INVESTIGATION OF FUELWOOD CONSUMPTION AND ITS CONTRIBUTION FOR CLIMATE CHANGE: A CASE OF NEGELE ARSI TOWN, WEST ARSI ZONE, ETHIOPIA.

BY

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APPROVAL SHEET - I

This is to certify that the thesis entitled ‘‘Investigation of household fuelwood consumption and its contribution for climate change’’ submitted in partial fulfillment of the requirements for the degree of Master of Science with specialization in Renewable Energy utilization and Management of the graduate program of the Department of Environmental science, Wondo Genet College of Forestry and Natural Resources, and is a record of original research carried out by Gemedo Mohammed Bona Id. No MSc/REUM/R010/10, under my supervision, and no part of the thesis has been submitted for educational institutions for achieving any academic awards.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it be accepted as fulfilling the thesis requirements.

Zerihun Demrew(PhD) __________________________ ________________________

Name of Supervisor Signature Date

APPROVAL SHEET - II

We, the undersigned, members of the board of examiners of the final open defense by Gemedo Mohammed Bona have read and evaluated his thesis entitled ‘‘Investigation of household fuelwood consumption and its contribution for climate change’’, 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 in Renewable Energy utilization and Management at Hawassa University, Wondo Genet college of Forestry and Natural Resources.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the CGS through the DGC of the candidate’s department.

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DEDICATION

I dedicate this thesis to my father Mohammed Bona and my mother Medina Giro for their inspiration, love and support throughout my life and also to my lovely brother Suleyman Mohammed too.

DECLARATION

This thesis paper is my original work and has not been presented for the award of a degree in this University or any other institution of higher learning for examination.

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Signature Date

GEMEDO MOHAMMED BONA

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVATIONS

ANCED	Arsi Nature Conservation and Environmental Development
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
ECRGE	Ethiopia's Climate Resilient Green Economy
EDRI	Ethiopian Development Research Institute
FAO	Food Agriculture Organization
FDG	Focus Group Discussion
IEA	International Energy Agency
ICS	Improved Cook Stoves
MOWIE	Ministry Of Water Infrastructure and Energy
NAWEO	Negele Arsi Water and Energy Office
NGO	Non Governmental Organization
ORS	Oromia Regional Survey
SPSS	Statistical Package for Social Science
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WMEO	Water Mine and Energy Office

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ABSTRACT

Developing countries still heavily rely on biomass to meet their basic energy needs. Such heavily reliance on traditional biomass is a threat to forest ecosystem and contributes to climate change. However, empirical evidences on the amount of fuelwood consumption and contribution to climate change were limited. This study was carried out to investigate the household fuelwood consumption and its contribution for climate change, in Negele Arsi town, West Arsi zone, Ethiopia. Door to door survey, focus group discussion and key informant interview were made to gather relevant information. This study found fuelwood was the common and major energy source of the area accounting for 84.5% of energy used for home based activities. The survey results showed podocarpus facaltus, Eucalyptus species and Acacia Etbaica are the most preferred fuelwood species. It was found that about 212,831.5 tones of fuelwood have been consumed for baking Injera in the area and 13.1 tones of CO_2e of CO_2 was emitted from the individual household annually from the activity. Injera baking using mirt stove saved about 48.88% of fuelwood consumption of the area compared to the traditional open fire method. The household family size encountered with the type of business the family engaged in was affecting the extent of household fuelwood consumption. Fuelwood consumption was found a significant contributor of forest resources degradation and climate change.

Keywords: *Fuelwood Consumption, Climate Change, Fuelwood, Greenhouse Gases Emission, Species Preferences*

1. INTRODUCTION

1.1. Background of the study

Energy is essential for one country sustainable development and socioeconomic activities. It plays a significant role in meeting our basic needs mainly for cooking, heating, boiling water and lighting. About half of the global population is dependent on traditional fuel and stoves to meet their energy needs (Klasen et al, 2013). The main source of fuel energy in both urban and rural areas within developing countries is biomass (FAO, 2012). Biomass is commonly available in two forms: charcoal and firewood. Charcoal is energy that is made from wood, while firewood is collected and used directly from the field (FAO, 2012). Fuelwood gathered from forested areas is the most important source of domestic energy for the developing world (Heltberg et al., 2005).

In many developing countries, firewood users are dominant in rural areas, whereas charcoal is commonly employed in urban areas (Arnold et al, 2006). Unlike firewood use in rural areas, there has been concern about the environmental impact of charcoal use in urban areas (Gebreegziabher, et al, 2012); that is because collected firewood is mostly from dead wood or small branches, though charcoal is mainly produced from living trunks or branches. Traditional biofuels have harmful effects, such as human health issues caused by indoor air pollution and impacts on forest areas, so an energy transition from traditional biofuels to modern fuels is needed (DeFries R.. Pandey, D., 2010). Understanding the household energy transition is of vital importance in searching policies to support this transition process. A common model to describe the household fuel choices in developing countries is the “energy ladder”, where primitive fuels (such as firewood and agricultural wastes) are replaced by transition fuels (such as charcoal and kerosene) and then advanced fuels (such as electricity and liquefied petroleum gas) in the processes of urbanization (Van

Der Kroon et al, 2013). On the other hand, studies showed that the energy transition does not occur as a series of simple, discrete steps as the “energy ladder” implies; instead, “energy stack” is more common, where with increasing income, households adopt new fuels and technologies that serve as partial rather than perfect substitutes for more traditional ones (Van Der Kroon et al, 2013). Comparisons of household energy consumption between rural and urban areas would help understand the energy transition patterns and their environmental impacts.

At the household level the potential problem of fuelwood consumption concerns the health of people who are exposed to indoor air pollution stemming from incomplete combustion of wood due to use inefficient stoves. The consequences of this are respiratory diseases and lung cancer which culminate into unwarranted deaths (Smith, 2003), hence causing social and economic problems. Fuelwood consumption has adverse effects on the environment as reflected by deforestation, which leads to extinction of species, habitat destruction, ecosystem simplification and climate change. According to ECRGE, Ethiopia’s climate resilient green economy strategy document (2011), fuelwood consumption is the main source for GHG emissions in Ethiopia. The fuelwood is mainly used for residential baking and cooking purposes. Highly inefficient technologies (open fire or three stone methods) have been used by most households and the environmental concern here is huge. The relationship between household energy use and issues of climate change at the local and global level has to be investigated and it will help to inform the future environment and policy makers.

1.2. Statement of the problem

The consumption of biomass fuels in Ethiopia is increasing from time to time (Alemu, 2000). Unsustainable fuelwood consumption is the second largest driver of deforestation and the major cause for forest degradation, causing the emission of an estimated 25 Mt of CO_2 from deforestation in 2010(EDRI, 2010). Consequently, biomass degradation due to unsustainable fuelwood consumption will reach 22 Mt per year in 2030, from 14Mt in 2008. This increase in CO_2 concentration is raising the issues of climate change in the country. Climate change is disrupting the national economies and affecting lives, costing people, communities and countries dearly today and even more tomorrow.

Among many areas exposed for such problems Negele Arsi Woreda is one of the area of Central Rift Valley. The, Langanoo, Abijata, and Shalla Lakes area of the mid rift valley is entertaining the same environmental degradation as that of the national catastrophe due to human interaction in existing ecosystem (Zerihun Woldu *et al*., 1999). In general the vegetation of the area is under threat by the combined forces of resource exploitation and forest degradation and particularly in Negele Arsi woreda. Therefore, the main reasons for initiating this research was:- 1) Cutting of trees for fuelwood without replacement has become serious problem contributing to climate change in the study area resulting an increase in temperature and reducing crop yields; 2) Most of the domestic energy sources comes from fuelwood causing significant deforestation; 3) Inefficient cooking stoves have caused wastage of a lot of energy and exacerbates deforestation in the study area; and 4) High consumption rate of fuelwood due to absence of affordable alternative energy sources for people in the study area. Against this backdrop, the present investigation examined the household's fuelwood consumption and its contribution for climate change in the study area.

1.3. Objective of the study

1.3.1. General objective

The overall objective of the study was to investigate household Fuelwood consumption and its contribution for climate change in Negele Arsi town Oromia regional state.

1.3.2. Specific objectives

The present investigation was conducted with the following specific objectives:

1. To measure fuelwood consumption at household level in the study area.
2. To examine the contribution of fuelwood consumption for forest degradation and climate change.
3. To assess the socioeconomic characteristics of the household vs. the extent of fuelwood consumption in the study area.
4. To determine the contribution of improved stove in reducing fuelwood consumption as compared with traditional three stone stoves.

1.4. Research questions

1. How much fuelwood is consumed for household uses in the area?
2. What is the contribution of fuelwood consumption for forest degradation and climate change in Negele Arsi town?
3. What socio-economic characteristics of the household affect the extent of fuelwood consumption?
4. Do you think that the use of improved cook stoves reduces the amount of fuelwood consumption?

1.5. Significant of the study

In Ethiopia, the household energy need is satisfied by the use of biomass fuels such as firewood, charcoal and animal dung which accounts almost 90% of the energy consumption (Mekonnen and Kohlin, 2009). Extreme dependence on such fuels has its impact on natural environment. Especially, the heavily reliance on fuelwood has significant problems which is related with deforestation, land degradation, health and climate change crisis. Access to clean, cheap, modern reliable and sufficient energy provides opportunities for developing countries to eradicate poverty and achieve economic development (Barnes et al, 2011). As Ethiopia aims to leap frog to a middle income country, with an ambitious zero net emission by 2025, the country is working strenuously on renewable and clean energy. But on the other hand rapid economic growth and population expansion are putting high demand for energy, water and food.

