ENERGY PERFORMANCE OF RESEDENTIAL BUILDING IN

ADAMA CITY, ETHIOPIA

Fikadu Feyisa Biratu

A Thesis submitted to

The department of Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of

Master of Science in Environmental Architecture

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

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Approval of Board of Examiner

I, the advisors of the thesis entitled **"<u>Energy performance of residential building in Adama city, Ethiopia</u>"** and developed by Fikadu Feyisa Biratu, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Fikadu Feyisa Biratu have read and evaluated the thesis entitled **"<u>Energy performance of residential building in Adama city, Ethiopia</u>"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Environmental Architecture.

Chairperson	Signature	Date
Internal Examiner	Signature	Date
Eternal Examiner	Signature	Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

Declaration

I hereby declare that this Dissertation entitled **"Energy performance of residential building in Adama city, Ethiopia"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials used for this thesis have been duly acknowledged through appropriate citations.

Fikadu Feyisa	______________________	_______________
Name of student	Signature	Date

Recommendation

I, the advisor(s) of this thesis, hereby certify that I have read the revised version of the thesis entitled **"Energy performance of residential building in Adama city, Ethiopia"** prepared under my guidance by Fikadu Feyisa Biratu in partial fulfillment of the requirements for the degree of Mater's of Science in Environmental Architecture. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Tibebu Assefa (PhD)	______________________	__________________
Major Advisor	Signature	Date

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ACHRONYM AND ABBREVIATION

Btu	British Thermal Unit
BEE	Bureau of Energy Efficiency
BEI	Building energy index
CFCs	Chlorofluorocarbons
EEPCO	Ethiopian Electric Power Corporation
EPI	Energy performance index/indicator
EUI	Energy use intensity
GDP	Gross Domestic Product
GHG	Green House Gas
GTP II	Growth and transformation plan II
HVAC	Heating ventilation and air conditioning
IPCC	Intergovernmental Panel on Climate Change
koe	Kilogram of oil equivalent
kWh	Kilowatt-hour
m. a. s. l	mean above sea level
Mtoe	Megatons of oil equivalent

ODEX	Energy Efficiency Index of Industry
PES	Primary Energy Supply
SDG	Sustainable Development Goal
SSA	Sub- Saharan Africa
toe	Tons of oil equivalent

ABSTRACT

Energy is a major issue in advocating one country's development. Buildings account for more than 40% of energy use in the world. Using energy is becoming more demanding because of the rapid population growth increasing energy intensity in the city. Next to the industrial zone, residential buildings use energy the most. Less practice on energy assessment on the demand side is a reason for bringing about high energy use in the buildings. This study aims to investigate and evaluate the energy consumption pattern, energy performance index, and modeling benchmark for energy use in a residential building of Adama city found in the Oromia Region. It was conducted on 203 residential buildings, of which 16 villa houses, 84 apartment houses, and 103 detached housing units were selected by random cluster sampling. Energy use in the residences was identified using a survey and organized on Microsoft excel which then exported to Statistical Package for the Social Sciences for data analysis. Linear regression was used to benchmark energy consumption in a building. It was found that the major sources of energy are electric energy (82.91 %), charcoal (16.88 %), and wood fuel (0.21%). About 3/4th it is used for heating. It was discovered that households use average electric energy of 3773.93kWh per year. The EPI is calculated and found to be in an average of 54.74 kWh/ m2/yr.,146.09 kWh / m2/yr. and 113.21 kWh / m2/yr. in the villa, detached, and apartment housing units, respectively. The result shows that the average Energy performance index of residential buildings is 104.68 kWh / m2/yr. The potential of energy saving in the buildings was anticipated and found to be 4.5% of total energy consumption annually. Which is about 20,418,082.77 kWh/yr. energy saving and a cost-saving of about $37,569,272.29 per year based on the housing units reported. Concluding that Adama residents use excess energy and more environmentally suspicious energy sources which bring to bear the addition of carbon dioxide emission. This shows that buildings inhibit poor energy performance depicting poor environmental performances. It is recommended that energy improvement programs and retrofit should be established to cut off spare energy costs and resource exploitation on the demand side in the city to make sure sustainability in the city.

Key words: Adama Ethiopia, Energy efficiency, Energy performance Index, energy retrofitting

CHAPTER ONE

INTRODUCTION

Energy employs a high portion in facilitating growth in a country. Population growth in Adama is a main reason for urban expansion which leads rise of energy demand. Urban expansion in the city has aggressively arisen by housing development. Energy efficiency was given lower attention in most developing countries, which caused the society to experience inefficient use of energy. Besides, the immense capacity of resources the city has for renewable power generation like wind and solar energy sources, evidence shows that there is lower consideration of the adoption and development of energy assessment programs and policies are run into on the demand side. This makes the society experience higher energy use, which affects the social, economic and environmental development of the city. For this reason, these paper objects, to investigate sustainability towards energy and cost saving for both the society and the government, minimizing energy intensity in the city.

Motifs of the study is the increasing energy demand of energy is huge in developing countries particularly in urban centers. Saying that it was conducted on residential buildings as a lot's energy reduction emphasized in these typologies of buildings. This chapter describes the background information around the topic area that has been done before, states the problem, aim, research question, scope, and significance of the study.

1.1. Background

Energy use is inevitable to perform different tasks in-home or workplaces. Many studies identified buildings consume more energy than transport and industry. Energy spent in buildings accounts for a substantial percentage of a country's total energy consumption. The International Energy Agency (IEA) statistics estimate that globally, the building sector handles more electricity consumption than any other sector, 42 percent. Population growth and economic development are the key driving forces for energy demand. A tendency shows it has been go together with by an equally notable increase in energy consumption, which strongly correlated with socioeconomic development (Wilkinson et al., 2007). Energy takes a direct imposition on social-economic development. Adapting different actions via best practices in energy utilization is mandatory to ensure sustainability in a country. Energy efficiency policies and regulation becomes a vital role in the reduction in environmental degradation.

Energy efficiency in the building sector is essential to use efficient materials in a building before construction and best practices after construction. Reducing energy use for HVAC systems should be the first role of the building energy sector to enhance energy saving in the country. Building designs and materials exerts a significant effect on the energy consumed for a set of end uses. Without access to modern and efficient fuels, households are forced to rely on polluting and dangerous sources of energy, such as the burning of dung, charcoal, and kerosene (Morrissey, 2017). This is the issue took great parts on global warming by increases greenhouse gas (GHG) emissions. Socioeconomic problems make it difficult to adapt new technologies in most developing countries. This forces the use inefficient technologies imposing in environmentally suspicious energy sources adding energy intensity in the countries.

The annual increase of 3% in energy consumption is expected in developing countries, which is very high when compared to developed ones (Keho, 2016). This may explain why the past decade has seen a surge in energy demand studies in developing countries. It is reasonable for policymakers and planners to be interested in evidences that can guide decision-making; for the reason of cash constraints and the expected future growth of energy consumption. Following that besides information on present energy consumption patterns, knowledge of the significant determinants of energy demand is a tool for both investment and planning decisions. Efficiency improvements decrease marginal costs. As long as the pricing principle of equating marginal cost with marginal revenues is maintained in the sector; this pulls electricity tariffs down (Kebede, 2006). Increasing electric distribution could be a major problem in most developing countries. Evidence shows that less consideration of the demand side has still greater influence on the energy sectors not to meet the expected goal. Given the lack of alternatives, many in SSA still rely on traditional forms of energy. When looking at the primary energy supply (PES) mix of African regions, it is immediately clear that bio-energy dominates (60–80%) on any other source in SSA (Morrissey, 2017). In developing countries, access to electricity has received much attention. But the reliability of its supply has been given less focus, though power outages happen often and are expected to limit gains from electricity connections.

Buildings are the ones responsible for the increment of energy resulting in temperature rise in the cities. Managing energy use in a building contribute a significant advantage in reducing in energy consumption. Energy management is facilitated by the use of quantitative indicators of energy consumption. Many developed countries made energy performance assessments of existing buildings to manage energy use in the buildings. Most common metrics used for the assessment is EPI (energy performance index) to identify energy consumption normalized by usable floor size per year in order for energy use improvement. Ineffectiveness on energy efficiency regulations and policies on most of developing cities is being experienced in not evaluating and examining of on occupants' energy use. Among different normalizing factor for energy consumption most building practitioner and architects' us this index to enhance energy efficiency in a building. It is mostly applicable for residential and commercial buildings. An empirical study shows that most commercial buildings in India have an EPI in between 150 and 200kWh/yr./m^2.

1.2. Statement of the problem

Need for energy is necessary for human services such us to cook our food and heat our homes. Energy is an integral part of a modern economy because of the critical role it plays as a factor employed in the production of goods and services when combined with capital and labor. Energy is a major thing to assure once country's development. Many scholars have hypothesized that economic growth influences energy use and some say vice versa and some argue that it is directional. From this, certain that the energy situation of one country is important.

Other than industrial and commercial sector, energy management and monitoring were poorly insisted in the household's sector. According to Getie, M. Z., & Dedefa, M (2020) the major energy consuming sector that is the domestic sector is mostly associated with poor energy utilization practice. One of reason for this is; energy saving program was understood on the distribution level exclusive of the demand side. In addition, energy policy program model was not revisited based on actual occupants' energy use pattern. This pushed the users to exploit in environmentally suspicious energy sources or non-renewable energy sources. The study will address to fill this gap.

Energy utilization in a building affects both socio-economic and environmental situations in a building. The gap between a growing demand for fuel sources and supply scarcity has escalated fuelwood prices in urban centers resulting in extensive deforestation in Ethiopia. Besides, potential on the energy production, it was pioneered that the best use of the modern fuels was less considered in most households of Adama city. Most residents use biomass fuel for their day-to-day activity. This affected the dwellers in the city not only financially; it is affecting health issue increasing the mortality rate. Access to electricity is not the key problem for most Ethiopian urban dwellers like Adama. However, relatively most people cannot afford the appliances that make use of such conventional energy sources, causes the society to use different biomass fuels exerting in increased energy intensity in the country. Which emphasizes poor energy performance in a building.

1.3. Objective of the study

General objective:

To analyze energy performance in the residential building of Adama City.

Specific objective:

1. To estimate and compute energy consumption of residential building in Adama City.
2. To compute energy performance index of residential building of Adama city.
3. To compare the energy performance based on a model benchmark.

1.4. Research question

1. How much energy is consumed in households of Adama city?
2. What amount of energy consumed under their usable area?
3. Which of the households are consuming higher energy under self-benchmarking buildings of the city?

1.5. Scope of the study

This study covers on the investigation of the building energy performance and quantify energy use of existing residential building in Adama city, Ethiopia. It covers residential building units within the boundary of the city. The building energy performance was examined on the individual building system. In this study, the energy use by the end uses of households were considered within a year or annum.

1.6. Significance of the study

Energy efficiency is one of the measuring tools for one country's development. The applications of regulation and strategies on embodied energy, material efficiency, and best energy efficient practice are vital issues in validating energy efficiency. Except the first, best practices have given less consideration. It directed the assessment of energy in a building using normalization factor like number of occupants, internal load, building floor size, etc. Based on the current and existing review, there were no studies that have analyzed household energy performance using this metrics, EPI. Implementation of energy efficiency strategies and policies provides the country to promote sustainable development. In many developing countries, baseline data on building energy consumption are missing. This pulled back from the implementation building energy regulations, policy instruments in the buildings. It mainly resulted in a lack of awareness of the importance and the potential of energy regulation and efficiency improvements, lack of financing, lack of qualified personnel and insufficient energy service levels (Ürge-Vorsatz, D. et al , 2007). Enhancing assessments on building energy use in a building set a guide towards energy saving in the building.

The study is vital for the energy sectors in city to develop energy modeling to inquire energy saving. This results in reducing cost for energy supply which benefits society in addition of extra infrastructures development by the government. In addition to this helps the government in energy security lessening imported oil. It is also beneficial for the society to employ awareness of their energy use. The relevance of the paper is undeniable towards improvement on the energy efficiency practice. The study also set up research institutes to urge for environmental conscious experiment and further development of scientific studies.

1.7. Limitation

In carrying on the study, it was encountered the most difficult challenges during the data collection. As this study is much dependent on numerical quantification, the residents were afraid and uncertainty to reply to question on the survey. The other one is some dwellers do not have clear understanding on the activities performed on energy use. This was a reason to use the nonprobability sampling method which allows jumping when this problem was encountered.

1.8. Description of Study area

The study was conducted in Adama City which is one of the fast-growing cities in Ethiopia. It stretches between 8°26’15” N to 8°37’00” N latitude and 39°12’15” E to 39°19’45” E longitude. Adama is one of the cities found in the Oromia National regional state of Ethiopia. The city is located about 100 km southeast of the national capital Addis Ababa along the main highway leading to Djibouti ranges from 1444 to 1974 m. a. s. l covering 134.1 km^2.

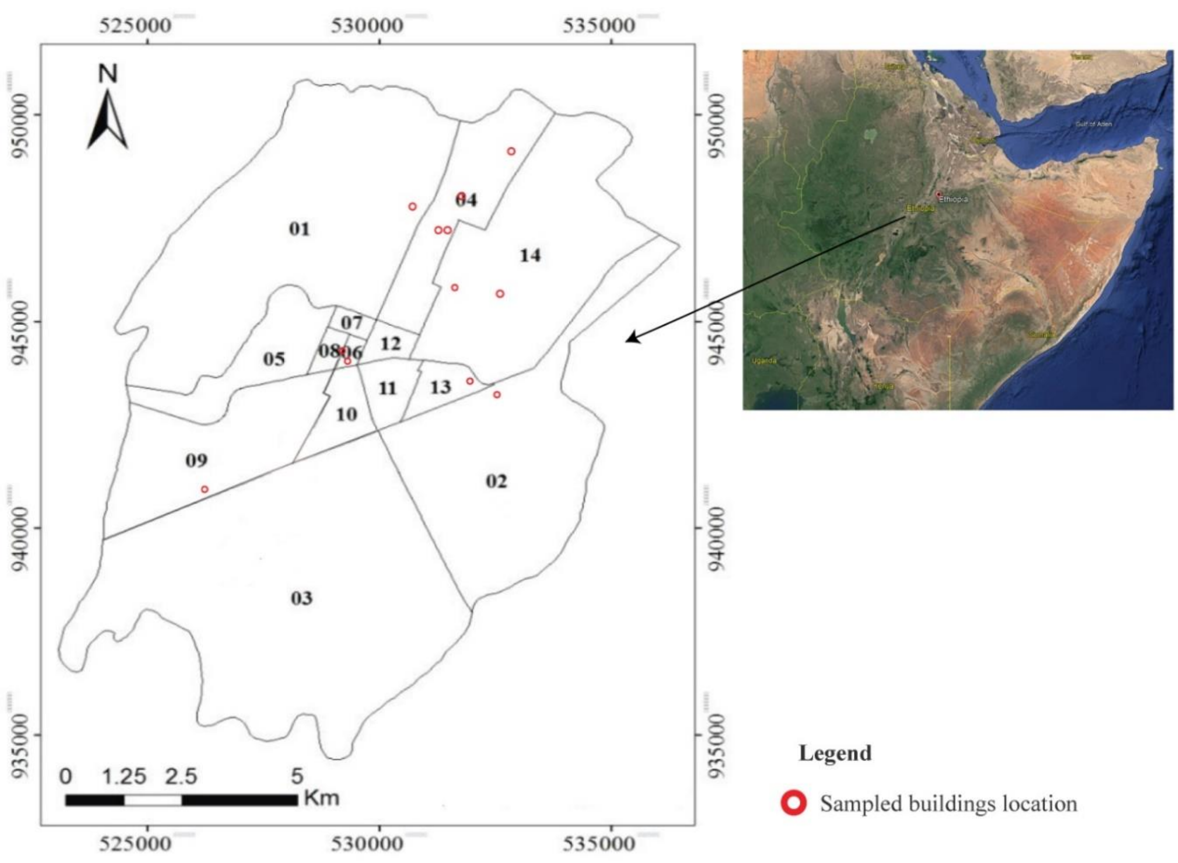

Figure 1. The Study area

1.9. Definition of key terms

Energy conservation: - means reduction in the amount of energy consumed in a process or system through elimination of waste and economical and rational use.

Energy efficiency: -means the ability to provide the same or higher level of products or services at lower energy consumption.

Energy performance: - is the term that indicates the quality of energy use.

CHAPTER TWO

LITERATURE

2.1. Theoretical review

2.1.1. Energy

Energy is an integral part of human well-being and is one of the basic services that humans have to succeed. It provides the means to cook, heat, cool, lights up homes, charges mobile phones, and use other electronic devices. It was deeply drawn energy in each of the economic, social, and environmental dimensions of human development. The dominant sources of energy on which our modern lifestyles are fossil fuels (oil, coal, and natural gas). Electricity is a convenient final energy form for many services, including artificial lighting, entertainment, and many uses in the kitchen because of its high exergy level. It is impossible to operate a factory, run a shop, grow crops, or deliver goods to consumers without using an energy. Most studies of the relationship between energy use and economic development have focused on how the latter affects the former. Economic growth almost always leads to increased energy use, at least in the early stages of economic development. In many poor countries, under-investment in public utilities, inefficient management, underpricing, and an unattractive climate for private investment cause energy shortages and hold back economic growth and development. There is a plethora of empirical studies on the link between energy consumption and economic growth, though we found few in Africa. A study conducted in testing the long-run relationship between energy access and economic growth for fifteen African countries from 1980 to 2008 suggests that causality runs from GDP to energy consumption in the short run, and from energy consumption to GDP in the long run (Ouedraogo, 2013).

Modern energy services can also improve the environment, for example, by reducing the pollution caused by inefficient equipment and processes and by slowing deforestation. But rising energy use worse pollution, and mismanagement of energy resources harming ecosystems. This association between wealth and energy signals a fundamental challenge for tackling climate change, and is an important reason energy efficiency alone will not sufficiently reduce greenhouse-gas emissions without additional attention to the character of energy used. Given the central role that cities play as energy consumers, it is crucial to understand the adherent energy consumption patterns to identify intervention points for reshaping energy toward a more sustainable energy system.

The global energy situation is about to change at a speeding up pace. The growing awareness of the environmental effects of energy use pointed in the right direction toward the energy conservation in buildings. Equally, it is a topical concern for the health and well-being of the occupants of these buildings (Baker et al., 2000).

