____________________

10. What is the price of Ethanol stove in your locality? _________ (in birr)

11. What would you say about its cost as compare to the price of the other clean cookstoves?

Cheap ☐ Fair ☐ Expensive ☐

12. Which number contains the most likely barriers to adopt ethanol stove in your locality?

A. Shortage of Ethanol stove B. Shortage of Ethanol fuel C. higher price of the stove D. higher price of the Ethanol fuel E. Lack of awareness about Ethanol stove's benefits

***SECTION* II** Households' awareness and attitude on ethanol fuel and stove

13. Do you have information about the health, economic and environmental benefits of using 'Ethanol' stove?

Yes ☐ No ☐

14. Are you aware of the adverse effects of cooking by traditional biomass and kerosene?

Yes ☐ No ☐

15. What is your attitude towards ethanol stove technology?

A. positive B. negative

16. If your answer for question 15 is Negative, please specify why for?___________________

____

17. Which source of information do you think that the most likely accessible, as compared to others, for the urban households regarding to ethanol stove and fuel? Choose one.

a. Ethanol fuel distributors.

b. Ethanol stove producers.

c. Media like TV and radio d. Government bodies such as energy experts and health extension workers

***SECTION* III** source and distribution of energy

18. Please choice all types of energy sources and the amount in kilogram that currently you are using for your family from alternatives given below. Put the numbers represent your choice in the box provided. The sources of energy are represented by the numbers as follows. Dung, leaf branch and sawdust=1, firewood= 2, charcoal=3, electricity=4, kerosene=5, LPG=6, ethanol stove=7, ethanol=8, solar= 9, and others=10

☐

19. What types of energy source does your family frequently use for cooking and heating? Choose one.

A. Kerosene. **B .** charcoal . C. electricity. D. solar E. firewood . F. Dung, leaf branch and sawdust

20. Which practice is consuming the largest amount of your family's energy supply?

Cooking ☐ backing ☐ lightening ☐

21. What types of energy source do you frequently use for the practice consuming the largest amount of your family's energy supply? Choose one. A. **e**lectricity B. Firewood C. Dung, leaf branch and sawdust

22. Is there any fuel available for free of charge for your family energy consumption?

Yes ☐ no ☐

SECTION V *Fuel and stove characteristic*

23 For question 23-29 please state an opinion for the extent to which the following factors given in the table below affect the adoption of ethanol stove and indicate for each given reasons by using 1= strongly disagree 2= disagree 3= neutral 4= agree 5= strongly agree.

	Statements/ Reasons	1	2	3	4	5
23	The shortage of ethanol fuel hinders the stove adoption					
24	The scarcity of the stove hinders the adoption					
25	Inability of the stove to prepare food for the household size hinders the stove adoption					
26	The absence of guarantee of the stove hinder the adoption					
27	Unsuitability of design of the stove hinders the stove adoption					
28	Traditional beliefs such as food taste, cooking style by the stove hinder adoption					
29	Fear of accident of the stove hinders the stove adoption					

Other,specify____

____

4.1 Ethanol stove adoption and other related issues

30. If you purchase and using ethanol stove, please state an opinion for you buy and use it as compare to conventional fuels and stoves for question 30-32 in the table below and indicate for each given reasons by using 1= strongly disagree 2= disagree 3= neutral 4= agree 5= strongly agree.

	Statements/ Reasons	1	2	3	4	5
30	The stove is clean and free of emissions					
31	The stove is safe					
32	Due to its time and fuel saving property					

33. Is there any problem associated with use of ethanol stove? Yes ☐ No ☐

34. If you say yes, what is it? Shortage of fuel ☐ Maintenance problem ☐

☐ Accidents ☐ Other, specify

35. Are there any technical support services to adopt ethanol technology?

A. Yes B. No

36. Did you get any maintenance and operational training on ethanol stove technology?

Yes ☐ No ☐

37. Do think that the give technical support is enough? Yes ☐ No ☐

38. If the ethanol stove does not operate or fails, what do you use for cooking?

☐ Kerosene Electric stove ☐ Traditional stoves ☐ solar stoves ☐Other

39. How do you get the stove? With subsidy ☐ Full payment ☐

Free ☐

APPENDIX B: Checklist for FGD

Checklist for FGD

1. Have you ever done some fieldwork or surveys with ethanol stove users? ______________

What could you tell me about ethanol stove users? ________________________
____

2. How do you evaluate about the users training and maintenance services of ethanol stoves for users?

Is it satisfactory? ____

3. What would you suggest could be done in relation to market and supply chain in order ethanol stove market is to be successfully scaled up? ____

If no,why____

5. In your experience, what are the most likely barriers of ‘ethanol’ stove adoption?
6. Do think providing financial supports (e.g. such as providing tax holidays, tax removal on ethanol and materials imported) can radically improve ethanol stove supply and encourage adoption?

7. Any final comments/opinion that you would like to add? ____

APPENDIX C: Variables in the Equation

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	age	-.265	.051	26.827	1	.000**	.767
	sex(1)	-3.956	1.697	5.434	1	.020*	.019
	Fsize	-.591	.288	4.213	1	.040*	.554
	Educ(1)	.128	1.341	.009	1	.09***	1.136
	In come	.005	.002	4.095	1	.043*	1.005
	Price	-.002	.001	5.134	1	.023*	.998
	Constant	10.302	3.774	7.452	1	.006	29806.809

NB: * and ** and *** indicates 5% and 1% and 10% level of significance respectively