Energy plays a central part in Ethiopia's effort to the reduction of poverty and to achieve sustainable development, since it touches all features of development; economic, social and environment including household welfare, health, population levels, and education and gender issues. In addition none of the SDGs can be met without access to clean and efficient energy services. Global initiatives have shown their concern especially in developing countries like Ethiopia and have raised funds to foresee the implementation and adoption of clean stoves and CRGE to achieve economic development goals in a sustainable way. Therefore this study is in line with the Ethiopian Government's effort to achieve the vision 2025 agenda and the UN Sustainable development goal. The outcome of this research will be useful to the policy makers in the formulation of policies in relation to energy production and consumptions. At the study area level it will help the households to adopt and use the cleaner and environmentally friend energy sources. Finally it will equip the future researchers with knowledge as they carry out their research study on sustainable energy sources.

1.6. Scope and limitations of the study

The study area was limited to Negele Arsi town, Negele Arsi woreda. The study was limited to the household level and it covered specifically the investigation of fuelwood consumption and its contribution for climate change in the study area. One of the limitations of the research was a limited research and resources available on energy use and technology in which case it was not possible to associate or compare previous facts in relation to energy use and technology in the area. The second limitation of the study was inability of getting fully dependable data on monthly income and expenditure of respondents on fuelwood. Therefore, it was not possible to calculate the fuel expenditure per head and make comparative analysis with those who have improved cook stoves (ICS) and have not. The third limitation was that sampling of quantitative survey was dependent on the amount of the research fund and time availability rather than taking into consideration the target population in the study area.

2. LITERATURE REVIEW

2.1. Household energy consumption in developing countries

The world total primary energy accounts for 9% with an increasing dependency of more than two billion in developing countries (FAO, 2011). Therefore, energy plays a crucial role in contributing to an improved social economic status of many people in developing countries. In sub-Saharan Africa, about 90% of rural population and half of the urban are highly dependent on biomass to meet their energy demands (WHO, 2006). Accordingly over 95% of people in sub-Saharan countries have no access to modern energy with countries such as Ethiopia, Tanzania, Kenya and Nigeria leading with the highest fuelwood consumption percentage of 96, 90, 76 and 67 respectively.

The main source of household energy in both urban and rural areas within developing countries is biomass (FAO 2012). In China as in most developing countries, wood is a key source of energy for rural residents. Despite the extremely rapid economic growth that China has experienced over the last 30 years, a large number of rural households still heavily depend on traditional biomass energy for both heating and cooking, especially in remote areas where it is sometimes the only energy available. Biomass is commonly available in two forms: charcoal and firewood. Charcoal is energy that is made from wood, while fuel wood is collected and used directly from the field (FAO 2012). Approximately, 60% of the world total wood removals from forests and trees outside forests are used for energy purposes. Fuelwood gathered from forested areas is the most important source of domestic energy for the developing world (Heltberg et al. 2000).

African countries still heavily rely on fuelwood to meet their basic energy needs. An estimated 60-85% of Africans use fuel wood as their primary source of fuel (FAO 2009). Heavy reliance on biomass fuels in developing countries has raised global concerns over both environmental consequences such as forest degradation and soil erosion, and the adverse health consequences of indoor air pollution generated by burning wood, animal dung or agricultural residues.

2.2. Household energy transition in developing countries

2.2.1.The energy ladder model

The energy ladder was developed as a model to explain the household energy choice in developing nations (Van Dar Kroon., et al, 2013). The energy ladder notion takes as its standing point the differences in energy use patterns between households with differing economic status. This model assumes households tend to maximize their utility the neo classical consumer manner implying they will tend to move to more refined energy sources as their income increase (Van Dar Kroon., et al, 2013). Fuel switching is a central notion in energy ladder concept, meaning a move to a new type of energy is moving away from the previously used one (Heltberg, 2005). Recent empirical evidences on the transition of energy transition found out different than the simple energy ladder model that portrays the adoption of fuel in a progressive manner (Van Dar Kroon., et al, 2013). This raised to the issues that different types are used for different types of tasks; households can choose or mix different energy sources rather than simply abandoning the conventional energy sources (Heltberg, 2004). This notion brought about another energy model, energy stacking.

2.2.2.Energy stacking model

When households use different fuels at the same time it is called energy stacking. Households stack fuels for several reasons as; keeping the conventional energy systems when the modern forms of energy show prices increment, as a form of insurance when there is a shortage of modern energy form, as an insurance against modern energy supplier failure, based on the type of food being cooked (Masera et al., 2007). The empirical studies done by Leiwen in rural China in, (2003) indicate that some forms of traditional energy are still used by the wealthiest households. Barnes proposed a ‘‘rural energy ladder’’ that illustrates the steps through which rural households generally move from traditional biofuels and human and animal power to a mix of traditional and modern fuels (Barnes et al., 2011).

2.3. Socio-economic characteristics of the household and fuelwood consumption

Income: It is argued that, the higher your income levels, the better the fuel choice and the lower your income levels, the poorer the fuel choice. With this notion, the transition to energy consumption pattern is expected to change and people tend to shift fuel from charcoal to kerosene to PLG and finally to natural gas (Mishra, 2008). This upward shift is most notable in urban areas as people in rural mostly rely on solid fuel due to its availability and affordability (Masera et al., 2007). In Burkina Faso, Ouedraogo (2006) observes a positive correlation between income and fuelwood consumption. According to the World Bank statistics, households do not switch to modern energy even with increased income but rather consume a combination of fuels which may include solid fuel with non-solid energy depending on their budget, preference and needs. This then leads to fuel stacking (use of multiple fuel or stoves), as opposite to energy ladder.

Education: In their study in rural kisumu Kenya county Pundo and Fraser (2006) found that education level of wife significantly influence the probability of switching from fuel wood to charcoal or kerosene. The education level of the household head had a very significant negative impact on fuel wood consumption while at the same time encouraging demand for LPG (Heltberg, 2004).

Household Size: plays a major role in fuel choice decision because, increased household size results to increase energy demand thus increase in a number of people to collect firewood in terms of labors. Guta (2012) found that the relation between family size and fuel choice is insignificant. Similar findings are depicted by Helberg (2004) where fuel stacking theory is used in larger households.

Community Interaction: More recent statistics have shown that people may take up new technology due to learning from others observed experiences or social influence (Conley and Udry, 2010).

Age: Role of age in the fuel choice as per the various empirical findings still remains contradictory. Some studies depict the positive correlation between age and fuel choice. Guta (2012), basing his observation in Ethiopia concluded that the older a person the higher the chances of adopting cleaner cook fuels.

2.4. Wood demand and supply situation in Ethiopia

At present more than 90% of the domestic supply of industrial wood and firewood comes from the natural forests which are the main sources of wood products (Mekonnen and Kohlin, 2009). Fuelwood accounts for the bulk of the wood used, and is the predominantly preferred domestic fuel in both rural and urban areas. The projected demand for fuelwood and building poles based on assumed per capita requirement is increasing and is expected to be over 100 million m^3 by 2020 (Damte A, et. al, 2012).

On the other hand, the projected supply from all sources is expected to be only 9 million m^3 which is far below the demand. Ethiopia is one of the lowest electricity per capita consumers and from the current trend in the prices of electricity and other commercial fuels; Ethiopia will remain highly dependent on woodfuel for the foreseeable future. The rural people will remain to be the main users of fuelwood in the future. The urban poor also continue to depend heavily on wood fuels.

The urban populations have options to mix their energy use mainly depending on income level. The rural population on the other hand, collects fuelwood free and mainly depends on fuelwood as the main source of energy. Non-wood bio-mass are also important sources of fuel for the rural population. The increasing scarcity and cost of household fuels, particularly firewood threatens the ability of the people even to maintain the already low incomes and quality of life, particularly in the rural areas. To compensate for the worsening fire wood scarcity, dung and crop residues are being diverted to household fireplaces, reducing crop yields. While there is a continued need to explore other alternative sources of energy, large scale tree planting appears to be the only realistic option for resolving the woodfuel supply problem. The rural woodlots and agro-forestry on a massive scale are essential to allowing a sustainable energy supply to meet demand in the rural areas. In addition, the introduction of efficient cooking stoves for improved use of woodfuel, efficient charcoal making technology, and appropriate woodfuel marketing and pricing practices may improve the energy problem, thereby relieving the pressure on the few remaining natural forests.

2.5. Household energy and its efficiency

In order to overcome household energy problems and bring sustainable energy intervention a redefinition of household energy is needed. This definition must recognize the fact that energy is one of the most important parts of our daily life at the same time energy supply and use affect men and women differently. Addressing household energy issues can result in opportunities for time and labor saving, income generation, health improvements, and social empowerment especially for women because of their relationship to household energy (Joy Clancy, 2003).

One avenue for bringing about sustainable society and a socially just world is through green politics which according to Carolyn Merchant we are supposed to 'think globally and act locally'. To address social problems, there is a need to mainstream social theory, science and technology especially mainstreaming cross-sectional issues like gender and environment will be crucial if we are seeking sustainable development (Merchant, 2004). Whenever we are talking about sustainable development it will be logical to talk about social justice. Social justice is a key factor in the transition to a sustainable world and liberation of nature and women. In turn social justice without fulfillment of human basic need is unthinkable. As a result, societies have to be able to obtain basic needs such as food, clothing, shelter and energy and provide conditions for physical and emotional health (Merchant, 2004).

As part of redefinition of household energy, Carolyn Merchant has incorporated energy under the short list of basic needs. It illustrates the need to look behind the 'food', which is basic need, and recognize the importance of energy (Merchant, 2004). Aligned with the statement of Carolyn Merchant 'energy as basic need', Dankilman and Davisdson in their book entitled 'Women and Environment in the Third World' stated that, energy although still not officially considered as a basic human need such as food, clothing and shelter. It is essential for human being and as important as to cook food, boil, and heat and light the home (Dankilman and Davidson, 2008). It will be wise to discuss further the important point raised by Carolyn Merchant in stating energy as basic needs for two reasons. The first important reason is that the type of food people are consuming such as cereals need huge amount of energy for preparation.