2.1.2. Households' energy consumption

Building's energy consumption comprises about 40% of total consumption in the world. Households are the major one following the commercial sectors, which accounts about 30% of the total consumption in a building. As a sector, the household is a crucial driver of energy consumption in cities. Despite technical innovation as energy efficiency and renewable energy technologies, household energy consumption continues to rise. Households are a critical point of intervention (Chua et al., 2010). Economic growth and energy the commercial energy consumption will high in developing countries than in industrial countries. High rates of economic growth will continue to be needed in the developing world to provide the rapidly growing population with improved living standards. Some study mentioned an increment of 10% of the population will exert in doubling the energy consumption in these countries. This is the greatest challenge in developing countries, as providing standard living is the future necessity (U.S. Congress, Office of Technology Assessment, 1991).

Nowadays, electricity is becoming one of the prominent sources of energy in most households of the world. The increasing trend of electricity consumption is a reality. Households' energy sources are electricity, biomass fuel, LPG and natural gasses. Most of developed nation dwellings rely on clean energy sources. Dwellings in US used electricity in almost all homes, and retail electricity purchases accounted for 43% of total residential sector end-use energy consumption in 2020. Natural gas, which was used in 58% of homes in 2015, accounted for 42% of residential sector end-use energy consumption in 2020. Petroleum was the next most-consumed energy source in the residential sector in 2020, accounting for 8% of total residential sector energy use. Petroleum includes heating oil, kerosene, and liquefied petroleum gas (LPG), which is mostly propane. In Sweden it about 70% which were about 5% was charcoal, mainly as a result of strong management on energy conservation in the country. Inadequate electricity access in most emerging countries' households is a reason for the use inefficient or physically harmful energy sources or consuming multiple types of energy sources that make up both traditional and modern fuels (Dzioubinski et al., 1999). In Africa, nearly 660 million people (80% of the population) depend on the traditional biomass for cooking in households (EIA, 2010). Urban residential building of Malawi uses about 60% of charcoal the rest 40% is for electricity. On similar study conducted in Uganda revealed energy for cooking and heating of water was through the use of biomass, accounting for 65% and 75% or energy use, respectively.

Cooking is by far the largest use of fuel in rural areas; in urban and more developed areas, lighting and appliances (refrigerators and electric fans, for example) are also large energy users. Lighting accounts for only a small fraction of total national energy use in both developing and industrial countries. On the study conducted energy use trends in Uganda, a large proportion of residential buildings were connected to mains electricity, which was largely used for lighting and running basic appliances (refrigerators, televisions and cell phones). Over 60% of energy is consumed with water heating, refrigeration and others. Penetration of energy use in US homes in 2015 were space heating, air conditioning, water heating, lighting, refrigeration and cooking, which share 43%,8%,19%,5%,3% and 23% respectively.

2.1.3. <u>Scenarios on strategies of energy efficiency in a building</u>

An international panel of scientific experts of the IPCC recently concluded that emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases. It is reported that over 70 percent of GHG emission globally was experienced in the city, 40% were from the building’s energy use. It was reported that this experience is mainly because of urban areas' faster population growth than the rural areas (Musango, 2014). According to the International Energy Agency, IEA (2008) two-thirds of the world’s energy, as estimated in 2006, is consumed in cities. This estimate will as well grow to almost three-quarters by 2030 IEA (2008) implying that the consumption of energy makes a critical challenge urban center. Understanding the complex and often invisible set of interacting and interdependent policy decisions and outcomes of energy use can provide opportunities for identifying specific forces that shape a city's energy consumption and its consequences. Urban Metabolism (UM) is a multi-disciplinary and integrated platform that examines material and energy flows in cities a s complex systems as various social, economic and environmental forces shape them. Haberl (1997) pioneered that metabolic research could establish a more comprehensive understanding of urban metabolism if it is inclusive of its energy metabolism. The concept of energy metabolism provides a methodological framework where relevant pathways for energy can be analyzed at different levels, leading to the development of management systems, which increases the energy conservation (Pincetl. S et al., 2012). It also has a practical and theoretical relevance to achieving proper development and can serve as guidelines in policies development for effective energy management measures. With the current increase in the global, the issue is not how to produce the required energy but also ways to allocate sustainable use on a demand side. Rising demand for energy forced many organizations to make efforts to balance demand and supply. Many research was studied on consumption of total energy in buildings to share knowledge in energy efficiency and energy conservation initiatives.

Strategies and policies on energy efficiency have the greatest effects on the reducing and minimization of the energy usage and consumption. All new buildings must strictly comply with the building energy efficiency standard, with the supervision of implementation strengthened. Energy efficiency in buildings has become an essential instrument to ensure that the energy supply would last in the long term, as well as to meet the targets set in the Kyoto protocol (González et al., 2011).

Wai et al. identified three important phases towards the success of an energy efficiency program, such as planning, implementing and monitoring, and evaluation. Practicing energy efficiency will reduce critical health problems, improve environmental problems, reduce carbon dioxide emission and irreversible climate change (González et al., 2011). It is important to promote energy efficiency by using instruments comprising regulation, technical assistance and recognition or incentives (Manan et al., 2010). Through research, more strategies to reduce the electricity consumption can be explored, such as by implementing load shifting method and using energy index. According to Van Gorp, the energy saving can be achieved by consistently carrying out energy management practices and adopting recognized measurement, as well as verification procedures.

Adoption of energy efficient building code will help countries in reducing their energy demand for buildings. Building energy regulation specifies and recommends the energy performance indicators to be incorporated into these performance assessment methods and how they should be applied for building performance assessment, to reduce building energy consumption. According to Whole Building Design Guide (2009), implementing and enforcing energy regulations will cause fewer energy demand, fewer power plants and natural resources being used to provide electricity and natural gas. This reduces their carbon footprint as buildings contribute significantly to the greenhouse gas emission and make a significant economic saving in terms of fuel import and for the building owners. Integrating renewable energy technologies in the building will generate additional energy which excess could be sold to the national grid. Reviewing the building code is not enough, which does not develop awareness and implementation tools. Building permit requirements should include environmental design strategies and passive building measures. It has to build the capacity of architects, engineers and other building practitioners on sustainable building design. Integrate passive building design into universities curriculum, involving the youth into renewable energy technologies, special financial mechanism for credit, incentives and green mortgage can have dominant influence towards the achievements.

2.1.4. Energy performance assessment and indicator (EPI)

Energy performance is a term to show the quality of energy use. Building energy performance can be termed as the numerical quantification of energy consumed in a building to meet associates' needs of standards use of a building. It is also defined as 'the amount of energy consumed or estimated to meet the different needs associated with a standardized use of the building. Most developed countries have documented energy performance evaluation year to year, which helps them to manipulate the energy efficiency in weather fluctuation. So, energy performance can also be calculated in comparison with previous energy consumption models. Energy performance is a phrase used to specify the quantity of energy used in actuality or projected to satisfy the differing demands connected to a homogenous usage of the buildings

(Poel et al., 2007). This amount is mirrored in one or more numeric indicators referred to as Energy performance indicators (EPI). Most frequently used in many buildings and globally, is energy use intensities, i.e., kWh/m^2. The energy performance of a building is largely decided by six main variables namely climate, building envelope, building services and energy systems, building operation and maintenance, occupants' activities and behavior and indoor environmental quality provided.

In the building sector, energy performance evaluation approaches can be taken on by performance-based or feature-specific approaches. These two approaches adopt different methods of assessing building energy (Nii et al., 2017). The performance-based approach looks at comparing performance indicators (e.g., Energy Use Intensities or carbon dioxide emission) against yardsticks to inform on energy efficiency level. These two have their advantages and their disadvantages. The study by Wang et al. (2012) argues that the performance-based approach is preferable as computations are easily quantifiable based on performance indicators. However, they state that such an approach is bulky to develop, as it includes first, the establishing of a suitable method of quantification and its associated criteria.

Buildings as energy systems must respond to the functions and purposes assigned to them, bearing in mind local climatic conditions and ensuring healthy and comfortable conditions for all users, avoiding undue dependency on "external" energy. It was dictated by Boemi et al. (2016) that the criteria suited to a specific building type or a specific country do not work well for other typologies or locations. It was clarified that it is difficult to create a true holistic criterion of a building as a world.

Energy classification and energy performance diagnosis are most common in providing information on the energy performance level, i.e., mostly efficiency level and carbon emission to building stakeholders including the users of building, owners and public (Ayarkwa et al., 2015a). It is way that were adopted to inform the building owners or publics to the energy performance of the evaluated buildings (Wang et al., 2012). This allows them to maintain the instruments, providing information simply, and urges building owners to better improve the performance level of a building regarding energy. Instruments used for energy classification are available mostly together with energy benchmarking, energy certification, and energy labeling (Ayarkwa et al., 2015a). These tools possess varying specialties in the way energy performance is classified and displayed. Building energy performance assessment methods can be differentiated according to their objectives, the details and issues concerned. According to the above differences, Wang et al. (2012) classified the usage of energy performance evaluation into four classes comprising building environment assessment schemes, energy certification, whole-building benchmarking tools and hierarchical assessment and diagnosis tools (Ayarkwa et al., 2015a).

2.1.5. <u>Benchmark for buildings energy use</u>

In the study Wang et al. (2012) explained that whole-building benchmarking uses a statistical standard to measure the energy performance index for a whole building. They have that such benchmarks look at the whole assessment of existing buildings. Consequently, a suitable reference benchmark must be selected or an appropriate one must be developed. For this to be achieved, advances that benchmarks can be set up based on a statistical analysis of comparable and similar buildings referring to this as a statistical benchmark (Wang et al., 2012). This is more emphasized in situations where there is no comprehensive energy performance data for a sample of buildings, benchmarks will have to be set up based on using hypothetical reference building for calculation (Ayarkwa et al., 2015b).

2.1.6. <u>Empirical study on energy use in households</u>

Energy demand has been projected to rise for the next few decades. It is expected that the energy consumption in buildings will have exceeded 4400 Mtoe in 2050 from 2759 Mtoe recorded in 2007 which is a 37% increase (Florini, 2011). According to the IEA residential buildings handle over 60% of building consumption patterns with commercial buildings responsible for the rest. It is reported that between 2000 and 2016, the global energy-related CO_2 emissions increased by about 40% (Yau et al., 2013). In 2015, buildings handled about 40% of these global energy-related CO_2 emissions, about half of which originated from residential buildings (Nejat et al., 2015).

The main energy sources are natural gas in most European countries which accounts for 37% and electricity which has shown increment from 21% and 28% from 2000 to 2018. The rest accounts for oil which has a significant decrement 11% to 20% by the same years and wood has increased by 6% points since 2000 to 16% in 2018. In considering the variability in different countries, energy consumption in Europe's is around 458 Mtoe in 2016, of which buildings account for 41% of the final energy consumption and 60% of the electricity consumption. This shows that around 2/3rd of this consumption is for residential buildings. It was also reported that the average annual consumption per m^2 for many buildings has been reached around 200 kWh/m2 which greater than the average annual consumption per m^2 in commercial buildings of India today. Service buildings are on average 60% more energy intensive than residential buildings (300 kWh/m^2 compared to 170 kWh/m^2) (Odyssee M., 2018). This specific consumption varies significantly in Europe's countries; for instance, values for Spain and Sweden are respectively 25% lower and 5% larger than the average European's countries. Such differences can be explained by climatic conditions, a high share of space heating or air cooling, technical characteristics of dwellings, etc. Space heating has the highest share in household consumption in most countries (except Portugal and Malta) represents on average 0.9 toe/dwelling. Electrical appliances and lighting or water heating, depending on countries, represent the second. It accounts for about 0.1 to 0.3 toe/dwelling (except in Sweden, 0.5 toe/dwelling). Water heating consumption ranges from 0.05 to 0.3 toe/dwelling. Since 2014, unit consumption reduction for water heating has significantly slowed down in three large countries (France, Italy, Spain) and has even reversed (i.e., increased) in three countries (Austria, Belgium, Romania). Cooking unit consumption reduction has been divided by 3 since 2014, with an increase in Germany, Italy, Poland, and Czechia. Air cooling still represents a marginal share of dwelling consumption in most countries, except Malta, Cyprus, Bulgaria, and Croatia. Large discrepancies between countries from less than 5 koe/m^2 in Spain, Cyprus, Portugal, and Malta to 15 koe/m^2 in Latvia, Luxembourg, Czechia, and Hungary, because of differences in climatic conditions. Energy consumption per dwelling decreased less than consumption per m^2 because of an increase in the average dwelling size. This means that 20% of the energy efficiency progress for heating at EU level has been offset by the larger size of dwellings. Significant discrepancies in electricity consumption for electrical appliances and lighting: from less than 1500 kWh/dwelling in Latvia and Czechia to 2400 kWh at EU level, up to 3400 kWh in Finland and 5600 kWh in Sweden. Even if air conditioning represents only 1% of total electricity consumption at EU level, the average consumption per dwelling for air conditioning is increasing with the diffusion of air conditioning appliances (from 14 kWh/dwelling in 2000 to 42 kWh/dwelling in 2018). It is mainly significant in Malta, Cyprus, and Bulgaria. Cumulated annual energy savings for households reached 105 Mtoe since 2000, so without energy efficiency improvement, energy consumption would have been 105 Mtoe higher in 2018. Because of the slowing pace of energy efficiency improvement, annual additional savings have been decreasing by around 30% since 2014: from an average volume of 6.4 Mtoe/year over 2000-2013 to 4.3 Mtoe/year since 2014 (Odyssee M., 2018)**.**

In Greece, in 2014 the per capita electricity consumption was 5062.61 kWh/capita while in 2010 was 5333.44 kWh/capita and in 2008 was 5805.19 kWh/capita. The economic crisis in Greece since 2008–2009 in flue need the electricity consumption as in 2013 the average consumption fell to 5029 kWh/capita. Consumption per household is another indicator to monitor the electricity consumption in the residential sector. In 2000, the electricity per household (hh) was 3717 kWh/hh, while in 2010 it was 4023 kWh/hh (World Energy Council, 2016). India's domestic electricity consumption has increased from 80 TWh in 2000 to 186 TWh in 2012 and makes up 22 % of total current electrical consumption (Shukla et al., 2014).

2.1.7. Empirical study on EPI of residential buildings

Energy performance indicators (EPIs) give metrics for both baselining and benchmarking structures to manage approaches to residential energy use. It has been referred as energy use intensity (EUI) in different reports and scholars expressed in 1,000 kWh per square foot of conditioned space (kWh/sf) (Birtles et al., 1997; Filippín, 2000). Other studies measure EUI in terms of monthly/annual energy use per unit of conditioned area in British thermal units per square foot (Btu/sf) or 1,000 Btu per square foot (kBtu/sf), or million Btu per square foot (MMBtu/sf), often considering consumption of all fuel types (Federspiel et al., 2002; Kinney et al., 2002).Thus, the electricity usage in residential buildings in Malaysia amounts to approximately 10 to 25 kWh/m^2/year if the electricity use in office buildings in Malaysia is between 200 to 250 kWh/m^2/year (Noranai et al., 2012). On the study conducted site and source energy index values for approximately 348,000 single-family detached homes in Bexar County, Texas majority of single-family detached houses (45.8 % of total or 159,147 houses) have an energy index of 25–50 kBtu/sf/year (78.8–157.7 kWh/m^2 / year) (Gomez et al., 2014).

2.2. Contextual review

2.2.1. Energy use in Ethiopia

Ethiopia is endowed with abundant renewable energy resources and has the potential to generate over 60,000 megawatts (MW) of electric power from hydroelectric, wind, solar and geothermal sources. Now, the country has approximately 2,300 MW of installed generation capacity, which does not serve a population of over 95 million people (Vargas, 2016). The current Growth and Transformation Plan II (GTP II) has a new target to increase generation capacity to over 17,000 MW by 2020, with an overall potential of 35,000 MW by 2037. Despite Ethiopia's huge energy potential, the country is experiencing energy significant shortages as it struggles to meet growing electricity demand. Power demand is forecasted to grow almost by 30% per annum (Vargas, 2016).

In the year 2017, Ethiopia's final energy consumption was reported as around 40,000 GWh, where 92% was consumed by domestic appliances, 4% by the transport sector and 3% by industry (Ethio Resource Group, 2012). The share of households' energy consumption in Ethiopia is dominated by firewood. Sustainably produced firewood allows carbon appropriation. Replacing fossil fuel with these firewood decreases 2– 3 kg of corban dioxide for each kg of fossil fuel (Neil Burnside et al., 2021). It has been reported that the electric consumption of the residential households was about 34% of the total national electric energy consumption in the year 2014/2015 (Getie, 2020). Nevertheless, the electrification rate higher in urban areas of Ethiopia, consumption trend is mostly limited to lighting and some home appliances, and rarely used for food cooking (Tiruye et al., 2021).

The research conducted in Bahir Dar city disclosed that charcoal and firewood were found the dominant energy sources and accounted for nearly 78% of the energy demand of households in the year 2014. It was reported electricity consumption accounts for 20.8% of the total energy consumption of the households. In the study conducted households who live in condominium houses, 76.3% use electricity and firewood interchangeably when there is electric power fluctuation and 2.6% depend on biomass energy injera baking (Getie et al., 2020) . Because of irregular connection urban households of Ethiopia with electricity connection provides a monthly defensive expenditure of US$14.8 million and a monthly willingness to pay of US$6.2 million for improved electricity supply, on top of the regular electricity bill (Meles, 2020).

Biomass energy sources are the main and primary sources of energy consumption in Ethiopia. It was considered traditional fuels (charcoal, fuel wood, dung cakes and agricultural residues) reached about 87% of the total energy sources as of 2017. Only 13% was for modern fuels. Due to the limited access to national electricity, people in the rural areas use fuel wood and tree residues as a predominant source of lighting and cooking. According to the government report, the total energy requirement of the country increased slightly by 4% from 39,701 ktoe in 2016 to 41,461 ktoe in 2017. The household sector is a major energy consuming sector accounted for 88.2% followed by the transport sector with 8.4%.

