

ECONOMIC ASSESSMENT ON EFFICIENCY OF LIQUEFIED PETROLEUM GAS IN COOKING IN MALAWI (Case Study Blantyre)

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ABSTRACT

LPG is the abbreviated name for liquefied petroleum gas – the generic name for mixtures of light hydrocarbons, predominantly propane and butane, that change from a gaseous to liquid state when compressed at moderate pressure or chilled.

The research was conducted in Blantyre in areas of chitawira, chilobwe and zingwangwa. The researcher was determining the efficiency of liquefied petroleum gas in cooking. The efficiency was based on cost, time to cook a standard meal and on emission of gases like carbon monoxide.

The researcher used simple random sampling to choose the sample size of 60 households. The researcher sampled 20 households in areas of chilobwe, chitawira and zingwangwa respectively to reach a total of 60.

The household's survey shows that 25% of the sample size prefer cooking using LPG Gas stoves and 75% uses other cooking fuels. The household survey also reveals that LPG is efficient in terms of time and cost to cook a standard meal e.g., nsima.

The three laboratory tests done at Malawi bureau of standards shows that LPG is efficient in terms of emission of carbon monoxide, consumption power and takes less time to boil water.

The conclusion made by the researcher is that government, private sector partnership needs to work hand in hand to sensitize people on the benefits of LPG since the other fuels for instance firewood and charcoal are not efficient and results in deforestation. This deforestation at the end brings changes in climate.

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List of Acronyms and Abbreviations

CO …… Carbon monoxide

ESCOM…… Electricity supply corporation of Malawi

GDP…… Gross Domestic Product

LPG…… Liquefied Petroleum Gas

MSB…….. Malawi bureau of standards

WBT…… Water boiling test.

PPM…… parts per million

Chapter 1:

1.0. GENERAL INTRODUCTION

It is reported that globally 1.4 billion people have no access to modern energy while 1.3 billion rely on traditional biomass (wood fuels, agricultural by-products and cow dung) as their source of fuel (United Nations, 2012). In sub-Saharan Africa, energy for cooking dominates in the total energy consumed, with 76% of the population relying on traditional biomass (International Energy Agency, 2006). Though biomass is a renewable source, the unsustainable exploitation in sub-Saharan Africa threatens the extinction of supply, human and ecosystem health, as well as the natural environment in general (Pimentel et al., 1991; Smith et al., 2000b).

In Malawi, nearly all households depend on firewood and charcoal for cooking which translates to 95% of energy supply in rural households and 55% in urban households (Government of Malawi, 2003). The need to adopt energy efficient and clean cooking fuels and stoves is thus urgent (Van Leuween et al., 2017)

LPG is the abbreviated name for liquefied petroleum gas – the generic name for mixtures of light hydrocarbons, predominantly propane and butane, that change from a gaseous to liquid state when compressed at moderate pressure or chilled. LPG is derived either as a by-product from crude oil refining (39% of world production in 2013) or extracted from natural gas or oil production streams. LPG is generally liquefied for bulk storage and transportation because its density is much higher as a liquid. LPG is normally refrigerated for shipment by sea and storage of large volumes at receiving terminals; smaller volumes are generally stored in pressurized vessels. LPG has a high-energy content on a per ton basis (in a liquid state) compared to traditional fuels and most other oil products and burns readily in the presence of air giving off a hot flame.

The project goal was to assess the efficient of liquefied petroleum gas in Malawi. The efficient was based on cost efficient, time efficient when cooking a standard meal. The study took place in Blantyre in areas of chitawira, chilobwe and zingwangwa. This was

because these areas had population of people that uses charcoal, firewood, electricity and LPG that are under this study.



Figure 1 shows gas stove and gas cylinder



Figure 2 shows cooking eggs using gas stove from a certain household in chitawira.

1.1. Background

1.1.1 Overview of Malawi

Malawi is a landlocked, least-developed country (LDC) situated in Southern Africa. Malawi is bordered by Mozambique to the southeast, Tanzania to the northeast, and Zambia to the west. The country's total land area is 118,484 km2, 20% of which is covered by water, primarily Lake Malawi.

1.1.2 Population Demographics

According to the Malawi Population and Housing Census Main Report (2018), Malawi has a population of 17,563,749 people or 3,984,929 households. Of this population, 51% are women and 49% are male. Of this national population, 51% of people are under the age of 18. The census shares that 84% of the population or 14,747,257 people live in rural areas while 16% or 2,816,492 people live in urban areas. When

looking strictly at the urban population of Malawi's four cities: Mzuzu, Lilongwe, Blantyre, and Zomba, the city population is 2,115,867 or 12% of the country's total population.

1.1.3 Poverty Prevalence

More than fifty-one percent (51.5%) of Malawi's population is considered poor or have an income below the poverty line of $1.25 per day. In rural areas, the poverty level is higher at 59.5% than in urban areas (17.7%). This means that approximately three out of every five people in rural areas as compared to one out of every five people in urban areas live in poverty (IHS4, 2018)

1.1.4 Literacy Levels

Of Malawi's population over the age of five (5), 68.6% is considered literate. The 2018 Population and Housing Census Main Report estimates higher literacy for men than women – 71.6% and 65.9%, respectively. The Northern Region had the highest literacy rate at 79.0% than the Central and Southern Regions both at 67%.