Typical cooking patterns in Ethiopia are associated to agro-ecological zones. In highland areas where agriculture is dominated by cereal production teff (traditional bread of Ethiopia, Injera, made out of). Injera is baked on a large clay pan (mitad) of about 55-60 cm in diameter and requires a large size stove to accommodate the pan. Injera baking requires the bulk of the domestic energy demand in large parts of Ethiopia. It is reported that injera baking alone contributes 50% of the total primary energy consumption of the country (GTZ, 2008). We can observe that the basic food identified above requires huge amount of energy for baking before consumption which makes energy basic need. Secondly, in case of fuelwood crisis the alternative method to save fuel at individual level will be mainly by eating uncooked food or eat those requiring less energy. Saving energy with such practices have negative impact on nutrition of a family which will cause the family to have health problems such as infection and malnourishment and this eventually result in reduced agricultural productivity (Dankilman and Davidson, 2008).

The problem of household energy is serious in a country like Ethiopia where about 60.8 % of the population lives without electricity and 94 % and more of the household energy source is biomass (UNDP, 2008). Moreover, most people especially women use the three-stone fire stoves and studies have confirmed that open fire stoves (Three-stone open fire stoves) have a very low efficiency estimated at 10-15% for cooking and about 7% for baking (Rest, 2012). Thus, most of the potential energy 85-90 % is wasted. The low utilization efficiency of the open fire stoves have resulted in a relatively higher demand for biomass particularly for households that primarily or entirely rely on biomass fuel ‘the fuel of the poor’ constitutes only 1% of energy consumption in developed world (Michael Atchia , 2005).

One way to increase cooking efficiency is introduction of improved stoves or closed stoves which can save energy and are also environmental friendly. Under laboratory conditions, improved stoves may save up to 50% of the wood which would have been used for the same task over an open fire. Factors such as time saving, convenience, smoke reduction, house heating and food test are at least as important for users to qualify these stoves as fuel efficient.

However, improved stove designs often fail to offer some of these qualities to the users. In some cold areas the heat as in the open stove is needed and the smoke is also believed to protect houses from worms and insects (REST, 2012). Improved household energy supply can significantly contribute in reducing health problems when compared to open stoves. Further improved stoves help to save time, money and to generate income which will contribute to women’s advancement (Clancy, 2003). Especially, when women are engaged in food processing, production and income generating activities a reliable, affordable and safe energy sources are needed. It is only with affordable energy that women can generate income since they are engaged in small scale and informal sectors. They also need credit services, trainings and technical assistance to generate income using energy efficient technologies (UNDP, 2004)

2.6. Improved cook stoves in Ethiopia

Ethiopia provides an interesting context for these clean stove initiatives, as most of the nation’s energy consumption is based on biomass sources. Indeed about 94% of the country’s energy demand is fulfilled by wood, charcoal, branches, dung and agricultural residues, which all produce smoke and harmful emissions when they are burned. Stoves occupy a central place in the health, environmental, economic, and social lives of families in developing countries.

Improved cook stoves therefore can provide a number of benefits. They can reduce indoor and outdoor air pollution by providing more complete combustion, decrease indoor exposure by providing better ventilation, and decrease burns by elevating the cooking surface off of the floor. Improved stove efficiency can boost household economics and empower women by reducing the time, dangers, drudgery and expense involved in obtaining and preparing fuel, leaving more time for childcare or economic activities. Reducing fuel consumption can also serve to improve soil fertility and reduce deforestation, soil erosion and desertification. Improved stoves can also have subtle but important social benefits like improved cooking convenience because they can be made to any height and require less attention to tend the fire.

Traditional cook stoves can be particularly dangerous to human health as well as to the environment. Many developing countries use wood or other biomass sources as fuel for cooking and heating. Inefficient stoves create a hazardous indoor environment, as smoke often pollutes the insides of homes. According to the World Health Organization (2014), over four million people die each year from indoor air pollution. Inefficient stoves also require people to cut down a lot of trees for fuelwood, which leads to deforestation, forest degradation and, ultimately, global warming.

Also, sub-Saharan Africa has the highest rates of deforestation in the world, and Ethiopia's rapidly-growing population is adding to the strain on the increasingly scarce supply of firewood. Every year, nearly 200,000 hectares of land are destroyed in an effort to collect wood, and every year, firewood becomes more difficult to find. Clearly, Ethiopian households could benefit significantly from new stove technology. Because Ethiopia is a developing nation in a region that suffers from vast environmental degradation, clean stove technology could play a significant role in promoting sustainable development.

2.7. Fuelwood savings

Estimating the benefits of any policy intervention requires a credible counterfactual, which describes what would have occurred had the intervention not taken place. This critical step in program evaluation requires that as much as possible be held constant except for the policy intervention. Mobarak et al. (2012), for example, analyze the determinants of low demand for improved cook stoves. They find that rural women rely overwhelmingly on free traditional cook stove technologies and are not willing to pay much for new cook stoves. They point to the need to design nontraditional cook stoves with features, such as reduced operating costs, that may be valued highly by users. Very little work has been done that includes credible estimates on whether improved stoves reduce carbon emissions, though Johnson et al. (2009; 2010) is a notable exception.

Possible approaches to measure how much fuelwood is used per unit of time include randomized kitchen performance (KPT), controlled cooking (CCT) and water boiling (WBT) tests. Each has its advantages and drawbacks (Lee et al. 2013). The KPT measures total fuelwood use in a household several times before and after an ICS intervention. The advantage is that it can account for the technology combinations that imply leakage. KPTs, however, have the disadvantage that little is known about the actual cooking use and mechanisms after adoption. It also requires virtually complete on-site measurement of fuelwood use; otherwise measurement errors can be large.

Because of the intensive nature of the required measurement, sample sizes tend to be small. This can be a very serious problem if ICS have multiple uses, because in regression models it may not be possible to effectively adjust for potential confounders. Alternatively, and less effectively, experimental subjects can keep fuelwood use logs pre and post intervention. Such an approach has the risk of serious reporting errors that can perhaps only be obviated through direct measurement

2.8. Estimating Reduced CO2 Emissions from ICS

The contribution of fuelwood conservation to reduced forest degradation and therefore fewer carbon emissions depends on the nature of fuelwood harvest (Lee et al.2013). A key parameter is therefore the fraction of woody biomass used "that can be established as non-renewable biomass" (UNFCCC 2012). The degree to which biomass harvests are unsustainable depends primarily on the management regime. If fuelwood is taken under open access regimes, for example, very limited management, including replanting and harvest mitigation, is expected (Ostrom, 2010). Such settings are likely to have close to 100% nonrenewable biomass.

CO_2 emissions from the use of cook stoves depend primarily on the technical specifications of the stoves and assumptions about fuels displaced. Under the Framework Convention on Climate Change non-Annex 1 countries, such as Ethiopia, do not have emissions reductions obligations. The relevant emissions reductions displaced are therefore in Annex 1 developed Countries using commercial fuels. UNFCCC (2012) has therefore provided default estimates of percent non-renewable biomass for low-income countries and many countries in sub-Saharan Africa have default values above 90%. Perhaps because Ethiopia in 2007 passed important forestry legislation that has improved management (Mekonnen and Bluffstone, 2014), the default value was set at 88%.

3. MATERIALS AND METHODS

3.1. Description of the study area

Negele Arsi town is the centre of administration for Negele Arsi woreda, which is one of the 13 woredas of West Arsi zone of Oromia Regional state. The town is found in the Ethiopian rift valley system, 225 km south of Addis Ababa and 23km from the zone capital sheshemene on the paved high way to southern Ethiopia. Geographically the town is located at longitude and latitude of 7°21'N and 38°42'E and has an elevation of 2043 meters above sea level. It is bounded by Negele Arsi woreda in all directions (fig. 3.1).

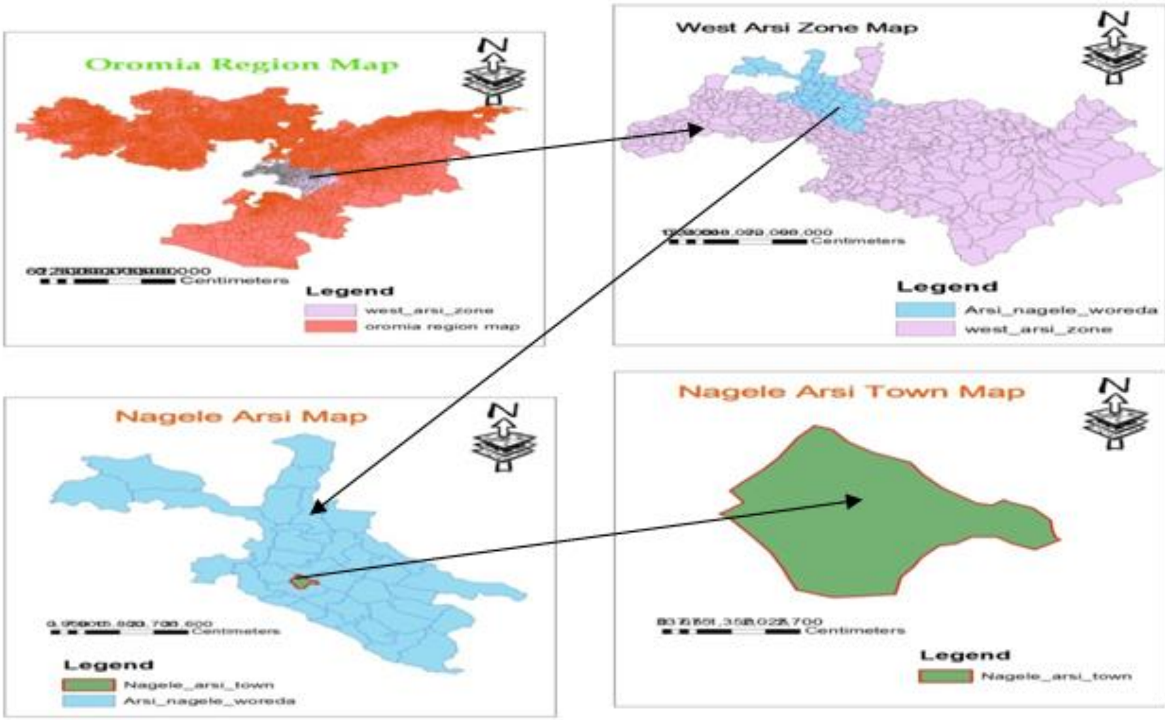

Fig: 3. 1 Map of the study area.