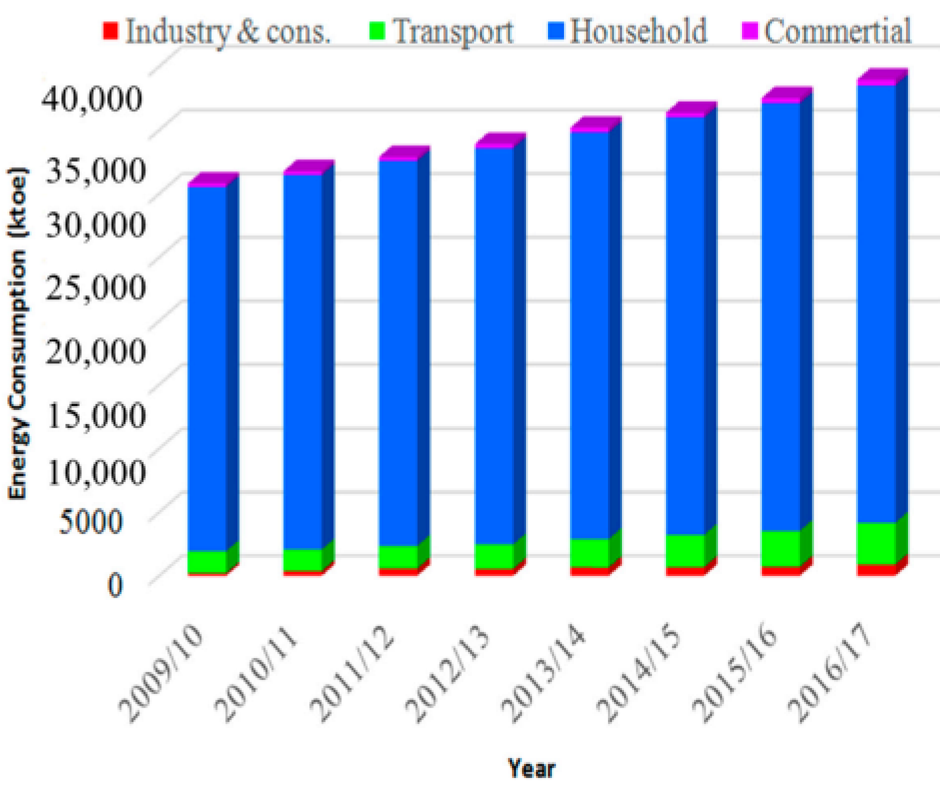

Fig 2 Ethiopia Total energy consumption by sector between

2.2.2. <u>Energy use in households of Ethiopia</u>

In Ethiopia, the household consumes nearly 91.3% of the total final energy, of which 98.5% constitute biomass fuels and 1.5% constitute modern fuels. There is some variation in terms of the level of energy consumption between rural and urban areas. In the rural area, households consume 92% of the total energy, of which 99.5% constitute traditional fuels and only 0.5% of the energy makes up modern fuels. The urban households consume 8% of the total energy of which 86.7% accounts for traditional fuels and 3.3% accounts for modern fuels (Woldegiorgis, 2002). The per capita consumption of electricity in Ethiopia remains relatively low at about 200 kWh per year (Guta, 2015).

Ethiopia has an inadequate energy supply and use. There is a need to transform from traditional to modern energy sources to support the development need of the country. The goal of the energy sector in Ethiopia is that to approve energy conservation and efficiency measures in all sectors and influence the establishment of the mechanisms to adhere to standards and codes.

The main end-use in households of the country is cooking, which is mainly performed by using traditional fuels like firewood, animal manure, or agricultural residue. The usage of energy for hot water, for tea coffee, and rarely for shower and other similar activities also consumes fuel mainly firewood or charcoal. Many papers investigated in Ethiopia show that there is a high demand for the consumption of charcoal in developing urban cities. From different research conducted, it was raised that the lower income of the households is one factor towards the consumption of nonrenewable energy. The data from the last census in 2007 shows that households in most Ethiopian cities dominantly use traditional fuels for cooking purposes. The share of households without access to commercial energy or electricity and for which dependence on non-commercial (traditional) fuel exceeds 75% of total energy use is an arbitrary benchmark to determine whether there is a dependence on traditional fuels (EEA, 2005). And defined as charcoal and firewood are still the dominant source of energy for cooking in the households. On research carried out on differentiating the causes of crude oil consumption in households of urban areas was described that it has been going on because of the cultural issue and lesser understanding of sustainable energy use. Identifying and quantifying energy consumption is the only way to control this impact, as it helps the community to understand the effects of non-renewable energy sources.

2.3. Summary of literature review

Energy is the most relevant for basic services to performs tasks. It serves to carry out different services in a building. The building took the largest percentage of energy consumption so that CO_2 emission. Nowadays, the increment issue has forced most developed country to establish different policies and regulations on energy saving. Most developed countries have energy efficiency measurement by identification of energy use in the building. The energy performance index is the one largely applied in most commercial and residential buildings which is one of the energy efficiency indicators. In general, the advocating energy measurement and management is crucial towards advocating energy efficiency in a country.

Besides the immense resource in power generation has the country, energy conservation has been less being the unaware energy use special in households. Even though traditional energy sources use was considered in rural of the country urbans households consume the most.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Sampling technique

In this study non-probability sampling technique was adopted to take sample from households in Adama city. It was applied by using random walk or quota based to take samples from the *kebeles* encountered in the city. This sampling technique is usually used since it removes constraints in researcher when the dwellers unable to responds on the survey and when there is no list for the household units to make probability sampling technique. This method is quietly used by many researchers, Legamo et al. (2021) used to assess energy expenditure and fuel choices among households in the Sidama region, southern Ethiopia. The selected sampled were represented in terms the building typology and *kebeles* they were where located. It was conducted in 9 *kebeles* of the city in where higher residents' clusters were encountered. It is estimated that 64,701 housing units are found in Adama city. The households' units were considered those exhibit energy use patterns for particular activities in their buildings. From the total units of household, samples taken where households encountered in a single *kebele*. The total sample was taken using simplified statistical calculation adopted by Yamane (1965) :

$$n = N / (1 + Ne^2) \qquad \text{Eq 1.}$$

Where; n= sample size, N = population size (64,701), and e = Margin of error (MoE) which is 0.7 for 93% confident level. The sample sizes are then 203 which were summarized in Table 1.

Table 1: Sample taken from kebeles

Kebeles	Apartment	Detached houses	Villas	Total
09	72	5	-	79
04	33	35	5	73
Bole	-	10	4	14
01	-	4	7	11
08	-	4	-	4
14	-	14	-	8

06	-	2	-	2
13	-	7	-	7
02	-	5	-	5
	105	82	16	203

3.2. Data

Data were collected from both primary and secondary sources. The primary data was based on a survey conducted to get information on end-uses and energy sources, units in the houses, and usable floor area (refer Appendix 1). Some of them are like conversion factors for different sources of energy, like electronic appliances, charcoal, and wood fuels, and CO_2 emission factors were taken from secondary data like published documents, journals, etc.

3.2. Data collection

Data were collected using the survey method. Questioners were used to collect primary data. Even though the interview wasn't a part of data collection, but the questioner design allows the respondents to give some qualitative data. It was revised based in the field observation to evaluate questions whether supplement needed information to obtain aim of the study. The data were collected by experts on the study from May 23 to May 27/2021. The data collection for each aim were presented on Table 2.

3.3. Methods

3.3.1. <u>Energy use pattern</u>

The study used a mixed approach. Bottom-up data acquisition was used to estimate the residential building energy usage by disaggregated individual components. This approach was found to be consistent with the study's fundamental objective in investigating the urban residential buildings' energy consumption by individual end-uses in Adama city. The questionnaire sought to collect information on the popularity of energy end-uses annual expenditure on energy including electricity and other alternative sources.

To imply the energy use in households' questioners were developed (refer Appendix 1). The questioners inform dwellers fist to select the set end uses have and simultaneously were asked to the energy sources employed for the particular end use. For electric consumption, it was composed by desegregating electric appliances employed in the buildings for such an activity. Different energy sources were identified by the average consumption based on the dweller's consumption intuition either with day/month/week. Defining each source of energy use different secondary data were involved to convert energy sources of different units of measurement to the convenient equivalent units(kWh) which were selected for the study. The quantitative data collected the energy use by end uses were organize in Tabular format with annual consumption.

The total electric energy was collected by identifying each electronic appliances found in selected housing units. To get energy use by each appliance was calculated by Eq. 1.

$$E_0 = p * t \qquad \text{Eq. 1.}$$

Where,

E_0= energy consumed by the appliances

p = rated power for the appliances

t = working time of the appliances

Then, the total electric energy consumption was calculated by Eq. 2.

$$\mathrm{E} = \sum_{k=1}^{n} \mathrm{E}_0 \qquad \text{Eq .2.}$$

Where,

E = total annual electric energy consumption

E_0= electric energy consumed by each electric appliance in a year

Energy consumption for different sources of energy was calculated independently. Energy sources like charcoal wood fuels and kerosene were identified. To make the calculation it was calculated by Eq. 3.

$$E_1 = m * k \qquad \text{Eq .3.}$$

Where,

E_1 = energy consumption of charcoal, kerosene, wood fuel etc.

m = amount in kg or L,

k = the amount of energy produced per kilogram (kW/kg) or. Liter kW/L

From the total energy consumed in a building finally will be the summation of total electric energy consumed in a building and total energy consumed of charcoal, kerosene, wood fuels etc. It was calculated by Eq. 4.

$$E_T = \text{E} + E_1 \qquad \text{Eq 4.}$$

Where,

E_T = total energy consumption

E_1 = energy consumption of charcoal, kerosene, wood fuel and etc.

E = total electric energy consumption

The data collected were organized in tabular format on MS-excel. Then the type and amount of energy consumed in the households will be identified and showcased in different graphical and tabular formats.

3.3.2. <u>Energy Performance Index (EPI)</u>

The floor area of each housing units was founded by employing on site measurement. With the total energy calculated above on Eq 4. Consumed and floor for specific building, the energy performance index was calculated by Eq. 5.

$$EPI = \frac{Total\ energy\ consumed\ in\ a\ building(kWhr)}{UFA(m^2)} \qquad \text{Eq .5.}$$

Were,

EPI= Energy performance index of the building,

UFA= Usable floor area (m^2).

3.3.3. Benchmarking the building

It uses a simple method to inform decision makers with a relative energy performance level by comparing the whole building energy performance index of the assessed building with pre-set benchmarks (Wang et al., 2012). For this study empirical benchmarking was employed. The EPI of the building was calculated from the data collected from a sampled building was used to develop benchmark model. Best assumption on energy benchmarking for the stock building is comparing the building each other.

Table 2: Summary of methods

Objective	Data used	Source of data	Collection method	Instrument used	Data analysis
To identify the energy use patterns in households of the city	Average energy consumed in the building.	Sampled residents	Survey	Computer, Journals document	Statistical analysis using SPSS (mean, SD)
To quantify EPI of the building	Total energy consumed in the building (TEC) and usable floor area	Sampled residents and building	Direct measurement	Length measuring tape, Computer,	Normalizing energy use with building floor size (I.e., Energy performance index)

To compare the energy performance with model benchmark and other building type.	Usable floor area of the building Calculated EPI	Sampled resident, Journals document	Calculation and direct measurement	Computer	Statistical analysis using SPSS (mean, SD) Multiple linear regression method)

3.4 Data analysis

3.4.1. <u>Energy use pattern</u>

Data collected was organized in MS-Excel and exported in Statistical analyzer software (SPSS) for data analysis and present the result in terms of different graphical and tabular forms. In the analyzer package, descriptive statistics were used to analyze energy utilization regarding preference on the energy sources and type of end-uses. Energy use concentration in the dwellings was examined by the cumulative end-uses and individual appliances in a dwelling. Then it was compared and contrasted with the secondary data to summarize and recommend the result got from descriptive statistics.

The growing consumption of energy has raised concerns over the effects on the environment, supply difficulties, and depletion of resources. Managing energy use in households are the important intervention point to eases environmentally unfriendly practices in the society. Environmental policies coined should be inclusive of the resource consumption models from the actual measurement. Emphasis of strategies and policies at both institutional level and society is necessity to probe better service quality. The analysis was takes places based on a common approach.

3.4.2. <u>Energy performance index (EPI)</u>

Energy use in a building now a days are becoming crucial as 40% percent of greenhouse gas emission in the world were strives from it. With a limited natural resources, strategies and programs are must for best practices on consumptions. Employing metric is what most countries have to control their peers on the resource utilization. In this study, buildings' energy performance was analyzed on the most informed metrics called energy performance index. The energy performance index (EPI) quantified was used to analyze the dwelling's energy consumption with theirs working floor size of the building, which informs energy intensity in the housing units of the city. Then the mean and standard deviation were used to identify average energy performance in a particular building. The results were presented in scattered plot and correlation to understand the relationship of energy use in the buildings with dwellings floor size of the building. It was examined with Pearson’s correlation, which was considered as in the study Evans (1996) in the relation were considered were weak relation ($r < 0.39$). and ($r \geq 59$) strong relation to analyze variability in expected value with favored variable. The result was then compared with other studies on the literature to analyze and draw a conclusion on energy intensity in the dwellings.

3.4.3. <u>Benchmark of buildings</u>

Benchmarks for the building most common approaches used to analyze the potential on energy saving in buildings and guide the decision makers. It creates a criterion to set programs for energy saving. Multiple linear stepwise regression method was used to establish the model by considering two energy consumption influencing factors initially, which were family size and floor area. The significance of obtained regression equation and the regression coefficients were tested and the diagnosed by the statistical methods using t-test. The Sig value (significance level) of the model for family were ($p>0.050$), which adapted by Gelman (2012) indicating that it is not significant. This intel family size doesn’t really affect the dwellings energy use. So, the model was developed considering one influencing variable, floor size. The model developed were based regression analysis method with a formula:

$$\mathrm{y} = \mathrm{a_o} + \mathrm{b}x$$

Were, $\mathrm{a_o}$ is constants, and b are coefficient, x stands for floor area; it is presented with different housing typology of a building. The estimated index EPI_o, then was sorted and reported with tabular format. It sorts the difference of EPI_o value predicted by the model and actual value as a residual value. This value shows the amounts of energy saving in a stock building. The higher the residual value is, the higher the building energy consumption above the reference value is, and the building got less energy saving capability. It was also employed in the study Jia Y. (2015) in benchmark energy consumption in office building. The graphical representation using scattered plot presents the linear relationship of predicted value with the normalizing factor's

CHAPTER FOUR

RESULT

4.1. Energy use patterns

4.1.1. Energy use pattern in apartment houses

The analysis of was based on the average consumption of residents by an activity which calculated throughout a year. Energy sources in apartments housing units is found to be electricity and charcoal. Most residents consume other sources of energy when they encounter discontinuity in electricity occurs. On average, the electric energy consumption among households in apartments building is 3773.93 kWh per year, and charcoal is 71.09 kg/yr. (578.71 kWh/yr.). From the fig 2 it can be summarized 86.70% of the selected sample households consume electric energy for their day-to-day activity, the rest 13.03% of it is a charcoal. It was founded selected apartment residents' energy use accounts a total annual energy consumption of 4,352.64 kWh. for their day-to-day activity. As it was shown on Table 3 energy use of different sources over the building floor size is equal to 14.55 kWh/m^2/yr. for charcoal and 94.89 kWh/m^2/yr. for electricity.

Table 3: Energy usage in apartment households'

Energy sources	No. of dwellings	Average use of Mass (Kg)	Electricity Energy Equivalent (kWh) [Before Conversion Losses]	Energy use per floor size(kWh/m^2/yr.)
Charcoal	100	71.09	578.71	14.55
Electricity	All (103)	-	3,773.93	94.89

NB: energy equivalent for charcoal is 8.14kWh/kg.

4.1.2. Energy use pattern in detached houses

Besides for apartments, most households that live in detached consumes significant amount of wood fuels. Likewise, here also electric energy is dominant sources of energy used up by households. There is a significant consumption of charcoal is observed as a compulsory source of energy. Even though wood fuels are not the most frequent source of energy, sometimes it used as the best option to cook '*injera'* since there is no affluent electric energy for *'injera* *mixad'*. Almost all residents also consume charcoal when they encounter discontinuity or blackouts of electricity has occurred. On average, the electric consumption among households in detached buildings is 4,347.45 kWh/ yr., charcoal and wood fuels are 214.23 kg/ yr. (1,743.82 kWh/yr.), and 7.64 kg/yr. (37.47 kWh/ yr.), respectively. From the fig 2. it can be summarized 70.94% of the selected sample household's consumption is electric energy for their day-to-day activity, the rest 28.45% is charcoal and 0.61% is wood fuels. It is found that total annual energy consumption in these selected residents is 6,128.74 kWh. As it was shown on Table 4 energy use of different sources over the building floor size is equal to 0.78 kWh/m^2/yr. for wood, 36.36 kWh/m^2/yr. for charcoal and 90.64 kWh/m^2/yr. for electricity.

Table 4: Energy usage in detached households'

Energy sources	No. of dwellings	Average use of Mass (Kg/yr.)	Electricity Energy Equivalent (kWh/yr.) [Before Conversion Losses]	Energy use per floor size(kWh/m^2/yr.)
Wood	20	7.64	37.47	0.78
Charcoal	83	214.23	1743.82	36.36
Electricity	All (84)	-	4,347.45	90.64

NB: energy equivalent for charcoal and wood is8.14kWh/kg and 4.90 kWh/kg respectively.

4.1.3. <u>Energy use pattern in villa houses</u>

Electric energy is found to be the prominent sources of energy in villa housing unit. On average, the electric consumption among households in villa houses is found 5,386.6108 kWh/yr., and charcoal is 64.53 kg/yr. (525.28 kWh/yr.). From the fig 2 it can be summarized 91.11% of the selected sample household's consumption of electric energy for their day-to-day activity, the rest 8.89% is charcoal. In the Table 5.

It is founded these selected residents accounts of a total annual energy consumption 94,590.32 kWh. As it was shown on Table 5 energy use of different sources over the building floor size is equal 4.67 kWh/m^2/yr. for charcoal and 47.93 kWh/m^2/yr. for electricity.

Table 5: Energy usage in villa households

Energy sources	No. of dwellings	Average use of Mass (Kg)	Electricity Energy Equivalent (kWh) [Before Conversion Losses]	Energy use per floor size(kWh/m^2/yr.)
Charcoal	15	64.53	525.28	4.67
Electricity	All (16)	-	-	47.93

NB: energy equivalent for charcoal and wood is 8.14kWh/kg.