Source: town administration office

3.1.1. Topography and Climate Condition

The study area has got Midland (Woyna-dega) agro-ecological zone based on temperature, rainfall, altitude and vegetation parameters. The altitude of the study area ranges from 1500 to 1600m a.s.l (ORS, 2010). The mean annual temperature of the town varies from 10-25C°with annual rainfall between 500-1000mm. Like most other parts of Ethiopia, the main rainy season of the area is summer (also called Ganna) which is occurring from June to mid of September, and autumn season (Arfaasaa) is the small rainy season occurring from March to May (ORS, 2012).

3.1.2. Population characteristics

The total population of the town is estimated to be 136,084 of which 67,362 are males and 68,722 are females with an average density of 2,714 people per km^2 (CSA, 2016). According to the survey the town has 17,500 households of which live in the three kebeles of the town.

3.1.3.Economic activities

The major livelihood economic activities of households in the study area include marketing, self jobs, government employment and non-governmental employment. Based on their economic status households were categorized under poor, medium and rich wealth category. Poor households account for 31 percent, while the medium households account for 47 percent and the rich were 22 percent of the total households of the town.

3.2. Sampling technique and Sample size

Negele Arsi town of the woreda, and three kebeles from the town: Meja-kiltota, Kiltu-dema, and Melka-sheyiti were selected purposively because of the heavily household dependence on fuelwood consumption and the existence of improved cook stoves technology distribution for households. According to the report of the town administration, Negele Arsi has a total of 17500 households, and the three kebeles: Meja-kiltota, Kiltu-dema, and Melka-sheyiti have 5957, 4809 and 6734 households respectively. The sample size was determined using Yamane,(1967) formula as quoted by Israel,(1992).

$$n = N * \frac{cv2}{cv+(N-1)*e2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq(1)$$

Where:

n= sample size,

N=population,

CV=coefficient of variation (0.5) and

e= tolerance of desired level of confidence take 0.05 at 95 percent confidence level.

Accordingly, the expected sample size was 99, however due to time and budget constraints, a total of 90 households from the three kebeles of the town were included for the proposed investigation. The selection of household was done using systematic random sampling and every second or third household on the Eastward to Westward streets 50m between each transect line in the town was selected until the sample size of 90 has achieved. To determine the sample size of the kebele, proportional sampling technique was employed. Hence, 31, 25 and 34 households were selected from Meja-kiltota, Kiltu-dema and Melka-sheyiti respectively.

Purposive sampling was also used to identify individuals for focus group discussion and the key informant interviews. According to Gay and Arrasian (2003), purposive sampling involves selecting a sample based on experiences or knowledge of the desired study. The key informants were from institution concerns with ICS such as NGOs and experts from WMEO (Water Mine and Energy office). The FGDs, was those with the knowledge on ICS.

3.3. Measuring household fuel wood consumption

To quantify the daily fuelwood consumption, the sampled household's weekly consumption was measured. To reduce the complication in analysis recorded data were converted into kilogram using method suggested by EPA (2003) and the average daily consumption per household was determined. To reach at households' annual consumption, the value was multiplied by 365 days of the year.

The consumption mass balance was employed to measure the household weekly consumption and the fuelwood consumed was computed using the equation below:

$$FC = (FP + FB) - (FE) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . Eq(2)$$

Where:-

FC = fuelwood consumed within the week,

FP = fuelwood purchased in the week,

FB = fuelwood at beginning of the week and

FE = fuelwood at the end of the week

3.4. Estimation of fuel wood consumption reduction with the use of improved stoves

24 households were randomly selected to measure the reduction in fuelwood consumption using improved stoves for domestic use. To estimate the consumption reduction KPT was employed using both the traditional and improved stoves. The Kitchen Performance Test (KPT) was computed with injera baking. Out of selected households 12 of them were traditional method injera bakers and 12 were those baking injera with improved mirt stove. Households were equally selected from the three categories (poor, middle and rich) considering their economic status. That is 4 households from each category for both traditional and improved stove users. Mixed or pure teff flour of 4kg or 3.8kg was used for the baking and eucalyptus and maize residues were used as fuel sources. Consumption measuring balance was used to measure the weight of consumed fuel for the baking and the reduction in consumption was computed using Eq(3) below.

$$CR = TMC - IMSC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. Eq(3)$$

Where:

CR= Consumption Reduction,

TMC= Traditional method use consumption and

IMSC= Improved Mirt stove use Consumption.

3.5. Data types and instruments

3.5.1. Data types

The study employed both quantitative and qualitative methods of data collection which was gathered from both primary and secondary data sources. The primary data was collected mainly by use of questionnaire which was administered orally to the various selected household. The questionnaire contained both close ended and open ended questions. The secondary data was collected from the existing published and unpublished information sources such as; books, governmental official reports, journals and other institution reports.

3.5.2.Data instruments

3.5.2.1. Focus group discussion (FGD)

Involved interviewing a small amount of respondents drawn from the similar background but who believed to represent the general populations' opinion towards the fuelwood consumption and contribution to climate change. So to get detail information in depth interview were made with kebele elders, agricultural development agents and kebele executives. From each kebele three focus group discussions were conducted separately. A total of 24 people were participated in FGDs from different social groups. One FGD contains 8 people and 3 FGD was conducted in each kebele.

3.5.2.2. Key informant interview

The semi structured interview scheduled was used by the Negele Arsi office of Water, Mine and Energy, ANCED and other experts that deal with Energy consumption and climate change in their work station. The interview was done with 8 key informants of which were experts of energy, environmentalist and climate change mitigation and nature conservation.

3.5.2.3. Questionnaire

The questionnaire was administered face to face to the selected households in the study area. Both close ended and open ended questions were used because of their ease of administration. The questionnaire was developed as per the study objectives and administered to the selected households within the study area.

3.5.2.4. Observation and photographs

They enable the generalization of the first hand information that are uncontaminated by other factors. Apart from interview and discussions, this study also employed the use of direct market and kitchen observation to capture and evaluate existing situation about the fuelwood consumption within the study area.

3.6. Data analysis and presentation

Data were analyzed using descriptive analysis of statistics with the use of tables and graphs. All the data collected from the field as in the questionnaire, FGD and in-depth interviews were filtered of any error and omissions and analyzed as follows; The primary data extracted from the questionnaire was fed into the excel sheet.

The data was organized, coded, tabulated and summarized using computer software SPSS version 24. With the aid of this software data was analyzed using descriptive statistics and presented in the form of frequencies tables, pie-chart and graphs. The data collected from FGD and key informants were analyzed by use of extensive textual analysis.

The investigation focused on the determination of the household fuelwood consumption and contribution for climate change (emission of CO_2 and stock reduction). The annual carbon dioxide emission in the study area was calculated based on the United Nation Framework Convention on Climate Change and Clean development mechanism (2013) default net caloric values, emission factors and carbon storage in the forests (table 3.1).

$$E = FC\ X\ fNRB\ X\ NCV\ X\ EF - project - fossil - fuel \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..Eq(4)$$

Where:

E is emission in tones of carbon dioxide equivalent (tco_{2e}),

FC is the quantity of fuelwood consumed in ton/kg,

f_{NRB} is fraction of non-renewable woody biomass,

NCV is net caloric value of fuelwood and

EF-projected-fossil-fuel is default emission factor.

Table: 3. 1 Parameters used for calculating carbon emission

Parameter	Value	Source
Annual fuel wood consumed	From HHs	Field survey
Net calorific value fuelwood (wet basis)	15MJ/KG	(IPCC, 2006)
Emission factor fuel wood	81.6 CO2/TJ	(UNFCCC, 2013)
Conversion CO2/C	3.667	Ratio molecular weight
Fraction of non-renewable fuel wood	88%	(UNFCCC, 2012)

3.6.1.Multiple Regression analysis

In order to understand how the typical value of the dependent variable changes when any one of the independent varies, while the other independent variables are held fixed, regression analysis is used. It assumes a general form for the relationship, known as the regression model:

$$Y = \alpha + \beta 1X1 + \cdots + \beta kXk + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq\ (5)$$

Where: Y is the dependent variable, while X1... Xk are the explanatory variables or the independent variables. α, β1,...,βk are partial regression slopes corresponding to respective Xi and εi is the residual variance in y after taking into account the effects Xi variables included in the model (table3.2). The estimators, however, end up with almost the same standardized (marginal) impacts of independent variables (Muller et al. 2006). For this reason the study has used the multiple regression models to assess socioeconomic characteristics and extent of fuel wood consumption:-

$$yi = \beta 0 + b1 family\ size + \beta 2 + education\ level + \beta 3 income + \beta 4 community\ interaction + \beta 5 age + \varepsilon i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Eq(6)$$

If the error term (ε) is taken into account the multiple regression model becomes;

$$yi = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. Eq(7)$$

Where: β0 is an intercept which tells us the of fuel wood consumption when the coefficients of all included explanatory variable are assumed to be zero, β1→βn are slope parameters to be estimated in the model, respectively. The slope tells how the factors affecting fuel wood consumption as each independent variable changes. *Yi* is also referred to as the factors that affect amount of fuelwood consumption.

Table: 3. 2 Explanatory Variables and their Hypothesized effect.

Variable code	Variable type	Definition and Measurements	Expected Sign
Family size	Continuous	Total number of people in the household	+
Education level	Categorical	Education level the household head attained	-
Income status	Categorical	Household income status	_
community	Categorical	Household community interaction	+
Age	Continuous	Age of the household head	-

4. RESULTS AND DISCUSSION

4.1. Demographic characteristics of the household

The demographic characteristics of households in the study area were studied (Table: 4.1). The results indicate that the mean age of the households head included in the study was 41 years with standard deviation of 11.513. The household head age range was in between 18 and 78 years. The age distribution among each of the three kebeles (kiltu-dema, melka-sheyiti and meja-kiltota) was not showed a significant variation in the town. The study also showed that the number of person living in each household ranges in between 2 and 13 of person. The average family size in the study area was 6 of families (Table: 4.1). The average family size of this study almost exceeds the national average family size which is around 4 people per family.

The result revealed that the male and female distribution across the kebeles varies (Table: 4.1). It was also indicated from the study result that the total number of female was greater than total number of male in the study area table: 4.1 below.

Table: 4. 1 Demographics of the surveyed household (continuous variables).

Kebele	Variables	Descriptive statistic				
		N of respondents	Min	Max	Mean	St.dev.
Meja-kiltota	Age	31	18	67	36.03	9.127
	Family-Size		2	13	5.94	2.707
	Male		1	6	2.87	1.432
	Female		1	8	3.06	1.982
Kiltu-dema	Age	25	26	78	47.28	13.008
	Family-Size		3	12	7.44	2.103

	Male		2	7	3.40	1.291
	Female		1	7	3.96	1.695
Melka-sheyiti	Age	34	18	61	43.0	10.159
	Family-Size		3	11	6.82	2.195
	Male		1	7	3.15	1.459
	Female		1	7	3.68	1.886
Total	Age	90	18	78	41.79	11.513
	Family-Size		2	13	6.69	2.411
	Male		1	7	3.12	1.405
	Female		1	8	3.54	1.885

To know households background information the respondent heads were asked about gender, marital stage, occupation, religious affiliation, education level, house ownership and economic status.

The study involved 37 men and 53 women of the respondents for the survey (Table: 4.2). Among these respondents most of them (84 households) were married which accounts 93.4 percent of the total respondents interviewed and the remaining 6 households accounting for 6.6 percent of the total household heads were single, divorced, and widow household heads of their marital stage.

Concerning the occupational status of the respondents, the survey result showed that most (54.5%) of the respondents were unemployed (Table: 4.2). Self-employed, and employee were accounts for 32.2 percent and 13.3 percent respectively. Unemployed respondents were those who participate on farming, and small business activities in their compound while self employed respondents were those who have their own business and employees were those who are governmental and NGO workers in the town and/or elsewhere.

Majority of the respondents' education level (52.2%) of the total was found to be between primary school to secondary school and about 28.9 percent have no education and cannot read and write. The respondents with tertiary and university degree education qualification were 18.9 percent (Table: 4.2).

In relation to the property ownership the result showed that about 75.6 percent own a house while the remaining of the respondent rent a house from Kebele, and private as indicated in (Table: 4.2).

Wealth status of family of these respondents largely belongs to the middle income group accounting for about 46.7 percent. Low income followed the middle income family in decreasing order amounting for 31.1 percent and the rich household amounted for the remaining 22.2 percent (Table: 4.2).

Table: 4. 2 Demographics of the surveyed household (categorical variables)

Variables		Respondents kebele						Total respondent	
		Meja-kiltota		Kiltu-dema		Melka–sheyiti			
		N	%	N	%	N	%	N	%
Gender	Male	5	16.13	14	56	18	52.9	37	41.1
	Female	26	83.87	11	44	16	47.1	53	58.9
Marital stage	Single	1	3.2	0	0	1	3	2	2.2
	Married	27	87.1	25	100	32	94	84	93.4
	Widowed	2	6.5	0	0	0	0	2	2.2
	Divorced	1	3.2	0	0	1	3	2	2.2
Occupation	Self employed	19	61.3	2	8	8	23.5	29	32.2
	Employed	3	9.7	3	12	6	17.6	12	13.3

	Unemployed	9	29	20	80	20	58.9	49	54.5
Religious affiliation	Muslim	10	32.3	16	64	16	47	42	46.7
	Christian	21	67.7	9	36	11	32.4	41	45.5
	Wakefata	0	0	0	0	7	20.6	7	7.8
Education level	None	8	25.8	8	32	10	29.4	26	28.9
	Primary school	8	25.8	10	40	9	26.5	27	30
	Secondary school	10	32.3	4	16	6	17.6	20	22.2
	Tertiary school	4	12.9	1	4	4	11.8	9	10
	University degree	1	3.2	2	8	5	14.7	8	8.9
House ownership	Own	24	77.4	20	80	24	70.6	68	75.6
	Rental from private	7	25.6	4	16	8	23.5	19	21.1
	Government house	0	0	1	4	2	5.9	3	3.3
Wealth status	Poor	9	29	8	32	10	29	28	31.1
	Medium	14	45	12	48	16	47	42	46.7
	Rich	7	26	5	20	8	24	20	22.2

4.2. Fuelwood consumption by households

The kind of household energy sources used by respondents were various and some use combinations. The study result showed that fuelwood is the common and major energy source used by majority of households for home based activities (baking, cooking, boiling and lighting) in the area. Accordingly, 84.4 percent of households use fuelwood of which the majorities use only firewood accounting to 57.8 percent. The other 42.2 percent of the respondents use firewood in combination with Kerosene and Electricity as shown in (Table: 4.5). This finding was in line with that of Gurmessa (2010), which he found that about 84 percent of urban households rely on biomass as their primary cooking fuel. Dependence level of the households on biomass in Negele Arsi town has decreased when compared to (NAWEO, 2016) data. According to (NAWEO, 2016) data about 89 percent of Urban Households of Negele Arsi town depends on fuelwood for their cooking, boiling water, and lighting. This implies households could mix the alternative sources of fuels for their domestic uses which enabled them to reduce their dependence on fuelwood consumption. This dependence on biomass consumption has negative implication on the local environmental degradation and climate change. The finding was in line with the general situation of household energy in Ethiopia where the dominant household energy supply is biomass, the pattern of consumption and its implication on the depletion of the natural forest is huge and this in turn causes subsequent negative effect on soil erosion, deterioration of watersheds, and decreasing soil productivity (GTZ, 2008). The household survey results revealed that average daily household fuelwood consumption in the study area was 47.314 Kg/day with standard deviation of 39.39466 and ranges between 8.89 to 144.6 Kg/day (Table: 4.3).

The average household weekly consumption was 0.33 tons/week (Eq1). The annual average consumption of the interviewed households (average daily consumption 0.0473tonnes x 365 days of the year) found to be 17.26 tones. The present fuelwood consumption rate is greater than that of reported value of previous study, 14.6 tones of fuelwood per year in Adaba town (Alemayehu Zeleke and Motuma Tolera, 2018).

Fuelwood was more consumed by Meja-kiltota households compared with the other two kebeles in the town (Table: 4.3). The information gathered from the interviewed key informants argued that Araki is more produced in meja-kiltota and melka-sheyiti kebeles than Kiltu-dema kebele. Accordingly Araki was the first standing activity in firewood consumption in Negele Arsi town. They also argued that injera was the main food type in the town which consumed large amount of fuelwood for baking. Injera baking was the second fuelwood consuming activity next to Araki production and consumed nearly have the total consumption of the town. The result confirmed that the amount of energy needed to bake Injera constitutes 50 percent of the total household energy consumption in Ethiopia (GTZ, 2008). Hence, the kind of food consumed in the study area implies the need for huge amount of energy and special type of stove which accommodate the Injera pan ’mitad’.

Table: 4. 3 Household fuelwood consumption

Kebele	N of the respondents	Mean HH daily consumption (kg/day)	Std. Deviation	Mean yearly consumption (Tones/year)
Meja-kiltota	31	54.2761	35.79289	19.8
Kiltu-dema	25	37.0600	35.21451	13.5
Melka-sheyiti	34	48.5059	44.63579	17.7
Total	90	47.3140	39.39466	17.26

4.2.1.Sources of energy for the household consumption

Households were interviewed about the energy sources used in their village where the study was conducted and the result showed that different sources of energy were used by the respondents. Among the identified sources by the survey firewood, charcoal, electricity and LPG were the common and major sources of energy for domestic consumption. The major uses of these energy sources were for cooking meals, boiling water, coffee and tea, heating and lighting. The survey result of these fuel type and purposes of use is indicated in table 4.4 below that cooking and boiling activity were the major activities consuming more fuel accounting 76.7% of the total domestic consumption. It confirms that the household energy source in the study area is mainly biomass energy (particularly firewood and charcoal). The result was in agreement with Mowie, (2016). According to Mowie, (2016), 86.74 percent of household energy in Ethiopia comes from biomass sources.