From fig 2. Representative of electric energy source dominates in the apartments and villa typologies but in detached houses comparable energy consumption is encountered by charcoal consumption.

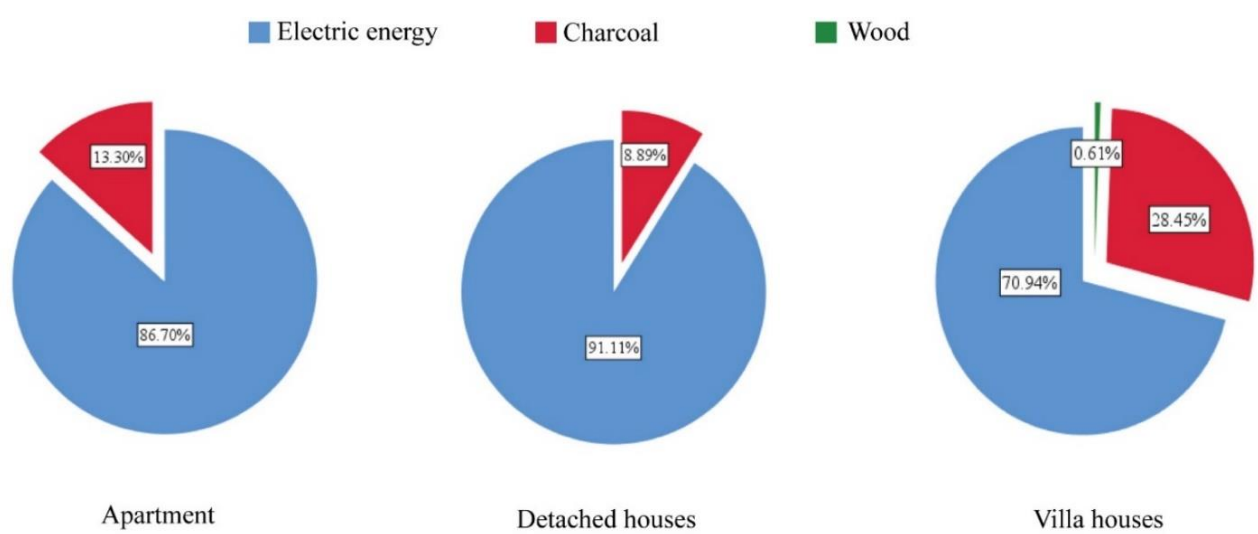

Figure 2: Source of energy in different housing typology

4.1.4. <u>Energy by end-uses</u>

The result show that most of selected households do not condition their rooms in cold or hot season. System for heating and cooling rooms were not encountered in all selected buildings. Even though the information was adopted on the data collection, it was discarded that all living in detached houses and apartments responded by not using air condition appliances; even though it was encountered the very few residents have but they do not use for the reason of electricity tariffs. Residents' lives in villa use air conditioning and water heating which accounts 0.96% and 17.73% of the total electric energy use, respectively.

The result show that most of the households' electric use is almost covered for preparing their meals. On average they at least prepare their meal twice a day. Largely electric energy is consumed for meal preparation. Electric stoves are frequent appliance in most dwellings. Besides these, in most of the dwellings, it has been encountered that they use charcoal and wood fuel for cooking for the reason of the frequent blackouts of electricity. It was found that they ignored using electric appliances for their meal preparation because of inconvenient electricity availability. And some of them also left in using electric appliances for the fear of the electric tariff increment. An '*injera mixad' is* another common appliance. In most households' these have been emphasized to prepare '*injera'* which is one of a common in meals of most of households in the country. On average, most residents prepare '*injera'* twice a week which and on average they spent 120min to prepare once. Households in apartment and villas use 41.86% and 46.33% of total electric usage for their meal preparation, respectively. While households in detached houses consume more than ½ of total electricity for meal preparation. Refrigerator is available in all households which performs throughout a year and it also has great deal energy consumed other than other appliances like television and computer.

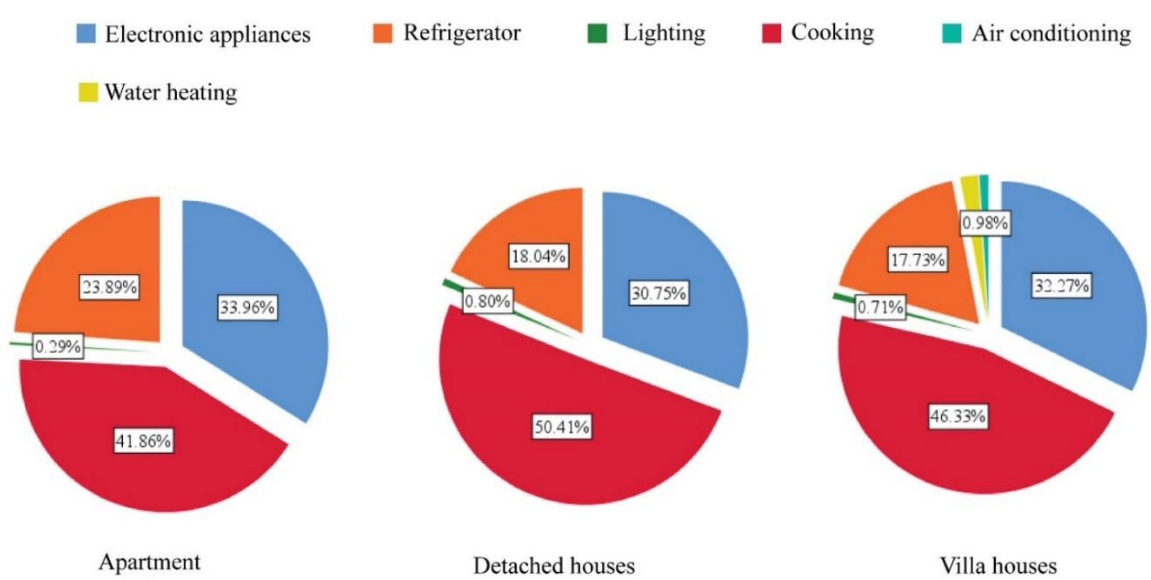

Figure 3: Electric energy use by an activities

4.1.5. Energy use penetration by appliances

In the survey the dwellers were insisted to provide information on the energy end-uses that applied to their households. They were provided with a list of energy end-uses from which they were then requested to select their household's energy end-uses. The list had been developed based on reviews of the literature and observed scenario. The results, which are presented in Figure 1, show that refrigeration 1093.52 kWh/yr., 23.66%, television viewing 475.48 kWh/yr., 10.29%, cooking stove 2048.71 kWh/yr., 44.32% and '*injera mixad'* 354.36 kWh/yr., 7.67%, and water heating 460.30 kWh/yr., 9.95% constitute some of the most important energy end-uses in the Adama urban residential building. The lower penetration of space lighting 28.48 kWh/yr., 0.62%, and, clothes washing 35.19 kWh/yr., 0.76%, computer 60.42 kWh/yr., 1.30% and air conditioning 66.25 kWh/yr., 1.43% is shares of appliances in the end-uses.

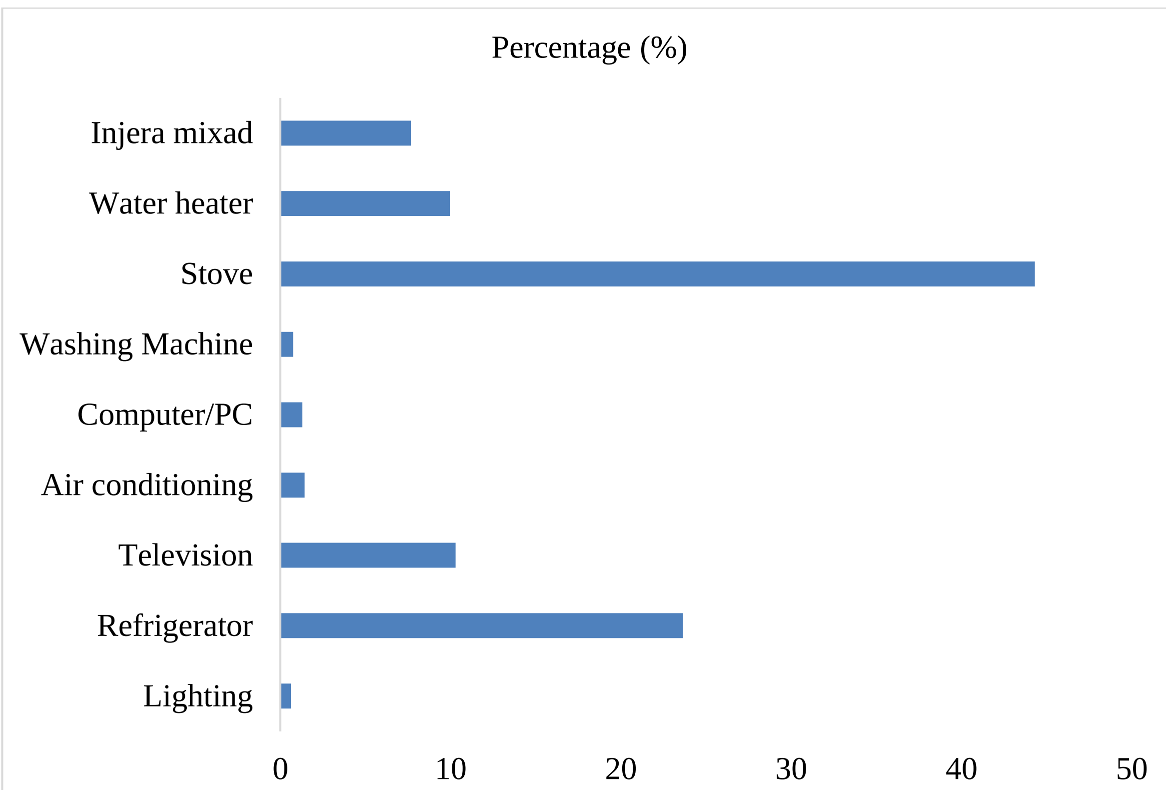

Figure 4: Appliance's penetration of energy by end-us

Apartment

From the selected housing unit, electric energy was categorized with the activities it is used up. The data collected was organized in considering activities in a building by lighting, refrigerator, electronic appliances, and cooking. Even though air conditioning was on the survey it was responded that no household in apartment uses energy to cool or to heat their units of rooms. From Table 6 the average consumption for lighting is 14.45kWh per year, for electronic appliances 1,683.83kWh per year, for cooking (*'injera mixad'* and stove) is 2,075.66kWh per year and for refrigerator is 1,184.76kWh per year. From the total electric consumption in

Villa

Electric energy identified was defined by lighting, refrigerator, electronic appliances, and cooking in villa households. And it was founded that households in villa are showcased to use electricity for air conditioning (fans) and water heating which not encountered in another typology. From Table 7 the average consumption for lighting is found 48.12 kWh per year, for electronic appliances 2,191.79 kWh per year, for cooking (*'injera mixad'* and stove) is 3,146.70 kWh per year, for refrigerator is 1,204.50 kWh per year, for water heating is 135.00 kWh per year, and air conditioning is 66.25 kWh per year. From the total electric consumption used up 46.33% is for cooking and 32.27%, 17.73%, 0.71% and 0.98%, is for electronic appliances, refrigerator, lighting, water heating and air conditioning, respectively which is illustrated in fig 3.

Detached houses

Electricity is used dominantly in these households for distinct sets of activities. The total electricity used up mainly for lighting, refrigerator, electronic appliances, and cooking. Like apartment households' air conditioning was not considered in units of rooms. From Table 8. the average electric energy use for lighting is 42.44 kWh per year, for electronic appliances is 1,631.09 kWh per year, for cooking (*'injera mixad'* and stove) is 2,673.93 kWh per year, for refrigerator is 956.70 kWh per year. From the total electric consumption in households, they used up 50.41% for cooking and 30.75%, 18.04%, 0.80% is for electronic appliances, refrigerator and lighting respectively which is illustrated in fig 3.

Table 6: Electric energy use among households

End-uses	Total annual electric energy consumption (kWh)		
	Detached houses	Apartment	Villa
Electric appliances	1,631.09	1,683.83	2,191.79
Cooking	2,673.93	2,075.66	3,146.70
Lighting	42.44	14.45	48.116
Refrigerator	956.70	1,184.76	1,204.50
Water heating	-	-	135.00
Air conditioning	-	-	66.25

4.2. Energy performance index (EPI)

An energy performance index is one of the commonly used indexes to asses and examine energy use in buildings. It is indices used to identify if the building is consuming high energy. It was calculated by dividing the energy consumed in the space over the usable floor area of those units of room or space, which can be expressed as kWh/m^2. It is energy efficiency indicator that is normalizes energy use in the buildings with used up floor size which mainly used by architects and building practitioners. It was calculated by adding individual energy consumptions over its usable floor size. It was summarized in the Table 7.

Table 7: Summary on energy use and EPI

			Detached	Apartment	Villa
Energy consumption	kWh	Average annual electric	4,347.45	3,773.93	5,386.61
		Average annual charcoal	1743.82	525.71	525.28
		Average annual wood	37.47	-	-
	Percentage (%)	Electric consumption %	71.37	87.78	91.11
		Charcoal %	28.62	12.22	8.88
		Wood %	0.01	-	-
Area	Area (m^2)	Occupied	47.96	39.77	112.38

EPI	kWh/m^2/yr.	EPI: total energy over occupied area	146.09	113.21	54.74

NB: energy equivalent for charcoal and wood is8.14kWh/kg and 4.90 kWh/kg respectively.

Apartment

From the Table 7 average floor size for selected apartment houses is found to be 39.77 m^{2,} and the calculated average EPI of the buildings is 113.21 kWh/m^2/yr. The result shows standard deviation is 34.94 kWh/m^2/yr. The correlation made EPI with the floor area by Pearson's r it reflects a weak relation (r=-0.382 <0.39). From the statistical analysis, it is seen that the Pearson r value is -0.382 which shows that EPI of the building will decrease by 38.2% with increased in 1 m^2 floor area. The relationship between floor size and total energy consumption was represented in fig 5. It represents that energy consumption increases as the floor size of the building increase.

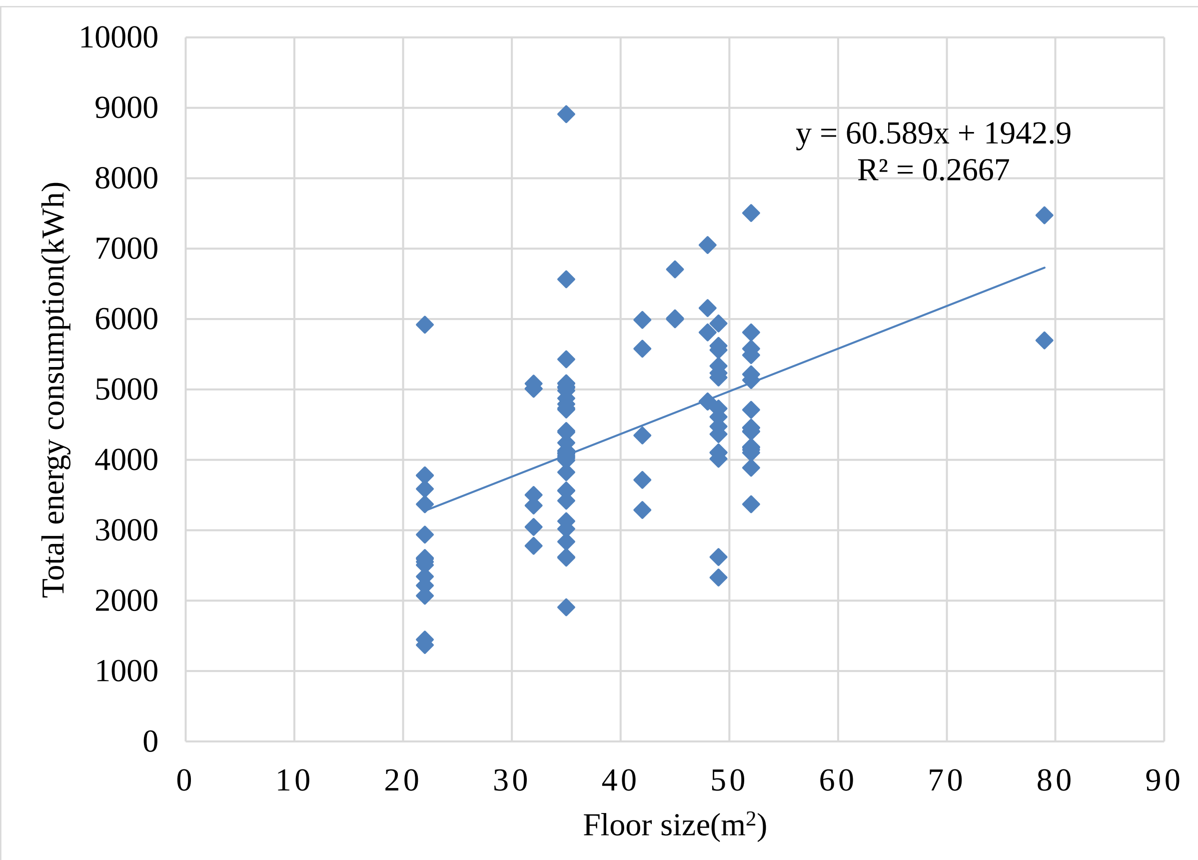

Figure 5: The relationship between total annual energy consumption with floor area in apartment houses

Detached houses

From Table 7 again selected detached houses have an average floor size 47.96 m^2 and have an average EPI of 146.09 kWh/m^2/yr. The result shows that the standard deviation is 75.208 kWh/m^2/yr. The EPI correlated with the floor area by Pearson's r were found (r=-0.705). From the statistical analysis, it is seen that the Pearson r value is -0.705 which shows that EPI of the building will decrease by 70.5% with increased floor area. The relationship between EPI and floor are is presented on fig 6. Which represents again energy consumed increases as building floor size increase.

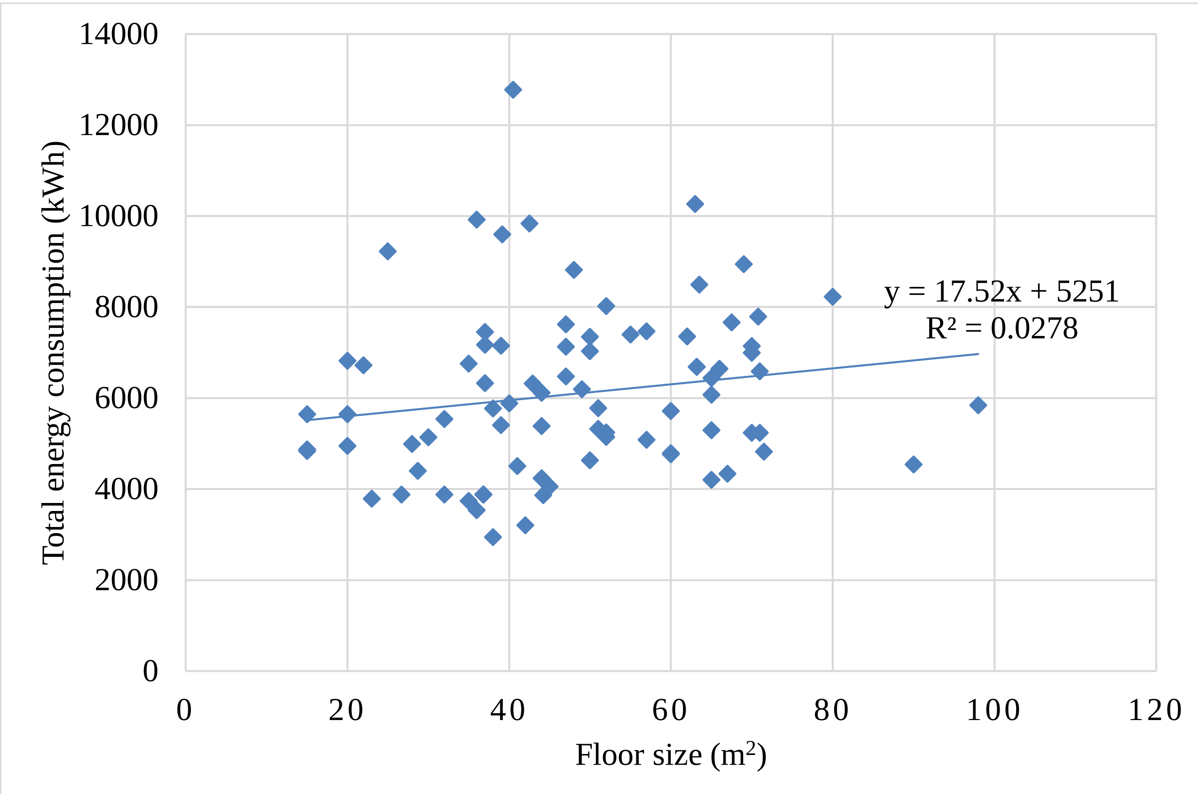

Figure 6: The relationship between total annual energy consumption with floor area in detached houses

Villa

From Table 7 it is represents that selected villa houses have an average floor size 112.38 m^2 and have an average EPI of 54.74 kWh/m^2/yr. The result shows that the standard deviation is 16.29 kWh/m^2/yr. The Epi is correlation with the floor area by Pearson's r it is strong relation (r = -0.636 > 0.59). Which is defined that Epi of the building will decrease by 63.6% with increased in $1m^2$ floor size. The relationship between EPI and floor are is presented on fig 7. In which floor size increases energy consumed increase. Other than the above typologies it was founded that floor size has lesser relationship with energy consumption of the dwellers which represents lower R^2 than the other.

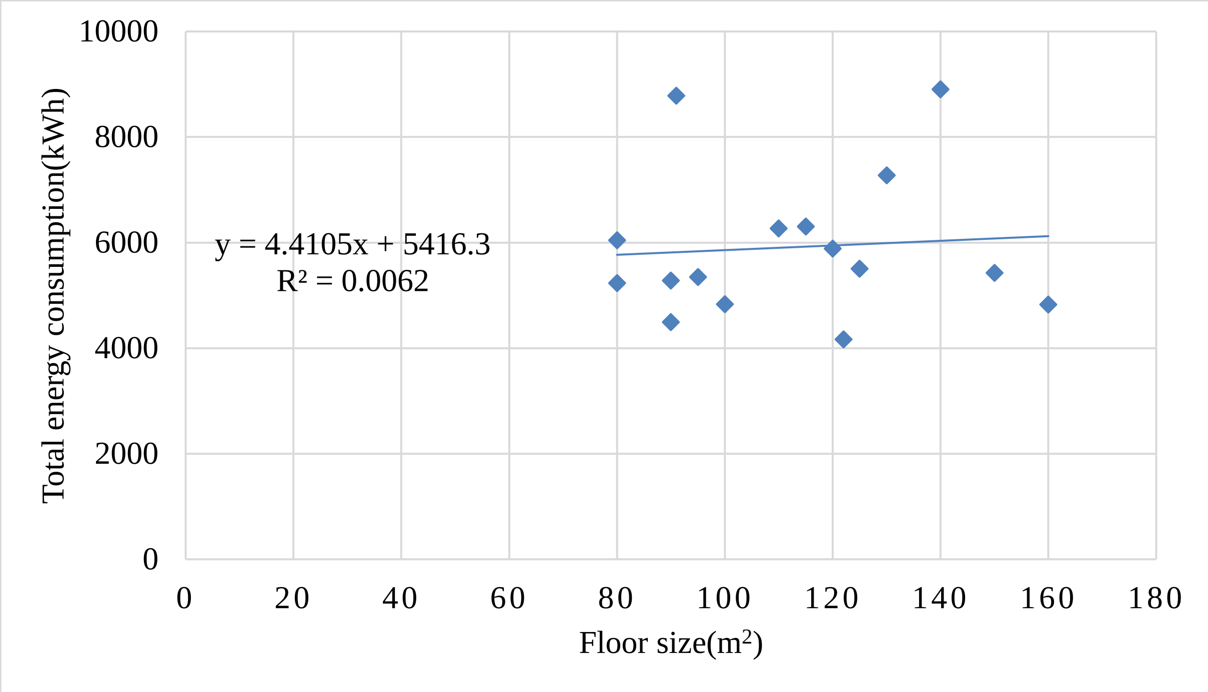

Figure 7: The relationship between total annual energy consumption with floor area in villa houses

4.3.1. <u>Variations of energy use in the buildings</u>

In fig 8 illustrates that the energy consumption for total energy used and electrical energy consumption within different typology houses in the city. In detached households that there is considerable variation or differences which means those households are higher opportunity in switching electric energy sources by other like charcoal or other alternative energies available. Households in villas and apartments use electric energy as the primary source which used in their daily activity. It also shows the total energy consumption in the buildings and electric use in a building. Reflecting dwellers energy consumption found in detached houses could be highly dependent in another fuel type which identifies energy intensity is higher in these houses than the other two (I.e., apartment, and villa).

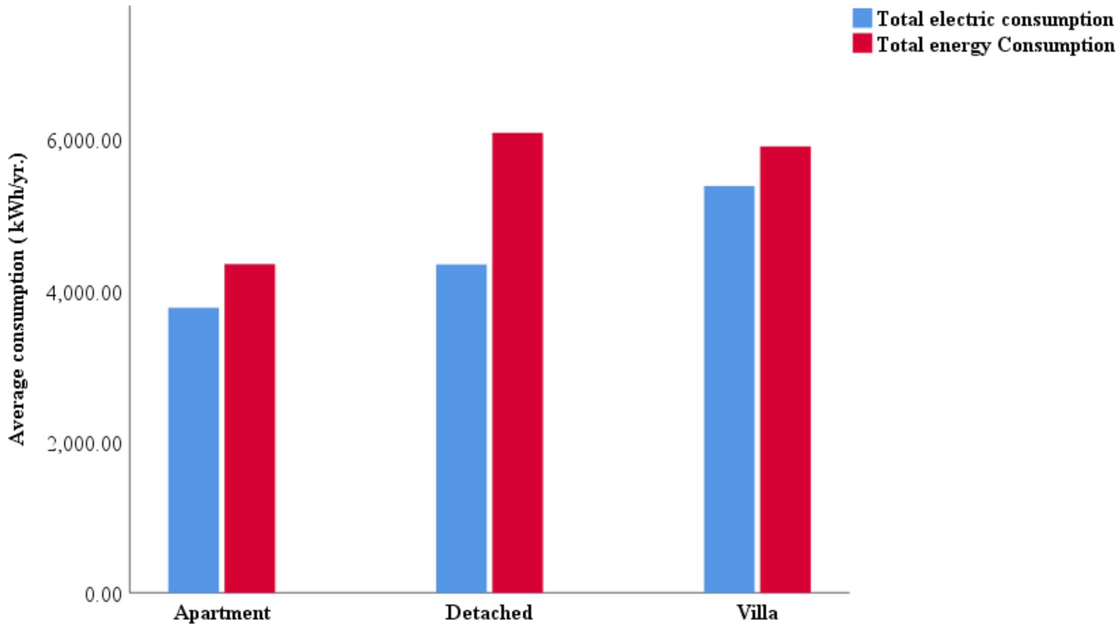

Figure 8: Energy consumption in different typology of houses

4.3. Modeling benchmark of buildings

4.3.1. Multiple linear regression method

On data analysis of energy consumption, independent variables were considered that determine the energy consumption in residents per the usable or gross floor size. The data gained was two important independent variables family size and floor area as determining factors of the EPI of the buildings. To develop the model first the variables were regressed to identify whether or not these two determinant factors were significant *($p<0.05$)*. The result shows that only the floor area is the strong determinant of the building energy index. From the statistical analysis the estimated equation for the test model has been developed by the variable (floor area) has given as:

$$y_1 = 291.705 - 3.036x$$

$$y_2 = 102.034 - 0.4216x$$

$$y_3 = 160.158 - 1.181x$$

Were y_1, y_2 and y_3 stands for model developed for detached houses, villa houses and apartment, respectively.

Detached house

In a Table 8 it is presented the coefficients table for detached housing typology showing how the dependent variable EPI if related with independent variable floor area. It is referred by t value or the p value under significant; the value of (t= -8.954, t≠0) or (0.000 shows $p<0.05$, of 95% confidence level) telling the variable is significant. The result show that the dependent variable has linear relationship with independent variable. The negative of t value represents inversely relationship of the variables.

Table 8: Test of model for detached houses

Model y_1	Unstandardized coefficient	Standard Error	Standard coefficient	t	Significant
(Constant)	291.705	17.296		16.866	0.000
x	-3.036	0.339	-0.705	-8.954	0.000

The difference between the EPI of predicted value based on the developed model and the actual EPI of the building has been represented in the table below. Fig 10. shows of energy could be saved in the building.

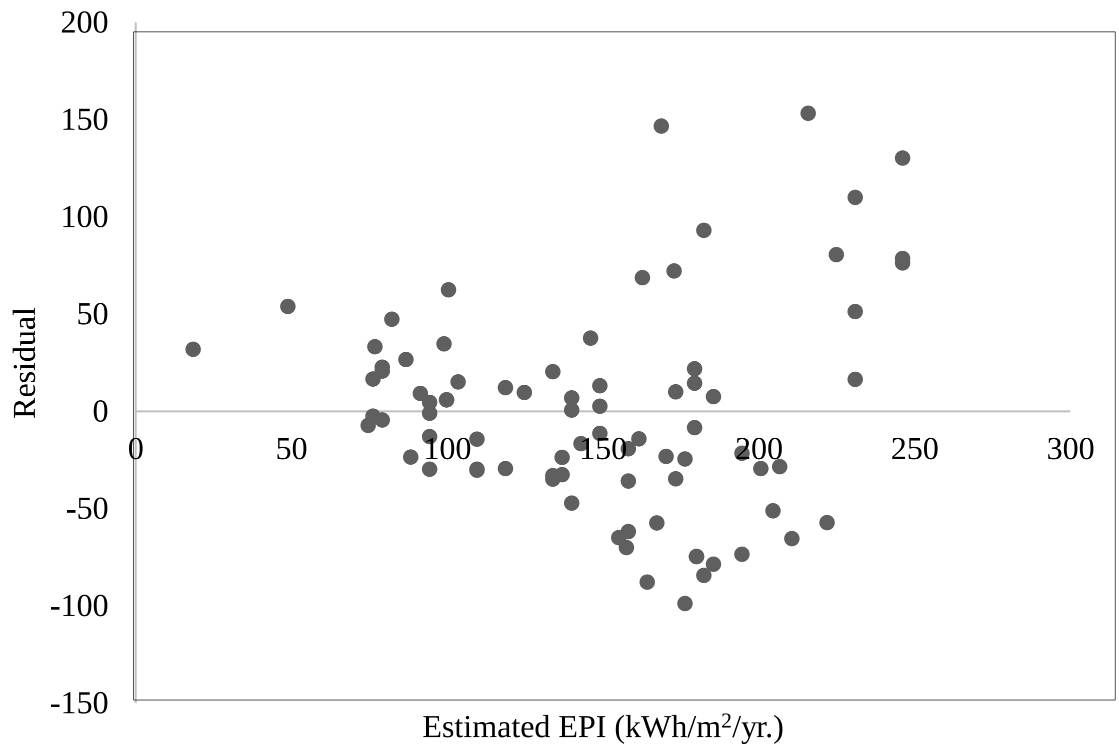

Figure 9: Estimated energy saving in detached houses.

From the test model this value is considered as residual positive value show that higher energy consumption than referenced building. The positive residual asserts that particular households are consuming more energy than they should consume. Which defines the extra energy aggravated in the building. While the negative show that the building is consuming lesser energy when compared it relative building stocks. In selected detached houses, we can have 1342.79kWh/m^2/yr. amount of energy saving. And from selected households out of 83 detached houses 32 of them saving chance meaning that energy can saved from 38.55% of detached houses in the city.

Table 9: Value of residual in detached houses

No.	Residual	No.	Residual	No.	Residual	No.	Residual
A1	-11.26	A22	-51.09	A42	-2.37	A63	47.44
A2	37.75	A23	-23.07	A43	153.32	A64	-34.64
A3	-24.44	A24	54.01	A44	-73.33	A65	20.83
A4	-19.07	A25	9.76	A45	68.89	A66	34.82
A5	-30.08	A26	-47.18	A46	51.34	A67	4.7
A6	-4.35	A27	110.13	A47	-28.27	A68	-87.77
A7	130.27	A28	93.17	A48	-8.27	A69	-32.52
A8	-74.57	A29	-0.92	A49	-12.91	A70	-7.16
A9	72.26	A30	2.75	A50	13.24	A71	-57.32
A10	12.33	A31	-14.19	A51	-57.17	A72	-16.45
A11	-14.1	A32	0.69	A52	7.01	A73	14.52
A12	62.58	A33	-74.57	A53	-98.7	A74	-61.69
A13	-29.36	A34	-74.57	A54	-84.24	A75	-29.7
A14	146.86	A35	6.02	A55	-78.46	A76	22.85
A15	33.31	A36	80.75	A56	-23.48	A77	-21.46
A16	9.38	A37	-34.83	A57	-29.68	A78	-65.36
A17	20.51	A38	22.01	A58	-23.57	A79	10.17
A18	7.7	A39	16.47	A59	15.14	A80	32.05
A19	76.48	A40	78.71	A60	26.77	A81	-64.94
A20	-70.03	A41	-35.72	A61	16.69	A82	-32.96
A21	6.02	A42	-2.37	A62	-29.4	A83	65.49

Villa

In a Table 10 it is presented the coefficients table for villa housing typology showing how the dependent variable EPI if related with independent variable floor area

Table 10: Test of model for villa houses

Model y_2	Unstandardized coefficient	Standard Error	Standard coefficient	t	Sig.
(Constant)	102.034	15.676		6.509	0.000
x	-0.421	0.136	-0.636	-3.084	0.008

It is referred by t value or the p value under significant; the value of ($t= -3.084, t\neq0$) or (0.008 shows $p<0.05$, of 95% confidence level) telling the variable is significant. The negative of t value represents inversely relationship of the variables. Fig 10 illustrates estimated energy saving in villa houses.

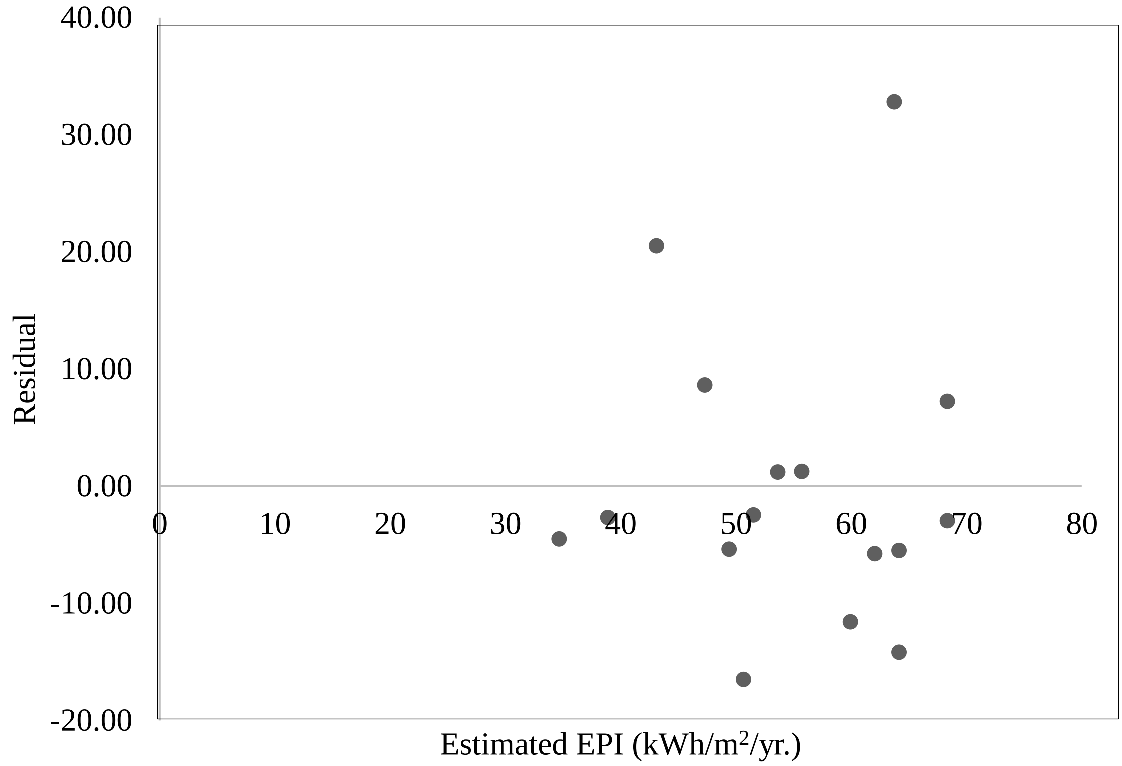

Figure 10: Estimated energy saving in the villa houses.