Fuelwood (firewood and charcoal) in the town was the major energy source which accounting 84.4 percent of domestic use for cooking and boiling. This implies the fuelwood dependency level of the households in the study area was less than the national dependency on the solid energy consumption of the households in Ethiopia, which is 96 percent (WHO, 2006). Households cooking and boiling with electricity and LPG was 15.5 percent of the total respondents. This indicates that electricity and LPG are at their initial stage as energy alternatives for household cooking and boiling purposes. This finding was greater than the fact that in Ethiopia, only 6 percent of household energy comes from electricity or petroleum products and almost 94 percent comes from biomass such as wood, crop residues and dung(GTZ, 2009). Electricity is most and majorly used energy source for the household home lighting service accounting for 98.78 percent (Table: 4.4). This result was agreed with (Heltberg, 2004). He found that different types of energy sources are used for different types of tasks; households can choose or mix different energy sources rather than simply abandoning the conventional energy sources.

Table: 4. 4 Fuel type used for domestic use

The major Fuel type	Purposes of use							
	Boiling		**Cooking**		**Heating**		**Lighting**	
	N	%	N	%	N	%	N	%
Firewood	8	8.89	44	48.9	-	-	-	-
Charcoal	5	5.56	11	12.2	8	8.89	-	-
Electricity	-	-	11	12.2	-	-	88	97.78
LPG	1	1.11	-	-	-	-	2	2.22
Total	9	10	60	66.7	21	23.3	90	100

4.2.2.Fuelwood supply and sources for Negele Arsi town

Fuelwood are widely used in the town. These fuels are supplied from different rural areas surrounding the town. According to the respondents, the fuelwood supplied to the town residents come from the surrounding rural residences and retailers. It is used for the household consumption such as for meal preparation, boiling, heating and lighting. The rural kebeles that supplied fuelwood to the town include: Lephis, Ashoka, Gonde-Gurate, Mararo-Hawilo, Gode-duro, Abjata-shalla, and langeno.

The respondents result showed that out of the interviewed households 3.3% of them collected fuelwood from natural forest and private farm land for their use while 96.7% of them purchased fuelwood from the local fuelwood markets (Atena_tera, Board, Tureta or from Orthodox Church compound) either directly from market sellers or retailers (Table:

4.5). The market survey result indicated that all purchased firewood comes from rural different residents and the sellers collect the firewood from natural forest which in turn causes significant environmental degradation to the rural villages from which firewood is collected.

T**able: 4. 5** Fuelwood sources for residents

Variable	Frequency	% respondents	Cumulative Percent	Source of fuelwood
Collect	3	3.3	3.3	Collected from natural and private farm land
Buy	87	96.7	100.0	Purchased from the local markets
Total	90	100.0		

4.2.3.Species preferences of households

Households were interviewed about their preference of the firewood species and most of the households reported some species preference. A species preference does not necessarily mean the most commonly used/available species. Households sometimes forced to use whatever available at a local market, including from the less preferred to most preferred fuelwood species. Eighteen different fuelwood species were identified as the energy source and five were ranked as the most preferred and commonly used species by the households (Table: 4.6).

It has been shown that podocarpus facaltus was the most frequently used and preferred firewood species with 30% households followed by Eucalyptus species which was chosen by 25.6% of households due to its availability and good quality (Table: 4.6). The determinant factors for their preference were availability, price and quality of the fuelwood. According to the respondents description good quality fuelwood species have a hot flame, and easily split and ignite. Additionally the preferred fuelwood have to burn without producing much more smoke and have a flame that does not produce sparks. Conversely if the fuelwood is difficult to split, produce much smoke and ash was considered as less quality firewood.

T**able: 4. 6** Tree species preferred by households.

Species	Frequency	% household interviewed	Valid Percent	Cumulative Percent	Determining factor(s)
Podocarpus facaltus	27	30	30	30	Availability and good quality
Eucalyptus species	23	25.6	25.6	55.6	Availability and good quality
A.etbaica	20	22.2	22.2	77.8	Good quality
Dry wood materials and branches	11	12.2	12.2	90	Availability and Low cost
A.senegal	9	10	10	100	Good quality
Total	90	100.0	100.0		

4.3. **Socioeconomic characteristics and the extent of Fuelwood consumption**

The studied socioeconomic characteristics of the residents in the town are presented below to understand the influence such characters pose on fuelwood consumption.

A regression result showed two of the five explanatory variables used in the model positively affected and three of them negatively affected the fuelwood consumption by the households table: 4.7 below.

Age: household head age was used in regression analysis as one of the explanatory variable that can affect the fuelwood consumption and the regression result has showed that household head age negatively affected the consumption and statistically significant with beta coefficient and p-value of -0.22 and 0.128 respectively. Accordingly the older households consume less by 22% than the younger household heads. This probably means that the older the household head age, the less fuelwood consumption and vice versa. It can also be generalized from this that the older the household heads, the more the chance and ability to adopt and use cleaner energy alternatives. This finding is similar with Guta (2012). Basing his observation in Ethiopia He concluded that the older a person the higher the chances of adopting cleaner cook fuels.

Family size: household family size positively affected the fuelwood consumption and statistically not significant with p-value 0.163 and β coefficient 0.195. This β coefficient indicates that the probability of fuelwood consumption is 19.5% higher for household who has large family size than those who has small family size. This may mean that, the increase in the number of the households, the increase for energy demand for meal preparation, boiling and lighting in the study area. The finding of this study is in parallel with (Abaynesh Kebede, et al, 2015 and Stephane Couture, et al 2010) found that family size is the most significant factor influences amount of fuelwood consumption.

Education level: education level of the household head negatively affected fuelwood consumption of the household and statistically significant with p-value 0.096 and beta coefficient of -0.194. This beta coefficient indicates that the probability of fuelwood consumption by more educated household heads is lower by 23% than less educated household heads. Meaning the more educated household heads consume less fuelwood than less educated or non educated household heads. Additionally more educated households have greater probability to adopt cleaner energy sources like electricity, solar energy, kerosene and LPG than less educated households. The finding of this study is similar with that of Heltberg (2005). He found that education level of the household head had a very significant negative impact on fuel wood consumption while at the same time encouraging demand for LPG (a clean fuel).

Income: according to the regression result shown on the regression table above the income level of the household head is negatively affected the fuelwood consumption with beta coefficient of -0.115 and statistically not significant due to the p-value of 0.300. This means the higher income level households have the probability to consume less fuelwood by 11.5% than those who earn are in lower economic status. It may mean that, the higher your income levels, the better the fuel choice and the lower your income levels, the poorer the fuel choice. The finding of this study is not agreed with Ouedraogo (2006) that He observed a positive correlation between income and fuel wood consumption In Burkina Faso. According to result from FGDs I made in this study in Negele Arsi town, households with increased income do not switch to modern energy rather consume a combination of fuels depending on their budget, preference and needs. This then leads to fuel stacking (use of multiple fuels), as opposite to energy ladder.

Community interaction: the regression analysis result indicated that community interaction of the respondent households positively affected fuelwood consumption in the study area with beta coefficient of 0.232 and statistically not significant due to the p-value of 0.038. This means that respondents those who have community interaction consumed more than those who have not community interaction by 23.2% in the area.

Table: 4. 7 Regression coefficient estimates of socio-economic characteristics influencing fuelwood consumption in Negele Arsi town.

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	44.707	34.294		1.304	.196
	Age of the household head	-.750	.488	-.220	-1.537	.128
	Family size of the household	3.157	2.242	.195	1.408	.163
	education level	-6.023	3.575	-.194	-1.685	.096
	income level of HHs	-6.122	5.866	-.115	-1.044	.300
	community interaction	36.007	17.074	.232	2.109	.038

Source: field

R=0.388

R^2 =0.151

Adjusted R^2 =0.099

Std. error of the estimate = 37.13782

4.4. Contribution of fuelwood consumption for forest degradation and climate change

If wood is not sustainably harvested, which is the case in most developing countries, biomass combustion releases CO_2 into the atmosphere, contributing to climate change. Fuelwood accounts for the bulk of the wood used, and is the predominantly preferred domestic fuel in both rural and urban areas. One of the factors of degradation of the forest in the last few decades is the demand for firewood in Negele Arsi town (NAWMEO, 2016). This study result also indicated that fuelwood is widely consumed and accounts for 84.4% of domestic energy use in the study area (Table: 4.5). Results from key informants interview and FGD indicated that fuelwood consumption in Negele Arsi town was contributing to the degradation in natural environment (particularly forest resources degradation, upstream soil erosion and severe land degradation) and climate change problems. This result was in agreement with (Zerihun Woldu and Mesfin Tadesse, 1990). They stated that degradation of woodland is most remarkable in the central rift valley where woodlands were reduced to 4 percent of the original extent within a time span of 50 years.

This consumption is responsible for cutting large amount of trees from both natural forests and private land of rural villages of the woreda as the fuelwood sources for the town was from rural kebeles of the district (Table: 4.5). It implies that fuelwood consumption as energy source is among the major causes for forests ecosystems declination and climate change of the area. This study also investigated for household Fuelwood consumption and its contribution for carbon dioxide emissions. The investigation result determined that the average yearly domestic fuelwood consumption of the town was 302218.2 ton/year (Table: 4.4). More than half of the purchased fuelwood by households were stem from forests, and therefore justified to assume that 88% of fuelwood consumed stem from forest for Ethiopia case (UNFCC, 2013). The CDM default value which is 88% for none renewable biomass percentage for Ethiopia (UNFCC, 2013) and emission factor of 81.6 $tCO_{2/}$ TJ and a net caloric value 15MJ/Kg of woody biomass used and this consumption is responsible for 18.6 tons of carbon dioxide emission per household per year and the total carbon dioxide emission in the town is estimated to be 325525.3 tCO_2e (Eq.4).

This emitted carbon dioxide tonic equivalent (325525.3 tCO_2e annually) possibly causes the air pollution and corresponds to the removal/deforestation of 302218.2t of wood annually for fuelwood consumption in the study area (Eq. 2).

4.4.1.The respondents perception on climate change

The respondents' perception on climate change was assessed. The result showed that 70 respondents which account for 77.8% of the total 90 sampled households were perceived that there is climate change in the study area (Table: 4.9). Those who did not perceived the presence of climate change accounted for 22.2% of the total. Table 4.8 also indicates that female (68.6%) and male (31.4%) respondents were perceived to climate change. Majority (75%) of the male respondents were not perceived the change. A significant variation in climate change perception between male and female respondents has been observed in the study area. From this finding it can be generalized that females are more aware about the climate change than males in Negele Arsi town.

The result also revealed that being a membership to the social organization has influence on climate change perception of the household (Table: 4.8). In the present study, members to social organizations perceived more than those who are not members to any social organization.

T**able: 4. 8** Respondents perception on climate change

Respondents perception on climate change	Gender						Membership to social organization					
	Male		Female		Total		Yes		No		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
1 There is climate change	22	31.4	48	68.6	70	77.8	68	97.1	16	80	84	93.3
2 Do not perceive any change	15	75	5	25	20	22.2	2	2.9	4	20	6	6.7

4.4.2.Causes of climate change

Households were interviewed about the causes of climate change in the area. Accordingly the result showed that the common and major causes are deforestation, fuelwood consumption, urban expansion and agricultural expansion. Deforestation was ranked as number one couse of climate change followed by fuelwood consumption and both accounts for 87.8% of the climate change resulting from antropogenic interaction (table: 4.9).

It has been reveald also during the focus group discussion that deforestation, urban expansion and fuelwood consumption for different household uses were among the three major cause for climate change in the area. They also agrued that fuelwood consumption and urban expansions in the study area increases from time to time and if not sustaiably managed, they will result in severe land degradation, soil erossion, food shortage, forest resources degradation and climate change. According to the FGD, urban expansion is the most threatening climate change factor with incearising in population of the town and surruonding rural population of the worada coming to the town

T**able: 4. 9** The major causes of climate change in the study area

Causes of climate change	Number of respondents	Percent	Valid Percent	Rank
Fuelwood consumption	37	41.1	41.1	2
Agricultural expansion	1	1.1	1.1	4
Deforestation	42	46.7	46.7	1
Urban expansion	10	11.1	11.1	3

4.5. Contribution of ICS in reducing fuelwood consumption

In order to reduce fuelwood scarcity problems and ensure sustainable supply and benefits of forest ecosystems, it is imperative to disseminate ICS. Based on the government initiative in cook stoves distribution in Ethiopia Negele Arsi woreda was distributed three types of stoves (mirt, lakech and tikikil) for the last five years. Distributed stove types by Negele Arsi Water, Mineral and Energy office is listed below in table: 4.10.

Table: 4. 10 Stoves distribution in Negele Arsi town

No	Distribution year (E.C)	Stove type			Distributed body
		Mirt	Lakech	Tikikil	
1	2007	180	2301	190	NGOs
2	2008	1200	170	110	Government with NGO
3	2009	2430	218	72	Cooperative workers
4	2010	4021	250	94	Cooperative workers
5	2011	6550	50	65	Cooperative workers
Total	2007-2011	14381	2989	531	NGO, Government and coop/workers

On the other hand, the office has been working on training the households how to install and use the distributed stoves and such training has been given for about 450 women living in the town (fig. 4.3). It was reported that the distribution of stoves and training have contributed for adoption of the technologies and the household's dependence on the traditional three stone stove for baking has been decreased as compared to what was before 10 years (NAWMEO, 2019).

Fig: 4. 1 Women training on the ICS installation.

In order to see the contribution of improved cook stove in fuelwood consumption reduction, the respondents were asked whether they use the ICS or not and the result indicated that around 54% of the respondents were using mirt stove for injera baking (table 4.11). This implies that mirt stove is familiar with the residents. The remaining 45.6% of respondents use traditional three stone stoves.

T**able: 4. 11** Households using and none using mirt stove

	Frequency of the respondents	Percent	Valid Percent	Cumulative Percent
Traditional three stone user	41	45.6	45.6	45.6
Users of mirt stove	49	54.4	54.4	100.0
Total	90	100.0	100.0	

Fuelwood consumption for injera baking in the study area was investigated. Both the traditional open fire and mirt stove injera baking method was used for KPT to see the consumption by each method. The result indicated that around 212831.5 tones fuelwood has been consumed for baking Injera in Negele Arsi town and the CO_2 emission from the individual household was 13.1tones of CO_2e per household annually. The result showed that the average daily consumption of fuelwood when baking with mirt stove per household was 10.94kg (table 4.12). For the same amount of injera baking activity 22.38kg of fuelwood was consumed using the traditional three stone methods. The result showed that a significant fuelwood saving (nearly 48.88%) was obtained using improved cooking stove as compared to traditional three stone injera baking stoves, with annual fuelwood savings per household of 4175.6kg (Eq.3). Under laboratory condition, the stove can save about half of fuel wood which in turn is assumed to impact on fuelwood consumption positively and contribute to forest protection. The result was within the range recorded by MME that fuel saving in family ranges 33-57% by using Mirt (MME, 2008).

Table 4.15 showed that 14381 mirt stoves were distributed in the study area for the last 5 years. It was found that 4.1756tones of firewood saved per year from a single mirt stove from household baking injera table 4.12 below. Therefore, Households could save 60049.3tons of firewood from14381mirt stoves per year since it was distributed. This was responsible to reduce the tonic equivalent carbon dioxide emission of 64679.98tCO_2e emitted from firewood consumption (Eq3).

Fig: 4. 2 Baking injera with mirt stove at home

T**able: 4. 12** Household fuelwood consumption for baking injera (kg/day)

Consumption rate	N		Minimum	Maximum	Mean	Std. Deviation
Traditional stove	12	Flour in kg	3.8	4	3.95	0.09
		No of injera	24	33	26.72	3.09
		Time taken	1:18	1:53	1:28	0.00
		Fuelwood consumed(kg)	15.4	34.7	22.38	4.76
Mirt stove	12	Flour in kg	3.8	4	3.92	0.099
		No of injera	24	33	28.42	3.12
		Time taken	1:12	1:39	1:25	0.00
		Fuelwood consumed	8.5	16.8	10.94	2.46

N = number of KPT sample

The present investigation also revealed that mirt stove not only save the amount of fuelwood consumed, but also the time taken for the baking (table 4.12). This finding was in line with Clancy (2003) elaborates that improved stoves help to save time, money and to generate income which will contribute to women's advancement.

This advantage of mirt stove enabled women to do another activity besides baking injera. It has also been revealed that as the number of injera baked increased the fuelwood saving of the mirt stove also increased (table 4.12).

5. Conclusions and Recommendation

5.1. Conclusion

Most households in the study area were highly dependent on biomass energy sources for their domestic consumption. In the present study the use of fuelwood as a source of energy and its contribution for climate change were investigated. The most common sources of energy in the study area were firewood, charcoal, electricity and LPG. It has been revealed that 84.4% of the households depend on fuelwood (firewood and charcoal) as energy source for cooking and boiling activities. All the fuelwood to be used for domestic consumption were either collected from natural forests and/or private farm land or purchased from the local market which has implication on forest resources degradation, deforestation and land degradation in which all brings environmental and socio-economic problems.

The current investigation showed that around 212831.5 tones fuelwood has been consumed for baking Injera in Negele Arsi town and the CO_2 emission from the individual household was 13.1tones of CO_2e per household annually. Injera baking using mirt stove saved about 48.88% of fuelwood consumption of the area compared to the traditional open fire method. The household family size encountered with the type of business the family engaged in was affecting the extent of household fuelwood consumption. The study result also indicated that the higher the education level of the household head the lower the fuelwood consumption and the better chance for fuel mixing. It has been observed that fuelwood consumption is causing climate change and if not sustaiably managed, it may result in severe land degradation, soil erossion, food shortage, forest resources degradation and climate change in the area.

Even though there is cook stoves distribution in the woreda, the distribution was not equitable and equal for all the households without considering their economic status.

5.2. Recommendation

Based on the finding of the present investigation, the following recommendations were drawn:

- In order to reduce dependency on biomass energy source and the resultant impacts on forest ecosystems, fuel mixing and alternative energy sources need to be introduced in the study area.
- Family size and education level of the households to affect fuelwood consumption, hence family planning and awareness creation on energy production and consumption related education is recommended.
- Fuelwood consumption and the issue of climate change resulting from fuelwood consumption is getting worse, therefore, fair and equal distribution of ICS designed to use for cooking cultural food is required.
- Finally it is recommended for the future researchers that, it will be fruitful to them and to the country at large if they conduct the research study on the sustainable energy alternatives.

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7. APPENDICES

A. Questionnaire for surveyed households

I am a student at Hawassa University of Wondo Genet College of Forestry and Natural Resources pursuing Masters of Science degree in Renewable Energy Utilization and Management. I am carrying out a research on the Investigation of Household Fuelwood consumption and its contribution for climate change, the case of Negele Arsi town. The research is purely for academic purpose. Any information given to me will be treated with confidentiality.