Table 11 represents the residuals of energy used in villa houses per their square meter. The residual is derived by subtracting the actual consumed energy from actual consumed energy from estimated energy consumption over floor size of the building (EPI-EPI_o). The positive residual asserts particular households are consuming more energy than referenced stock. Which defines the extra energy extra in the building. While the negative show that the building is consuming lesser energy when compared it relative building stocks. In selected villa houses we can have 71.66kWh/m^2/yr. amount of energy saving. And from selected households out 6 detached houses 16 of them saving chance meaning that energy can save from 37.5% of villa houses in the city.

Table 11: Value of residual villa houses

No.	Residual	No.	Residual
B1	20.51	B9	32.82
B2	-14.19	B10	-5.38
B3	-4.5	B11	-5.75
B4	-16.51	B12	1.26
B5	-2.69	B13	-11.57
B6	1.2	B14	-5.48
B7	-2.47	B15	8.64
B8	-2.94	B16	7.23

Apartment

In a Table 12 it is presented the coefficients table for apartment housing typology showing how the dependent variable EPI if related with independent variable floor area. It shows whether the estimate model is validated or not by testing the significance. It is referred by t value or the p value under significant; the value of ($t= -4.200$, $t\neq0$) or (0.000 shows $p<0.05$, of 95% confidence level) telling the variable is significant. The result show that the dependent variable has linear relationship with independent variable. The negative of t value represents inversely relationship of the variables.

Table 12: Test of model for apartment houses

Model y_3	Unstandardized coefficient	Standard Error	Standard coefficient	t	Sig.

(Constant)	160.158	11.617		13.786	0.000
x	-1.181	0.281	-0.382	-4.200	0.000

The difference between the EPI of predicted value based on the developed model and the actual EPI of the building has been represented in the Table 13. From the LR model this value considered as residual positive value show that higher energy consumption than referenced building. The following graphs illustrate the amounts of energy could be save in the building.

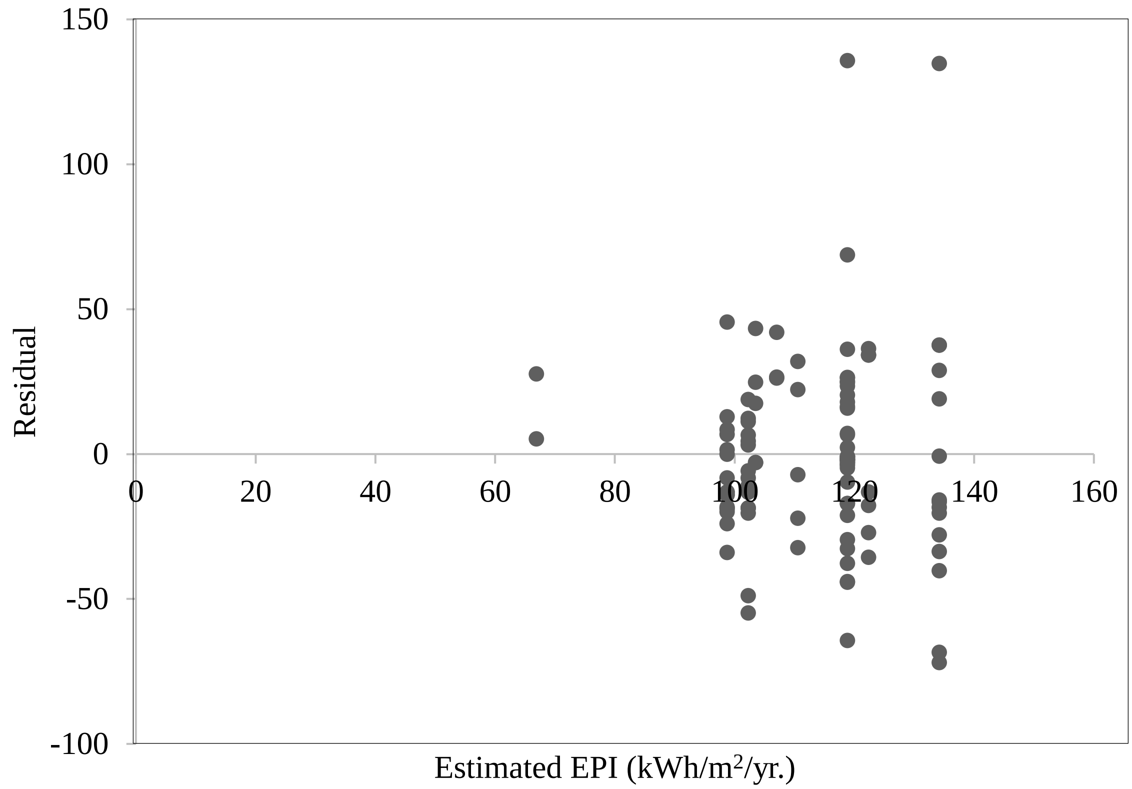

Figure 11: Estimated energy saving in apartment

In table 13 it is presenting the residuals of energy used in apartment houses per their square meter. The residual is derived by subtracting the actual consumed energy from estimated energy consumption over floor size of the building (EPI-EPI$_o$). The positive residual asserts particular households are consuming more energy than it should consume. Which defines the extra energy aggravated in the building. While the negative show that the building is consuming lesser energy when compared it relative building stocks. In selected apartment houses we can have 1215.45kWh/m^2/yr. amount of energy saving. And from selected households out 43 detached houses 105 of them saving chance meaning that energy can saved from 40.95% of apartment housing unit in the city.

Table 13: Value of residual in the apartment houses.

No.	Residual	No.	Residual	No.	Residual	No.	Residual	No.	Residual
C1	-19.09	C24	-68.41	C47	-14.1	C70	-27.84	C93	-13.07
C2	-64.36	C25	12.32	C48	20.42	C71	-33.64	C94	-20.4
C3	-43.96	C26	-2.92	C49	26.24	C72	-9.61	C95	-35.59
C4	-13.07	C27	-2.04	C50	36.18	C73	-0.06	C96	-18.55
C5	-14.06	C28	2.31	C51	-1.76	C74	-0.86	C97	-5.84
C6	-27.15	C29	18	C52	-24.04	C75	1.47	C98	-0.73
C7	-8.24	C30	45.6	C53	-20.37	C76	-1.09	C99	17.51
C8	6.54	C31	22.25	C54	15.87	C77	11.2	C100	37.58
C9	-8.19	C32	-32.62	C55	-1.82	C78	-2.92	C101	-29.47
C8	12.92	C33	23.5	C56	-3.92	C79	-2.04	C102	-18.59
C11	-17.09	C34	134.77	C57	31.97	C80	-18.31	C103	-40.2
C12	16.41	C35	135.72	C58	-3.43	C81	-13.05	C104	-16.45
C13	18.87	C36	-71.95	C59	-7.1	C82	-54.83	C105	24.74
C14	-37.74	C36	-44.23	C60	-15.83	C83	6.75		
C15	34.18	C36	26.46	C61	-18.36	C84	28.92		
C16	27.71	C39	26.39	C62	-22.17	C85	4.44		
C17	68.71	C40	7.13	C63	8.49	C86	43.4		
C18	-11.02	C41	-32.3	C64	34.18	C87	-17.01		
C19	-2.83	C42	-33.98	C65	5.25	C88	37.58		
C20	25.09	C43	26.52	C66	24.65	C89	19		
C21	-13.22	C44	6.68	C67	-18.56	C90	-19.87		
C22	36.42	C45	41.98	C68	-0.95	C91	-17.74		
C23	-21.15	C46	-4.81	C69	3.13	C92	-48.82		

CHAPTER FIVE

DISCUSSION

5.1. Energy use pattern

Energy is one of the crucial factors for once country's development. Many studies revealed its impacts on socio-economic and environmental issues. Thus, different policies and regulations were needed to reduce these effects. Environmental policymaking was restricted in developing countries is because of absence in systematic, integrated data on the current state of environmental pollution and degradation. In the study Iwaro et al. (2010) most of environmental policies were being established, but the lack in integrating the individual parts with a complex system. Indeed, the capability of electricity generation in emerging countries have toward economic growth, management and monitoring the end uses has irreversible benefits for the counties. Demand side energy assessment is important to ease socio-economic and environmental problem to the root.

Urgency in energy efficiency had lied on industrial countries however, the prevalence is high in developing countries. This most obvious in the building sector. Reducing the polluting energy sources will be pretty easier than the formers. Energy efficiency has a greater impact on advocating sustainability in the country, but also solving a different socio-economic problem in a society. Especially in developing countries, the heterogeneity in household income has made it the driving force in some activities, as some of them are under energy poverty. Energy policy also put its own influence on choices, innovation, cost effectiveness, subsides and access to energy sources. It is mostly recorded in most Sub-Saharan countries like Ethiopia which relied on imported oils, which adds tariffs on electric energy to secure the cost for imported oils.

Most studies emphasize the obvious economic variable as a determinant of energy use in the household level. It highly related both the choice of fuel type and the amount consumed to income. In developing countries, the consumption of biomass fuel is still high in middle- and high-income groups, but the share of modern fuels is also huge in these categories (Reddy, A. K. et al., 2000). This is clearly observed as considerably lower energy consumption was observed in detached households' than in villa households. There is a suspect that socio-economic characteristics and behavior play a bigger role in explaining the variation in heating or cooling consumption. The availability and extent of use of different type of appliances and the end use of energy sources influence the efficiency level of the energy used, which indirectly affects the type and amount of household energy required (Konemund, 2002).

The most common energy sources in households of Adama city are electricity and charcoal. In the study it was that revealed the energy consumption by classifying different typologies as detached houses, villas houses, and apartments. It was observed the annual energy consumption for electricity was 4,347.45 kWh in detached houses, 3,773.93 kWh in apartment, and 5,386.61 kWh in villa houses. In average the residential buildings in the city consume 4,502.66 kWh amount for electricity. When compared to households that consume energy other than electricity like charcoal and wood have higher energy consumption than those that use electricity the most. Charcoal annual consumption in a building stood an average 931.60 kWh (1743.82 kWh in detached, 525.71 kWh or 71.09 kg/yr. in apartment and 525.28 kWh or 64.53kg/yr. in villa houses). From those detached houses are one of the most common type and oldest residential buildings in the city. The majority of dwelling lives here are also old-aged residents which reflects that the low-understanding on-energy consumption which depends on unreliable clean energy sources. It was observed firewood was encountered only in this type of houses with an average consumption of 37.47 kWh or 7.64 kg/yr. Even though electricity is fairly distributed, the residents use charcoal about 28.45% and wood fuel about 0.61% of their total consumption, which means around 2/3rd of energy is biomass fuel which uses it for cooking. The rest 86.70% is for electric energy. On the study conducted by Kalua (2020) actual total appliances energy consumption of Malawian urban residential buildings stood at about 3,684 kWh and 5,602 kWh worth of charcoal energy annually. The study shows that 50-60% of annual consumption was for charcoal. This reflects beside the barriers towards use of clean energy sources most residents use modern fuels (electricity) as major energy sources (Kalua, 2020).

In comparison, households in apartments and villas' houses similarity on uses of different energy sources. They use charcoal mostly during the blackout, which accounts for about 13.30% in the apartment and 8.89% in villa houses. And also, it was identified these residents highly depend on electric energy other than another source of energy. Households in these buildings use less energy for cooking than households in detached houses, which is 41.86% in the apartment and 46.33% in villa houses.

Cooking takes the largest portion of energy around 50.41% and the rest 30.75%, 18.04%, and 0.8% of energy is for electric appliances, refrigerators, and lighting appliances, respectively. In the study Kalua (2020) about 40% of the energy consumption in Malawian urban residential were by cooking end uses. The study also identifies on energy penetration by appliances. It was observed that refrigeration, television view, cooking stove and '*injera mixad'* and water heating constitute some of the most important energy end-uses in the Adama urban residential building. The lower penetration where space lighting and clothes washing, computer and air conditioning is shares of appliances in the end-uses. Even though water heating is end use relatively higher energy use, households in villa houses exploited it only. Air conditioning also performed exceptionally in these dwellers. This is mainly be linked to the country's struggling economy, which would mean that these energy end-uses are unaffordable for other households. A similar trend was observed in Uganda where it was attributed to two reasons, namely the unavailability and lack of need for these end-uses and the cost of purchasing and operating the equipment that supports them (Kazoora et al., 2015). It has been found that the major source of energy consumed in the households of Adama city is electricity. More 3/4th of energy consumed is electric energy. It used vastly for cooking. With the frequent blackouts and inconsistencies on the electric power, most households were forced to use another source of energy for the same activities that could be done by the appliances. Even some of them proved the use of charcoal as basics for cooking. Some of them ignored electric appliances for frequent increment of electric tariff.

5.2. Energy performance index (EPI)

Nowadays, sustainability is becoming a crucial factor in every sector. Environmental degradation has been taking larger destruction in human lives and resource. Many organizations were established to minimized these destructions. It was occurring for the rise in temperature in the world caused by greenhouse gasses. Buildings took about 42% for greenhouse gases emission. Even though developed nation takes larger part of the emission, whole action is needed, especially in developing countries, which can be done with lesser effort. Energy use is the determining factor of CO_2 emission. One country's work on energy reduction simultaneously reduces carbon emissions. The building took a larger portion for the increment of heat in urban centers of the city. Different scholars have written that to reduce these effects, they develop metabolism concept in a building. Which assesses energy consumed and supplied in the urban. “The largest potential for improving energy performance in the short and medium-term is in the existing stock of buildings” (Balaras et al., 2007). To identify the effects, many countries developed the building energy use intensity of different typologies of the buildings. One of the major ways to identify this European Union has developed energy performance index (EPI) of the buildings, which is defined as the energy used in building throughout the year divided by its usable floor area. It is the most relevant way to identify the building are consuming energy above or below compared to the standard of the buildings. It is also referred to us as the building energy index (BEI).

Most building-specific energy modeling is considered at the design stage of the building. Other than embodied energy, the energy consumed after occupancy lasts until the building’s demolition. So, it is important to consider energy monitoring and management on the demand side. Building energy consumption modeling should be developed based on real energy consumption in the constructed building. On the measure to manage framework, which stresses identifying and quantifying of interest to track the positive changes. There is a saying that “if you cannot measure it, you cannot improve it” which is coined by Lord (Paul, 2013). Besides the energy monitoring and management at the design stage, knowing occupancy energy consumption led to the rightest energy demand model. In most of the developed countries, energy use is audited every year which helps them to control the energy use in users. To make these European countries developed evaluation on building energy performance, which aims in controlling energy performance in a building. It was made by adapting energy performance indicator for the buildings. One of the most common indicators used is the energy performance index (EPI) which is relevant indicator for a building to identify if it was energy efficient or not. On the study conducted in Bexar County, Texas it was reported majority of detached houses have an energy index of 78.8 to 157.7 kWh/ m^2 / yr (Gomez et al., 2014). This reflects that it has closer index in detached houses in the city which is between 71.062kWh/m^2/yr. and

221.118kWh/m^2/yr. In addition, the study conducted in three Malaysian residential colleges or hostel multi-residential buildings providing accommodation to university students shows that having an average energy performance of 24.23 kWh/m^2/ yr., 61.80 kWh/m^2/year, and 34.52 kWh/m^2/year.

The EPI was calculated and categorized with the building of different housing typologies. It was calculated and found most detached houses of selected have and EPI in between of 71.062kWh/m^2/yr. and 221.118kWh/m^2/yr. The apartment of selected houses has 78.57 kWh/m^2/yr. and 148.15 kWh/m^2/yr. Villa houses have in between of 38.45kWh/m^2/yr. and 71.03kWh/m^2/yr. In the study conducted on energy use trends in Ugandan residential buildings it reported that average energy consumption with respect to it floor size was found to be 21.1 kWh/m^2 which is less than of the average energy consumption normalized with floor area in villa houses of the city. The study showed that the average energy consumption normalized with floor area is less in 11.39% less than total energy use normalized with floor size encountered in Ugandans residential building.

Some study shows that energy efficiency index (EEI) of office building is higher than residential building. Based on this assumption, the comparison was considered with three standards to compare with, the EPI of office buildings in India, Standard for Malaysian office building and with standard developed by Bureau of Energy Efficiency for office building in hot and dry climate condition. It represents that the average energy usage in detached in its floor size has closer value to the office building in India and higher than both BEE standard and of Malaysian standard for office building. The EPI in an apartment is more of less has closer to energy use in office building in Malaysian office building and above BEE standard and of Malaysian standard for office building. Energy use in Villa houses were considered to be mor efficient than the rest house typologies.

From this, it can be said that these buildings were consuming higher energy exclusive of space heating and air conditioning asserting energy-intensive buildings in the city. Heating takes nearly half of the total energy consumed in the buildings. Climatic condition is one of the most determinant factors towards energy consumption in a building. The energy index shows that there are greater efforts are needed to make balanced the energy need to cool and heat the spaces in the building. So, to decrease energy intensity in a building the responsible sector has to decide on energy efficiency measurement for example optimizing the building by adding energy retrofitting like renovation on the wall to absorb extra heat inside rooms created by the heating appliances or biomass fuel.

5.3. Building energy benchmarking

The first step toward increased energy efficiency involves establishing a directly measured reference point (baseline or benchmark) to track future energy consumption, allowing utility companies and consumers to understand relative consumption patterns and identify specific targets for energy savings in existing structures/households (Vučićević et al., 2013) . The approach proposed in this study is to pair energy consumption with same building characteristics. To set up a benchmark for a comparison with other "similar" buildings in size, vintage, and the form of energy helps to identify consumption trends and areas of opportunity for significant energy savings. Energy benchmarking are tools to help homeowners and utilities understand how energy is used and determine energy-saving measures. Baselining of residential buildings involves comparing the current consumption of the house to previous years' consumption or to compare the energy consumption of one house to other, similar houses (Federspiel et al., 2002).

There are different methods to use to benchmark buildings for their energy use. In this study, empirical or hypothetical benchmarking was used which was best practiced when stock buildings were considered. Energy performance index of the building stock was calculated from the actual energy consumed in selected building. Then the benchmark for the buildings were modeled using the regression in statistical software. It was applied individually different residential building typologies found in the city. From independent variables considered (floor area) has a strong relationship in total energy consumed in a building. In selected households, it was found that 2,629.9 kWh can be saved in a single squared metered size of the building annually. Additionally, 39% of residential buildings in the city have an average energy saving by an amount of 876.6 kWh/ m^2/yr. So, the amount energy saving capacity in residential buildings in the city is about 876.6kWh in a single-mater squared unit's size of the building in a year in 39% households' out of total selected households' lives. This means in about 23,292 household units of the city have an energy-saving opportunity based on the housing unit reported. With intervention on the energy use in households of the city about 20,418,082.77kWh or 20.42GWh amount of energy reduce total energy consumption 451.75 GW (refer annex 5) in a single mater squared unit's size of the building in a year. Energy investments in adopting energy efficiency cost less than for the supply. The importance of benchmarking is it provides a map toward energy-saving informing in energy improvement and energy retrofit programs and business. By adopting different energy efficiency measures the energy sector can save 4.5% of the total energy supplied for the residential sector which has a huge saving in cost and resource eased for energy production. Household energy efficiency has improved by 28% at EU level since 2000 thanks to more efficient heating systems and buildings (Odyssee M., 2018). The city capacity on energy saving can be apprehended by adapting energy policies on measurement and monitoring energy use in a building. It is also reported that about 2-3kg of carbon emission can be reduced by adapting technologies like solar panels on a building in Ethiopia (Neil Burnside et al., 2021). This defines that assessment on energy use in a building should be known at the design stage of the building. In practice this is implicated or come to real when the understanding on the actual energy use of existing buildings is important as a benchmark to predict the potential towards the improvements. Therefore, architects should insist such a metrics on their design specification to refine energy use and reform users in a building.

CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Urbanization matters in influencing energy, particularly in developing countries. It was reported that 42% of the total CO_2 emission were from the building. Migration from the rural to urban areas has led influence increasing housing development. These will make that a great housing development particularly for the urbanized areas which influences the increments in energy consumption. Particularly the population growth rate in Africa is increasing significantly making in energy demand increase from 423 TWh to nearly 1,600 TWh in sub-Saharan Africa for example. Total electricity demand is projected to increase from 4192 GWh in 2012 to 27,321 GWh in 2030 in the universal electrification scenario in Ethiopia. In particular, demand by urban households is expected to grow from 1170 GWh in 2012 to 5839 GWh in 2030, with an average annual growth rate of 9.3%. With this the resident's average consumption of electricity on which increases energy intensity in the city. Most of the residents used to rely on biomass fuel like charcoal. From the increased energy scenario there is great potential towards energy-saving towards inefficient energy use.

Electricity and charcoal are the most dominantly used energy sources in the residents of the city. Even though residents consume electric energy largely, which is about 50%; in most detached housing and apartment it is visible that a comparable amount of energy form used is charcoal. Heating and cooling are the most dominant parts where energy is consumed. Out of total consumption, about 3/4th of total energy was used up to cook. Nearly 2/3rd of residential building has been reported to be higher energy consumers compared to the stock building of similar characteristics. Even though several occupants affect energy used it was showcased that resident were consuming higher energy in small sizes of building compared to larger sizes. This mostly occurs in the detached housing typology of a residential building. A higher cut of energy is expected in detached houses as they rely on about 33% of biomass fuel, which can be switched to more efficient sources like a solar panel.

The energy performance in the building was found to be poorer in detached houses and apartments, while it is better in villa houses. It illustrated that the average EPI in apartment and detached typology of housing were considerably consuming higher energy use which could be greater or equal to office building under comparable climate zone.

The EPI founded an average of 146.09 kWh/ m^2/yr. in detached houses, 54.74 kWh/ m^2/yr. in the villa and 113.21 kWh/m^2/yr. which is show that higher energy consumption in detached houses and apartment building defining that most residential buildings of this typology have low energy performance. This informs the dwellers use energy more than house needs to use to operates; these buildings are energy inefficient. This resembles a low environmental performance in the buildings like thermal comfort and indoor air quality. These was elaborated average of detached residential building and apartment operates above office buildings asserted by BEE, which reflects the extra energy use in the buildings. By making different techniques the city can save a lots resource and cost exploitation. About 4.5% can reduced from a total energy delivered which is equal to 20,418,082.77 kWh annually saving cost of US37,569,272.29.

Energy efficiency was given lower attention in most developing countries, which caused the society to experience inefficient utilization of energies in the countries. Adopting energy efficiency indicator is relevant toward identify energy use in a building. Energy performance index is one most relevant indicator to be adopted for residential and commercial building, reflecting ways toward the potential of energy saving.

6.2. Recommendation

- The energy sector in the city should implement planning, monitoring, and managing energy use in the building with logical evaluation on the demand side.
- Initializing on the awareness creation of the household occupants on the energy efficiency and energy conservation of energy used in their house and creating strategies in the knowledge's implementation created.

- Establishing and investing in research work on energy and resource utilization in the city to adapt technology advancement on the existing building towards energy saving like energy retrofitting and energy improvement programs.
- Developing policies and regulations towards achieving energy saving in the building in both the design stage and after construction.
- Adopting energy efficiency regulation to adapt side to side with the architectural design to emphasize sustainable development goal of the country.
- Enhancing technologies like solar panels in a building; compelling building designer to include environmental specification document at the design stage.

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APPENDIX-I

Adama Science and Technology University (School of Civil Engineering and Architecture) - Department of Architecture

Research questionnaire on energy performance in a residential building

How are you? My name is ________________________________, this study explores on the use of energy in residential buildings in Adama. Exploration is the gathering of primary data on the use of energy in households. Talk to someone who knows your energy consumption well with your family.

Collection A: of introductory questions for a field survey

1. The address of the residence? Kebele ________________________________ Block ____________________________________

2. When the study was conducted _____________________________

Collection A: About households

A_1 ... Let's start with some questions about your family. Have you or your family lived in this residence for more than a year?

1. Yes 2. No

A_2. Do you live in a private home? 1. Yes 2. No

A_3. Only your family lives in this home. 1. Yes 2. No

A_4. How many families, including your own family, live in your home? ____

Set B: Building

B_1 How many square meters is your home? I.e., Include kitchen, living room, toilet, bathroom, hallway, bedroom, etc. and excludes technical areas such as basement, attic, pantry, garage, boiler room, stairs, porch, balcony, etc. _______________________________

B_2. How many rooms does your home have? ___________

B_3. What kind of building is it in?

A. Individual detached or semidetached houses?
B. Apartment
C. Duplex (Villa)

Collection C: Electricity Consumption

C_1. How many kilowatts (kWh) of electricity have you consumed each month in the last 12 months? C_2. What is the average monthly price for electricity in the last 12 months? It was? ___________________________________

Collection D: Use of light bulbs

D_1 What kind of bulbs do you have in your home?

1. "Traditional" bulbs.
2. Compressed fluorescent lights (CFL).
3. Fluorescent lights.
4. Halogen lights.
5. Other (specify).

D-1	Light fixture	The number of lights	Your light fixtures that work for more than an hour
1	"Traditional" bulbs.		
2	Compressed fluorescent lights (CFL).		
3	Halogen's bulb		
4	fluorescent lights.		

Collection of E: Electric appliances

E_1 What appliances do you have in your home?

1 refrigerator with refrigerator

E-1-1	Number of refrigerators height / 120/150/180	Height / 120/150/180
1		
2		

2 washing machines and drying machines

3 TV.

4 personal computers.

5 Air conditioners. 6. Cooking.

E-1-2.	No. washing machines	Time od use
1		
2		

E-1-3.	Size	Year	How often do you turn it on?
CRT			
LCD			

E-1-5	**No.**	**How often do you turn it on?**

E-1-6.	No	How often do you turn it on per week or per day or hour in a day	Remark
Electric stove (stove)			
Electric oven - ‘injera’ bakery			

E-1--4	**No.**	**How often do you turn it on?**
laptop		
Desktop computer		

Set F: Space heating

F_1 Have you heated your home in the last 12 months? 1. Yes. 2. No.

How many square meters (m^2) of living space? ____

F-2. What energy source did you use for local heating? They used… 1 Electric____________2. Natural Gas ፡ Liter / kg ______________

3. Liquid fuel gas. ፡ Liter /kg _______________________________________4. Wood fuel____

F_12. Do you use charcoal to heat water or cook food? 1. Yes. 2. No. G_13. How much charcoal have you used in the last 12 months?

You can identify any suitable measurement? __________________________________

Annex 1: Energy use in detached houses

ID.	Kebele	Family size	No. Rooms	Lighting (kWh/yr.)	Refrigerator (kWh/yr.)	Electric appliances (kWh/yr.)	Cooking (kWh/yr.)	Total electric consumption (kWh/yr.)	Total Charcoal (kWh/yr.)	Wood fuels (kWh/yr.)	Total Energy Consumption (kWh/yr.)	UFA (m^2)	EPI (kWh/yr./m^2)	EPI_o (kWh/yr./m^2)
A1	0.4	8	4	284.7	876	1368.7	1890.7	3544.1	2930.4	0	6474.5	47	137.76	149.01
A2	0.4	5	4	21.9	876	1630.3	3259.5	4911.7	3907.2	0	8818.9	48	183.73	145.98
A3	0.4	3	3	10.9	1314	1850.5	3259.5	5120.9	651.2	0	5772.1	38	151.90	176.34
A4	0.4	3	4	21.9	876	1795.8	2347	4164.7	1953.6	0	6118.3	44	139.05	158.12
A5	0.4	8	5	20.9	876	1934.5	2161	4116.4	651.2	750	4767.6	60	79.46	109.55
A6	0.4	6	4	43.8	876	2252	2617.2	4913	325.6	180	5238.6	70	74.84	79.19
A7	0.4	4	2	20.9	876	1314	3986	5320.9	325.6	62.5	5646.5	15	376.43	246.17
A8	0.4	3	4	20.9	0	438	978.2	1437.1	2442	0	3879.1	36.8	105.41	179.98
A9	0.4	6	4	10.9	1314	3762.3	2161	5934.2	3663	0	9597.2	39.16	245.08	172.82
A10	Bole	3	4	10.9	876	1387	2161	3558.9	3907.2	187.5	7466.1	57	130.98	118.65
A11	Bole	8	5	10.9	1314	1671.7	732	2414.6	3907.2	0	6321.8	42.9	147.36	161.46
A12	Bole	9	6	65.7	876	1910.7	3409.5	5385.9	4884	90	10269.9	63	163.01	100.44

A13	Bole	2	3	43.8	876	1144.3	1507.7	2695.8	2442	0	5137.8	30	171.26	200.63
A14	Bole	5	6	20.9	1314	2361.5	3073.5	5455.9	7326	0	12781.9	40.5	315.60	168.75
A15	Bole	5	6	20.9	876	2088.1	3241.5	5350.5	2442	0	7792.5	70.8	110.06	76.76
A16	Bole	4	4	43.8	2628	3277.7	883.5	4205	2442	0	6647	66	100.71	91.33
A17	Bole	4	4	65.7	876	1388.05	2665	4118.75	3907.2	125	8025.95	52	154.35	133.83
A18	0.4	4	3	10.9	876	1233.7	3073.5	4318.1	2442	37.5	6760.1	35	193.15	185.45
A19	0.4	2	2	10.9	876	1233.7	2374	3618.6	1221	0	4839.6	15	322.64	246.17
A20	0.4	3	4	20.9	876	1208.5	195.3	1424.7	2442	0	3866.7	44.2	87.48	157.51
A21	0.4	6	2	20.9	876	1321.3	2905.5	4247.7	2442	0	6689.7	63.2	105.85	99.83
A22	0.4	4	3	20.9	876	1233.7	708.25	1962.85	2442	0	4404.85	28.7	153.48	204.57
A23	0.4	4	3	20.9	1314	1761.5	3902	5684.4	203.5	0	5887.9	40	147.20	170.27
A24	Bole	2	4	182.5	1314	1798	3902	5882.5	2344.32	0	8226.82	80	102.84	48.83
A25	Bole	6	4	182.5	876	2251.2	3986	6419.7	976.8	0	7396.5	55	134.48	124.73
A26	0.4	4	4	43.8	876	1642.5	2136	3822.3	814	125	4636.3	50	92.73	139.91
A27	0.4	5	3	65.7	876	1241	3073.5	4380.2	2442	0	6822.2	20	341.11	230.99
A28	0.4	3	5	43.8	876	1323.5	7536	8903.3	1017.5	0	9920.8	36	275.58	182.41
A29	0.4	5	3	43.8	876	1496.5	2905.5	4445.8	1628	0	6073.8	65	93.44	94.37
A30	0.4	4	3	20.9	876	1259	3818	5097.9	2035	0	7132.9	47	151.76	149.01
A31	0.4	5	2	43.8	1314	1576.8	3286.5	4907.1	814	0	5721.1	60	95.35	109.55
A32	0.4	4	5	73	876	1484.7	4658	6215.7	814	0	7029.7	50	140.59	139.91
A33	0.4	3	4	20.9	0	438	978.2	1437.1	2442	0	3879.1	36.8	105.41	179.98
A34	0.4	3	4	20.9	0	438	978.2	1437.1	2442	0	3879.1	36.8	105.41	179.98
A35	0.4	6	2	20.9	876	1321.3	2905.5	4247.7	2442	0	6689.7	63.2	105.85	99.83

A36	0.4	5	3	65.7	876	1241	3073.5	4380.2	2344.32	0	6724.52	22	305.66	224.91
A37	0.4	5	2	43.8	1314	1576.8	2876.5	4497.1	651.2	0	5148.3	52	99.01	133.83
A38	0.4	8	4	284.7	876	1368.7	1890.7	3544.1	3907.2	0	7451.3	37	201.39	179.37
A39	0.4	2	2	10.9	876	1343.2	2374	3728.1	1221	0	4949.1	20	247.46	230.99
A40	0.4	2	2	10.9	876	1267.2	2374	3652.1	1221	0	4873.1	15	324.87	246.17
A41	0.4	3	4	21.9	876	1795.8	2347	4164.7	1221	0	5385.7	44	122.40	158.12
A42	0.4	6	4	43.8	876	2252	2617.2	4913	325.6	180	5238.6	71	73.78	76.15
A43	0.4	4	2	20.9	876	1314	3986	5320.9	3907.2	62.5	9228.1	25	369.12	215.81
A44	0.4	3	4	20.9	0	438	978.2	1437.1	2442	0	3879.1	32	121.22	194.55
A45	0.9	6	4	10.9	1314	3762.3	2161	5934.2	3907.2	0	9841.4	42.5	231.56	162.68
A46	0.9	3	2	20.9	876	1314	3986	5320.9	325.6	62.5	5646.5	20	282.33	230.99
A47	0.9	4	3	10.9	1314	1603	2161	3774.9	1221	0	4995.9	28	178.43	206.70
A48	0.9	5	5	73	1314	2370.2	3073.5	5516.7	814	0	6330.7	37	171.10	179.37
A49	0.9	5	3	43.8	876	1683.7	3241.5	4969	325.6	0	5294.6	65	81.46	94.37
A50	0.2	4	3	20.9	1314	1752	3818	5590.9	2035	60	7625.9	47	162.25	149.01
A51	0.2	5	2	43.8	566	719.3	2374	3137.1	651.2	0	3788.3	23	164.71	221.88
A52	0.2	4	5	73	876	1638	4658	6369	976.8	0	7345.8	50	146.92	139.91
A53	0.2	3	4	10.9	876	1165	960.2	2136.1	814	0	2950.1	38	77.63	176.34
A54	0.2	3	4	20.9	876	1314	978.2	2313.1	1221	45	3534.1	36	98.17	182.41
A55	0.13	4	4	20.9	876	1323.5	1993	3337.4	407	0	3744.4	35	106.98	185.45
A56	0.13	4	5	43.8	876	1323.5	2161	3528.3	814	62.5	4342.3	67	64.81	88.29
A57	0.13	4	6	20.9	876	1241	2617.2	3879.1	325.6	0	4204.7	65	64.69	94.37
A58	0.13	8	4	43.8	876	1131.5	2161	3336.3	2442	220	5778.3	51	113.30	136.87

A59	0.13	7	5	20.9	1314	1631.9	3259.5	4912.3	2442	0	7354.3	62	118.62	103.47
A60	0.13	5	5	20.9	1314	1861.5	4154	6036.4	1628	0	7664.4	67.5	113.55	86.78
A61	0.13	6	5	21.9	1314	1966.95	2161	4149.85	2442	0	6591.85	71	92.84	76.15
A62	0.14	6	4	10.9	876	1357	2905.5	4273.4	814	0	5087.4	57	89.25	118.65
A63	0.14	8	6	10.9	1314	3153.6	4154	7318.5	1628	0	8946.5	69	129.66	82.22
A64	0.14	3	3	284.7	876	1233.7	3075.5	4593.9	814	100	5407.9	39	138.66	173.30
A65	0.14	6	5	10.9	876	1288.4	3259.5	4558.8	2442	40	7000.8	70	100.01	79.19
A66	0.14	6	6	73	1314	1726.4	4658	6457.4	2035	0	8492.4	63.5	133.74	98.92
A67	0.14	7	5	21.9	876	2770.3	2833	5625.2	814	0	6439.2	65	99.06	94.37
A68	0.14	5	4	20.9	876	1233.7	978.2	2232.8	976.8	0	3209.6	42	76.42	164.19
A69	0.14	4	5	21.9	876	1412.5	3073.5	4507.9	814	0	5321.9	51	104.35	136.87
A70	0.14	5	4	43.8	876	1384.5	2785.2	4213.5	610.5	180	4824	71.5	67.47	74.63
A71	0.14	7	4	43.8	876	1368.7	1872.7	3285.2	1221	0	4506.2	41	109.91	167.23
A72	0.14	6	4	21.9	876	1387	2347	3755.9	2442	0	6197.9	49	126.49	142.94
A73	0.14	4	3	10.9	1314	1868.75	3259.5	5139.15	2035	0	7174.15	37	193.90	179.37
A74	0.14	3	4	10.9	876	1233.7	2347	3591.6	651.2	90	4242.8	44	96.43	158.12
A75	0.14	8	5	43.8	876	1934.5	2161	4139.3	651.2	270	4790.5	60	79.84167	109.55
A76	0.8	5	4	20.9	1314	2708.25	2785.2	5514.35	1628	180	7142.35	70	102.03	79.19
A77	0.8	4	3	10.9	876	1233.7	3073.5	4318.1	1221	0	5539.1	32	173.10	194.55
A78	0.8	2	2	20.9	0	438	978.2	1437.1	2442	0	3879.1	26.7	145.28	210.64
A79	0.8	4	3	10.9	1314	3762.3	2161	5934.2	1221	0	7155.2	39	183.47	173.30
A80	0.1	5	4	102.5	1314	2224.01	2016	4342.51	203.5	0	4546.01	90	50.51122	18.47
A81	0.1	4	3	54.75	1314	2225.7525	1776	4056.5025	0	0	4056.503	45	90.1445	155.09