I. Socioeconomic Characteristics of Households

1. Location of household:

Town:________________________kebele:_______________________________

2. Household head information:

2.1. Gender: A. Male B. Female

2.2. Age__________.

2.3. Marital stage: A. Single B. married C. Windrow D. divorced E. under age

2.4. Occupation: A. self employed B. employee C. employer D. pensioned E. dependant F. Unemployed G. other______________

2.5. Monthly income of the household (average)_________________

2.6. Religious Affiliations: A. None B. Muslim C. Christian D. Other

2.7. Level of education attained: A. None B. Primary education C. Secondary education D. Tertiary education E. University degree

3. Household size and gender distribution

	Male	Female	Total
Household size			

4. Property information

4.1. House ownership: A. Own B. Rental from Private C. Governmental house

4.2. Construction material of the house (Explain):_________________________

4.3. Does the house have a compound?_______________________________ (yes/no)

4.4. If yes, A. how much is it? ______ (m^2) B. For what purpose it is been used ______ C. Monthly/yearly income from use of the compound__________

4.5. Kitchen characteristics A. Construction of material: _______________ B. Where the Kitchen is found? ______________ C. Is it ventilated? _____________ (yes/no)

5. For how long respondent lived in the town?

A. less than 2 years B. 2-5 Years

C. 6-10 Years D. more than 10 years

6. Are you a member of any social organization group in your town?

6.1. A. yes B. No

6.2. What are the compositions of the organization?

A. My neighbors B. MY friends

C. My community members D. Others

6.3. Is there any information exchange between the members regarding Fuelwood consumption and climate change? ______

6.4. Did your organization members have discussed about the technology in use in the households house? ________________

7. Are you an active participant in local associations and activities?

A. yes B. NO

Please state your opinion for each of the given statement using the following scales

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

		Scale	Comment
8	Do you believe that membership to a social organization can influence household fuel consumption?		
9	Do you believe that there is information exchange by social organization about wood fuel consumption influences on climate change?		
10	Neighbors have influence on household Fuelwood consumption.		

11. Do you have any cultural or religious influence that enforces you to use Fuelwood for your household?

    A. yes B. No

II. **Wood based energy consumption and climate change.**

1. What type of fuel you use for cooking?

    A. collected fire wood B. purchased firewood

    C. charcoal D. dung E. electricity F. kerosene G. LPG H. Other__________

2. What is your preference____?

    If Fuelwood is your preference:

    2.1. What type of Fuelwood is used?

    A. Chopped logs B. branches C. others_________________________________

    2.2. Which tree species is preferred and why____________________________________?

3. Do you collect fuel wood? (Yes/no)

    3.1. If yes: from where you are collecting?

A. Natural forest B. community forest C. self planted trees

D. commercial forest E. others________

3.2. What is proportion for each source?___________________________

4. Do you plant trees for Fuelwood? (Yes/no), If yes

4.1. What is the main purpose for this plantation? Is it for domestic use or sale? And proportion? Which part is used for Fuelwood?____________________________

4.2. If for sale how much you earn from these plantations annually? _______________

5. Do you buy Fuelwood? (Yes/no), If yes

5.1. What species is it? ____

5.2. What is the amount respectively? _________________________________

5.3. From which market?

A. Door to door sellers B. Market sellers C. Retailers D. others ________

5.4. Are they collectors/producers? (Yes/no)

5.5. What is the fuel wood price as compared to the past 5 years?

A. 25% higher B. 50% higher C. double D. Other _______

6. What is your expectation/prediction for Fuelwood price?

A. will increasing B. will be stable C. will decreasing

7. How will you respond to it? (e .g Switching to other fuels). ________________ _

8. How much fuel wood is used in your home for cooking per day? _________

9. What socio-economic characteristics influence the extent of Fuelwood consumption in this town?

A. income B. education C. community interaction D. age E. other

10. List the above mentioned socio-economic characteristics that influence fuelwood consumption positively or negatively?

A. positively affecting----------------------,-----------------------,------------------------

B. negatively affecting----------------------,----------------------,-------------------------

11. Do you perceive there is climatic change in this town in the past 5-10 years?

A. yes B. no

12. If your answer for the above question is yes, what is the major cause for the change?

A. Fuelwood consumption B. agricultural expansion C. deforestation

D. urban expansion E .other explain

13. Do you think Fuelwood consumption has contribution for climate change?

A. yes B. No

14. Do you use ICS in your home?

A. yes B. no

15. What type of ICS you use for cooking?

A. Wood ICS B. charcoal ICS C. both type D. other

16. Does the use of ICS reduce the fuel wood consumption?

THANK YOU FOR YOUR COOPRATION!!!

B. Key informants interview questions

This questionnaire is intended to assess the fuelwood consumption and its contribution for climate change, in Negele Arsi town.

This questionnaire is a general question for the selected key informants to generalize the fuelwood consumption trend and effect on climate change in the area and the future sustainability and affordability of energy sources and improved technology transfer.

1. What types of energy sources are used for household consumption?

    A, from where these sources supplied?

    B, are they sustainable?

2. What negative environmental implications resulting from these sources of energy to the area?
3. How can we overcome these negative environmental implications?
4. What clean technologies are in use to reduce impacts from these consumptions?
5. What types of ICS and designs are in use for the household consumptions?
6. Do these design is in line with the cooking culture of people in the area?
7. What is the average price of the improved cook stoves that provided to households?
8. How best the price be reduced?
9. Is there climate change in the area?
10. What are the causes and solution to overcome the challenges?

Thank you for your cooperation!!!

C. Focus group discussion guide

This questionnaire is designed to make discussion on the study with selected focus group members from the population under study to come up with the representative generalization on Fuelwood consumption and its contribution on climate change in Negele Arsi town.

1. What is the status of fuelwood consumption in the area?
2. What are challenges facing households and to the environment from fuelwood consumption?
3. In what ways can we overcome these challenges to the maximum possible step?
4. Are there technology options in the area?
5. What are available and affordable clean energy sources to households?

Thank you for your cooperation!!!

D. The KPT results

Traditional three stone baking method

household code	Flour in kg	No of injera	Time taken	Flour type	Fuelwood consumed in kg
Ht011	4	24	1:20	mixed	18.3
Ht012	4	26	1:26	mixed	18.6
Ht013	4	24	1:20	mixed	18.6
Ht021	3.8	32	1:48	Teff	23.8
Ht022	3.8	32	1:48	Teff	24
Ht023	3.8	32	1:48	Teff	23.58
Ht031	4	24	1:20	mixed	18
Ht032	4	24	1:20	mixed	19
Ht033	4	24	1:20	mixed	18.8
Ht041	4	26	1:26	mixed	19.8
Ht042	4	26	1:26	mixed	19.8
Ht043	4	26	1:26	mixed	19.4
Ht051	3.8	33	1:52	Teff	34.7
Ht052	3.8	33	1:53	Teff	34.7
Ht053	3.8	33	1:52	Teff	34.7
Ht061	4	25	1:20	mixed	15.4
Ht062	4	24	1:20	mixed	15.5
Ht063	4	24	1:41	mixed	15.5
Ht071	3.8	30	1:18	Teff	26.8
Ht072	3.8	30	1:18	Teff	26.8

Ht073	3.8	30	1:18	Teff	26.8
Ht081	4	26	1:32	mixed	21.6
Ht082	4	26	1:32	mixed	22
Ht083	4	26	1:34	mixed	22
Ht091	4	27	1:26	mixed	21.8
Ht092	4	27	1:26	mixed	21.8
Ht093	4	26	1:26	mixed	21.8
Ht101	4	24	1:20	mixed	24.6
Ht102	4	24	1:20	mixed	24.6
Ht103	4	24	1:20	mixed	20.6
Ht111	4	25	1:24	mixed	22.6
Ht112	4	25	1:24	mixed	22.8
Ht113	4	25	1:24	mixed	22.8
Ht121	4	25	1:23	mixed	21.4
Ht122	4	25	1:23	mixed	21.4
Ht123	4	25	1:23	mixed	21.4

Codes description

Ht = Households using traditional baking method,

The first two digits = Household code within the test and

The last digit = test number Mirt stove baking method

household code	Flour in kg	No of injera	Time taken	Flour type	Fuelwood consumed in kg
Hm011	4	24	1:12	mixed	8.6
Hm011	4	26	1:18	mixed	8.6
Hm013	4	24	1:12	mixed	8.56
Hm021	3.8	32	1:36	teff	11.8
Hm021	3.8	32	1:36	teff	12
Hm023	3.8	32	1:36	teff	11.9
Hm031	4	24	1:12	mixed	8.89
Hm031	4	24	1:12	mixed	8.89
Hm033	4	24	1:12	mixed	8.89
Hm041	4	26	1:18	mixed	9.8
Hm042	4	26	1:18	mixed	9.8
Hm043	4	26	1:18	mixed	9.8
Hm051	3.8	33	1:39	teff	13.6
Hm052	3.8	33	1:39	teff	14.7
Hm053	3.8	33	1:39	teff	14.3
Hm061	4	25	1:12	mixed	8.5
Hm062	4	24	1:12	mixed	8.5
Hm063	4	24	1:12	mixed	8.5
Hm071	4	30	1:30	mixed	15.9
Hm072	4	30	1:30	mixed	16.8
Hm073	4	30	1:30	mixed	16.8
Hm081	3.8	30	1:28	teff	10

Hm082	3.8	30	1:28	teff	10
Hm083	3.8	30	1:28	teff	10
Hm091	4	30	1:33	mixed	12.4
Hm092	4	30	1:33	mixed	12.4
Hm093	4	30	1:33	mixed	12.4
Hm101	3.8	30	1:27	teff	8.6
Hm102	3.8	30	1:27	teff	8.6
Hm103	3.8	30	1:27	teff	8.6
Hm111	4	26	1:24	mixed	12
Hm112	4	26	1:24	mixed	12
Hm113	4	26	1:24	mixed	12
Hm121	4	31	1:28	teff	10
Hm122	3.8	31	1:28	teff	10
Hm123	3.8	31	1:28	teff	9.8

Codes description

Hm = Households using mirt stove baking method,

The first two digits = Household code within the test and

The last digit = test number