A82	0.1	5	7	9.125	876	1791.51	3241.5	5042.135	203.5	0	5245.635	52	100.8776	133.83
A83	0.1	4	5	9.125	876	1408.23	4104	5521.355	325.6	0	5846.955	98	59.66281	-5.82

Annex 2: Energy use in apartment houses

ID.	Kebele	Family size	No. Rooms	Lighting (kWh/yr.)	Refrigerator (kWh/yr.)	Electric appliances (kWh/yr.)	Cooking (kWh/yr.)	Total electric consumption (kWh/yr.)	Total Charcoal (kWh/yr.)	Total Energy Consumption (kWh/yr.)	UFA (m^2)	EPI (kWh/yr./m^2)	EPI_o (kWh/yr./m^2)
A1	0.4	8	4	284.7	876	1368.7	1890.7	3544.1	2930.4	6474.5	47	137.76	149.01
A2	0.4	5	4	21.9	876	1630.3	3259.5	4911.7	3907.2	8818.9	48	183.73	145.98
A3	0.4	3	3	10.9	1314	1850.5	3259.5	5120.9	651.2	5772.1	38	151.90	176.34
A4	0.4	3	4	21.9	876	1795.8	2347	4164.7	1953.6	6118.3	44	139.05	158.12
A5	0.4	8	5	20.9	876	1934.5	2161	4116.4	651.2	4767.6	60	79.46	109.55
A6	0.4	6	4	43.8	876	2252	2617.2	4913	325.6	5238.6	70	74.84	79.19
A7	0.4	4	2	20.9	876	1314	3986	5320.9	325.6	5646.5	15	376.43	246.17
A8	0.4	3	4	20.9	0	438	978.2	1437.1	2442	3879.1	36.8	105.41	179.98
A9	0.4	6	4	10.9	1314	3762.3	2161	5934.2	3663	9597.2	39.16	245.08	172.82
A10	Bole	3	4	10.9	876	1387	2161	3558.9	3907.2	7466.1	57	130.98	118.65

A11	Bole	8	5	10.9	1314	1671.7	732	2414.6	3907.2	6321.8	42.9	147.36	161.46
A12	Bole	9	6	65.7	876	1910.7	3409.5	5385.9	4884	10269.9	63	163.01	100.44
A13	Bole	2	3	43.8	876	1144.3	1507.7	2695.8	2442	5137.8	30	171.26	200.63
A14	Bole	5	6	20.9	1314	2361.5	3073.5	5455.9	7326	12781.9	40.5	315.60	168.75
A15	Bole	5	6	20.9	876	2088.1	3241.5	5350.5	2442	7792.5	70.8	110.06	76.76
A16	Bole	4	4	43.8	2628	3277.7	883.5	4205	2442	6647	66	100.71	91.33
A17	Bole	4	4	65.7	876	1388.05	2665	4118.75	3907.2	8025.95	52	154.35	133.83
A18	0.4	4	3	10.9	876	1233.7	3073.5	4318.1	2442	6760.1	35	193.15	185.45
A19	0.4	2	2	10.9	876	1233.7	2374	3618.6	1221	4839.6	15	322.64	246.17
A20	0.4	3	4	20.9	876	1208.5	195.3	1424.7	2442	3866.7	44.2	87.48	157.51
A21	0.4	6	2	20.9	876	1321.3	2905.5	4247.7	2442	6689.7	63.2	105.85	99.83
A22	0.4	4	3	20.9	876	1233.7	708.25	1962.85	2442	4404.85	28.7	153.48	204.57
A23	0.4	4	3	20.9	1314	1761.5	3902	5684.4	203.5	5887.9	40	147.20	170.27
A24	Bole	2	4	182.5	1314	1798	3902	5882.5	2344.32	8226.82	80	102.84	48.83
A25	Bole	6	4	182.5	876	2251.2	3986	6419.7	976.8	7396.5	55	134.48	124.73
A26	0.4	4	4	43.8	876	1642.5	2136	3822.3	814	4636.3	50	92.73	139.91
A27	0.4	5	3	65.7	876	1241	3073.5	4380.2	2442	6822.2	20	341.11	230.99
A28	0.4	3	5	43.8	876	1323.5	7536	8903.3	1017.5	9920.8	36	275.58	182.41
A29	0.4	5	3	43.8	876	1496.5	2905.5	4445.8	1628	6073.8	65	93.44	94.37
A30	0.4	4	3	20.9	876	1259	3818	5097.9	2035	7132.9	47	151.76	149.01
A31	0.4	5	2	43.8	1314	1576.8	3286.5	4907.1	814	5721.1	60	95.35	109.55
A32	0.4	4	5	73	876	1484.7	4658	6215.7	814	7029.7	50	140.59	139.91
A33	0.4	3	4	20.9	0	438	978.2	1437.1	2442	3879.1	36.8	105.41	179.98

A34	0.4	3	4	20.9	0	438	978.2	1437.1	2442	3879.1	36.8	105.41	179.98
A35	0.4	6	2	20.9	876	1321.3	2905.5	4247.7	2442	6689.7	63.2	105.85	99.83
A36	0.4	5	3	65.7	876	1241	3073.5	4380.2	2344.32	6724.52	22	305.66	224.91
A37	0.4	5	2	43.8	1314	1576.8	2876.5	4497.1	651.2	5148.3	52	99.01	133.83
A38	0.4	8	4	284.7	876	1368.7	1890.7	3544.1	3907.2	7451.3	37	201.39	179.37
A39	0.4	2	2	10.9	876	1343.2	2374	3728.1	1221	4949.1	20	247.46	230.99
A40	0.4	2	2	10.9	876	1267.2	2374	3652.1	1221	4873.1	15	324.87	246.17
A41	0.4	3	4	21.9	876	1795.8	2347	4164.7	1221	5385.7	44	122.40	158.12
A42	0.4	6	4	43.8	876	2252	2617.2	4913	325.6	5238.6	71	73.78	76.15
A43	0.4	4	2	20.9	876	1314	3986	5320.9	3907.2	9228.1	25	369.12	215.81
A44	0.4	3	4	20.9	0	438	978.2	1437.1	2442	3879.1	32	121.22	194.55
A45	0.9	6	4	10.9	1314	3762.3	2161	5934.2	3907.2	9841.4	42.5	231.56	162.68
A46	0.9	3	2	20.9	876	1314	3986	5320.9	325.6	5646.5	20	282.33	230.99
A47	0.9	4	3	10.9	1314	1603	2161	3774.9	1221	4995.9	28	178.43	206.70
A48	0.9	5	5	73	1314	2370.2	3073.5	5516.7	814	6330.7	37	171.10	179.37
A49	0.9	5	3	43.8	876	1683.7	3241.5	4969	325.6	5294.6	65	81.46	94.37
A50	0.2	4	3	20.9	1314	1752	3818	5590.9	2035	7625.9	47	162.25	149.01
A51	0.2	5	2	43.8	566	719.3	2374	3137.1	651.2	3788.3	23	164.71	221.88
A52	0.2	4	5	73	876	1638	4658	6369	976.8	7345.8	50	146.92	139.91
A53	0.2	3	4	10.9	876	1165	960.2	2136.1	814	2950.1	38	77.63	176.34
A54	0.2	3	4	20.9	876	1314	978.2	2313.1	1221	3534.1	36	98.17	182.41
A55	0.13	4	4	20.9	876	1323.5	1993	3337.4	407	3744.4	35	106.98	185.45
A56	0.13	4	5	43.8	876	1323.5	2161	3528.3	814	4342.3	67	64.81	88.29

A57	0.13	4	6	20.9	876	1241	2617.2	3879.1	325.6	4204.7	65	64.69	94.37
A58	0.13	8	4	43.8	876	1131.5	2161	3336.3	2442	5778.3	51	113.30	136.87
A59	0.13	7	5	20.9	1314	1631.9	3259.5	4912.3	2442	7354.3	62	118.62	103.47
A60	0.13	5	5	20.9	1314	1861.5	4154	6036.4	1628	7664.4	67.5	113.55	86.78
A61	0.13	6	5	21.9	1314	1966.95	2161	4149.85	2442	6591.85	71	92.84	76.15
A62	0.14	6	4	10.9	876	1357	2905.5	4273.4	814	5087.4	57	89.25	118.65
A63	0.14	8	6	10.9	1314	3153.6	4154	7318.5	1628	8946.5	69	129.66	82.22
A64	0.14	3	3	284.7	876	1233.7	3075.5	4593.9	814	5407.9	39	138.66	173.30
A65	0.14	6	5	10.9	876	1288.4	3259.5	4558.8	2442	7000.8	70	100.01	79.19
A66	0.14	6	6	73	1314	1726.4	4658	6457.4	2035	8492.4	63.5	133.74	98.92
A67	0.14	7	5	21.9	876	2770.3	2833	5625.2	814	6439.2	65	99.06	94.37
A68	0.14	5	4	20.9	876	1233.7	978.2	2232.8	976.8	3209.6	42	76.42	164.19
A69	0.14	4	5	21.9	876	1412.5	3073.5	4507.9	814	5321.9	51	104.35	136.87
A70	0.5	5	4	43.8	876	1384.5	2785.2	4213.5	610.5	4824	71.5	67.47	74.63
A71	0.5	7	4	43.8	876	1368.7	1872.7	3285.2	1221	4506.2	41	109.91	167.23
A72	0.7	6	4	21.9	876	1387	2347	3755.9	2442	6197.9	49	126.49	142.94
A73	0.7	4	3	10.9	1314	1868.75	3259.5	5139.15	2035	7174.15	37	193.90	179.37
A74	0.6	3	4	10.9	876	1233.7	2347	3591.6	651.2	4242.8	44	96.43	158.12
A75	0.6	8	5	43.8	876	1934.5	2161	4139.3	651.2	4790.5	60	79.84167	109.55
A76	0.8	5	4	20.9	1314	2708.25	2785.2	5514.35	1628	7142.35	70	102.03	79.19
A77	0.8	4	3	10.9	876	1233.7	3073.5	4318.1	1221	5539.1	32	173.10	194.55
A78	0.8	2	2	20.9	0	438	978.2	1437.1	2442	3879.1	26.7	145.28	210.64
A79	0.8	4	3	10.9	1314	3762.3	2161	5934.2	1221	7155.2	39	183.47	173.30

A80	0.1	5	4	102.5	1314	2224.01	2016	4342.51	203.5	4546.01	90	50.51122	18.47
A81	0.1	4	3	54.75	1314	2225.7525	1776	4056.5025	0	4056.503	45	90.1445	155.09
A82	0.1	5	7	9.125	876	1791.51	3241.5	5042.135	203.5	5245.635	52	100.8776	133.83
A83	0.1	4	5	9.125	876	1408.23	4104	5521.355	325.6	5846.955	98	59.66281	-5.82

Annex 3: Energy use in villa houses

ID.	Kebele	Family size	Rooms	Lighting (kWh/yr.)	Refrigerator(kWh/yr.)	Water heating (kWh/yr.)	Air conditioning	Electric appliances (kWh/yr.)	Cooking (kWh/yr.)	Total electric consumption (kWh/yr.)	Total Charcoal (kWh/yr.)	Total Energy Consumption (kWh/yr.)	UFA (m^2)	EPI (kWh/yr./m^2)	EPI_o (kWh/yr./m^2)
B1	0.4	4	3	21.9	876	384	30	2400.76	5872	8294.66	610.5	8905.16	140	63.61	43.094
B2	0.4	2	4	58.4	1314	0	0	2009.49	2184	4251.89	244.2	4496.09	90	49.96	64.144
B3	0.4	3	4	58.4	1314	144	60	2428.01	2016	4502.41	325.6	4828.01	160	30.18	34.674
B4	0.4	4	3	21.9	1314	144	0	2369.75	1776	4167.65	0	4167.653	122	34.16	50.672
B5	0.4	5	7	10.95	876	0	60	1851.51	3241.5	5103.96	325.6	5429.56	150	36.20	38.884
B6	Bole	4	5	80.5	876	0	60	1468.23	4104	5652.73	651.2	6303.93	115	54.82	53.619
B7	Bole	5	8	80.5	1314	384	60	2406.04	3073.5	5560.04	325.6	5885.64	120	49.05	51.514
B8	Bole	3	4	21.9	1314	240	0	2439.45	2161	4622.35	610.5	5232.85	80	65.41	68.354
B9	Bole	4	5	54.5	1314	0	120	2216.26	5904	8174.76	610.5	8785.26	91	96.54	63.723

B10	0.1	4	3	54.5	1314	96	0	2218.64	2905.5	5178.64	325.6	5504.24	125	44.03	49.409
B11	0.1	4	3	54.5	1314	0	0	1914.21	3073.5	5042.21	305.25	5347.46	95	56.29	62.039
B12	0.1	4	3	54.5	1314	384	240	2899.11	2989.5	5943.11	325.6	6268.71	110	56.99	55.724
B13	0.1	4	5	29.2	1314	0	265	2258.23	1734.75	4022.18	814	4836.18	100	48.36	59.934
B14	0.1	3	4	10.95	876	0	15	1388.18	2904	4303.13	976.8	5279.93	90	58.67	64.144
B15	0.1	6	5	102.5	1314	384	135	2689.54	3504	6296.04	976.8	7272.84	130	55.94	47.304
B16	0.1	5	5	54.75	1314	0	15	2111.26	2904	5070.01	976.8	6046.81	80	75.59	68.354

Annex 4: Unit conversion factor

Type of light	Consumption (W)	Remark
LED light	10	
Incandescent lamp	60	

Electronic appliances Consumption (kW)

Size	15”	21"	32”	42”	55”	Remark
LCD television	0.063	0.105	0.1925	0.42	0.525	
CRT television	0.2275	0.350	-	-	-	

Appliances	Consumption (kW)	Remark
Washing machine	0.515	
Laptop	0.05	
Desktop	0.1	

Refrigerator with freezer	Capacity of the fridge (Z)	Consumption (kW/yr.)	Remark
150cm high	100-199	876	
180cm high	200-299	1314	

Appliances	Consumption (W)	Remark
Stove/single plate	1000	
Stove/Double plate	2500	

Appliances	Consumption (kWh)	Remark
‘Injera mixad’	3.5	

Sources	Consumption (kWh/kg)	Remark
Charcoal	8.14	
Wood fuel	4.90	

Annex 5: Total energy consumption in the city

To calculate the total energy consumption firstly the average energy used in building per its usable area were identified. Then calculated as total energy consumed in selected household divided by its floor area:

$$\mathrm{Epi} = \mathrm{TEC}/\mathrm{TFA}$$

Where, TEC stands for total energy consumed in the building which is equal to 1,057,193.765 kWh/yr. and,

TFA is for total floor area which is equal to 9954.76 m^2.

For the above equation we have Epi equal to 104.68 kWh/ m^2. yr. This show that one housing buildings in the city on average consumes 104.68 kWh in a year under 1 m^2 units of usable space in the building.

From this, total energy consumed in the existing residential building of the city can be calculated as follows. From CSA of Adama district there around 64,701 housing units.

$$\text{Average FA} = \frac{\mathrm{TFA}}{\text{number of housholds}}.$$

And the average floor area of the households is equal to 66.70 m^2. From this we have the average used up area for residential building to be 66.70 m$^{2.}$

Therefore, total energy consumption is calculated as:

$$\mathrm{TEC} = AFA * number\ of\ houshold * Epi$$

Therefore, we have 451,752,475.356 kWh/ yr. From this residential building in Adama city consumes around 451.75GW per year.

Annex 6: Total electric energy consumption in the city

To calculate the total electric energy consumption firstly the average energy used in building per its usable area were identified. The we calculated as total energy consumed in selected household divided by its floor area:

$$\mathrm{EPI(elctricity) = TEEC/TFA}$$

Where, TEEC stands for total electric energy consumed in the building which is equal to 84,3286.78 kWh/yr. and, TFA is for total floor area which is equal to 9954.76 m^2.

For the above equation we have EPI equal to 67.50 kWh/ m^2. yr. This show that one housing buildings in the city on average consumes 104.68 kWh in a year under 1 m^2 units of usable space in the building. From this, total electric energy consumed in the existing residential building of the city can be calculated as follows. It is estimated that there are around 64,701 housing units.

$$\text{Average FA } = \frac{\text{TFA}}{\text{number of housholds}}.$$

And the average floor area of the households is equal to 66.70 m^2. From this we have the average used up area for residential building to be 66.70 $m^{2.}$ Therefore, total electric energy consumption is calculated as:

$$\text{TEC } = AFA * number\ of\ houshold * Epi(electricity)$$

Therefore, we have 291,326,820.33 kWh/yr. From this residential building in Adama city consumes around 291.33 GW of electric energy per year.

Annex 7: Total charcoal, wood, and other energy consumption in the city

This can easily find by subtracting total energy consumed and total electric energy consumed. Which is equal to 160,425,655.026 kWh/yr. From this residential building in Adama city consumes around 160.43 GW of energy from charcoal, wood fuels and others sources per year.