1.1.5 Economy

1.1.5.1 Gross Domestic Product (GDP)

Malawi's Real Gross Domestic Product (GDP) grew an estimated 5.0% in 2019, up from 4.0% in 2018, despite the effects of Cyclone Idai (AfDB, 2020). Growth was supported by continued macroeconomic stability and improved agricultural performance as evidenced by an increase in maize output of 25.7% in the 2018/2019 agricultural season.

In 2019, the Government of Malawi's (GoM) tax revenue declined, and public debt increased. The government also attempted to reduce domestic debt from 30% of GDP in 2018 to 20% of GDP in 2019 by reducing 2019 fiscal spending from 29.5% of GDP to 25.6%. The 2019 deficit was an estimated 5.9% of GDP, and the 2020 deficit is

projected at 4.3%, which will be financed from external and domestic resources. The current account deficit was estimated in 2019 at 16.9% of GDP, up from 16.2% of GDP in 2018. This increase can be explained by a decline in tobacco prices. A current account deterioration is projected at 17.4% of GDP in 2020 and 17.8% of GDP in 2021.

1.1.6 Energy Sector

As electricity and natural gas grids can successfully displace LPG in cities as countries develop, LPG assets can be increasingly redeployed to peri-urban and rural settings (Bruce et al., 2017). Energy supply has become a growing concern in Malawi and an important factor towards achieving growth and development. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly. However, the country is faced with serious energy supply problems including, rising energy and electricity demand; insufficient power generation capacity; increasing high oil import bills; lack of investment in new power generation units; high transmission and distribution costs, transmission losses; poor power quality and reliability; heavily subsidized pricing; insufficient focus on alternative energy sources; and lack of access to modern electricity for a large segment of the population (MCC,2011). In addition, the country faces a widening gap between electricity demand and supply which is being exacerbated by urbanization, economic development, population growth and rural electrification (MCA, 2010). Electricity demand has been growing consistently at 68% per annum (GoM, 2010a). As a result, the existing system is greatly strained and the frequency of blackouts.

1.2. Statement of Problem Statement

In Malawi biomass is the main source of fuel energy for the majority of the population. This is because of high poverty levels as well as low coverage of electricity (Yaron et al., 2010). Biomass fuels releases carbon monoxide that leads to headaches, dizziness and in high concentration leads to premature death. In addition to that use of biomass result in cutting down of trees careless which can result into change in climate and

also can result into erratic rainfall pattern which can cause floods which can leave people homeless, therefore, there is a need to use cooking fuels that are efficient in terms of cost, time and emissions of hazardous gases.

1.3. Main Objective

- The aim of this study was to investigate the efficiency of liquefied petroleum gas in cooking: case study Blantyre.

1.4. Specific Objectives

1. Determine cooking time and cost of fuels.
2. Determine reasons to prefer certain type of cooking fuel.
3. To determine fuel efficiency

1.5. Research Questions

The following are the research questions which will help to achieve the specific objectives:

- What time it takes and cost of cooking fuels
- What reasons to prefer a certain type of fuel
- How efficient are the cooking fuels?

1.6. Justification of the Study

This study will help to alleviate energy poverty. Providing modern energy to the millions of people in poor countries especially in Malawi who are still forced to rely on dirty and inefficient traditional fuels. Use of LPG – a clean burning, safe and practical household fuel for cooking and water heating – can make a major contribution to eradicating energy poverty, bringing considerable health, developmental and environmental benefits. The physical properties of LPG enable significant amounts of energy to be transported easily as a liquid under moderate pressure in specially designed bottles. This portability makes it particularly suitable for applications in remote location.

LPG can contribute to Reducing Environmental Impacts. LPG will continue to contribute to minimizing the environmental impact of energy use during the current period of transition to a low-carbon energy future.

A century from now, it is plausible that fossil fuels – including LPG – will have been all but removed from the fuel mix, replaced primarily, if not entirely, by a range of renewable technologies. But in the intervening period, the world will still need to use LPG and other fossil sources of energy as bridging fuels to allow time for cost-effective low-carbon alternatives to be developed and commercialized around the world. The transition to low-carbon energy will undoubtedly involve an intermediate shift to the lowest-carbon fossil sources of energy as well as a move to non-fossil energy in order to achieve the fastest possible reduction in CO2 emissions at least cost.

LPG is close to natural gas as the least carbon-intensive fuel, so replacing coal and heavier oil products with LPG and natural gas can generate big reductions in greenhouse gas emissions; the supply of LPG will, in any case, grow with rising gas production as LPG is a by-product of natural gas processing. In this sense, LPG and natural gas can be seen as complementary fuels. In addition, the use of LPG can bring other environmental benefits, including greatly reduced indoor and outdoor pollution, and can help mitigate deforestation – a major cause of global warming.

As LPG is a relatively clean-burning fuel, efficiency tends to be higher than for most other fossil fuels.

STUDY AREA MAP

Figure below shows map of the study area

Blantyre city is the oldest urban center in Malawi, established by the Scottish missionaries in the 1870s and declared a planning area in 1897 (UN-HABITAT, 2010). The researcher chose areas of chitawira, chilobwe and zingwangwa as area of study. These areas are shown in the map which are shown below.

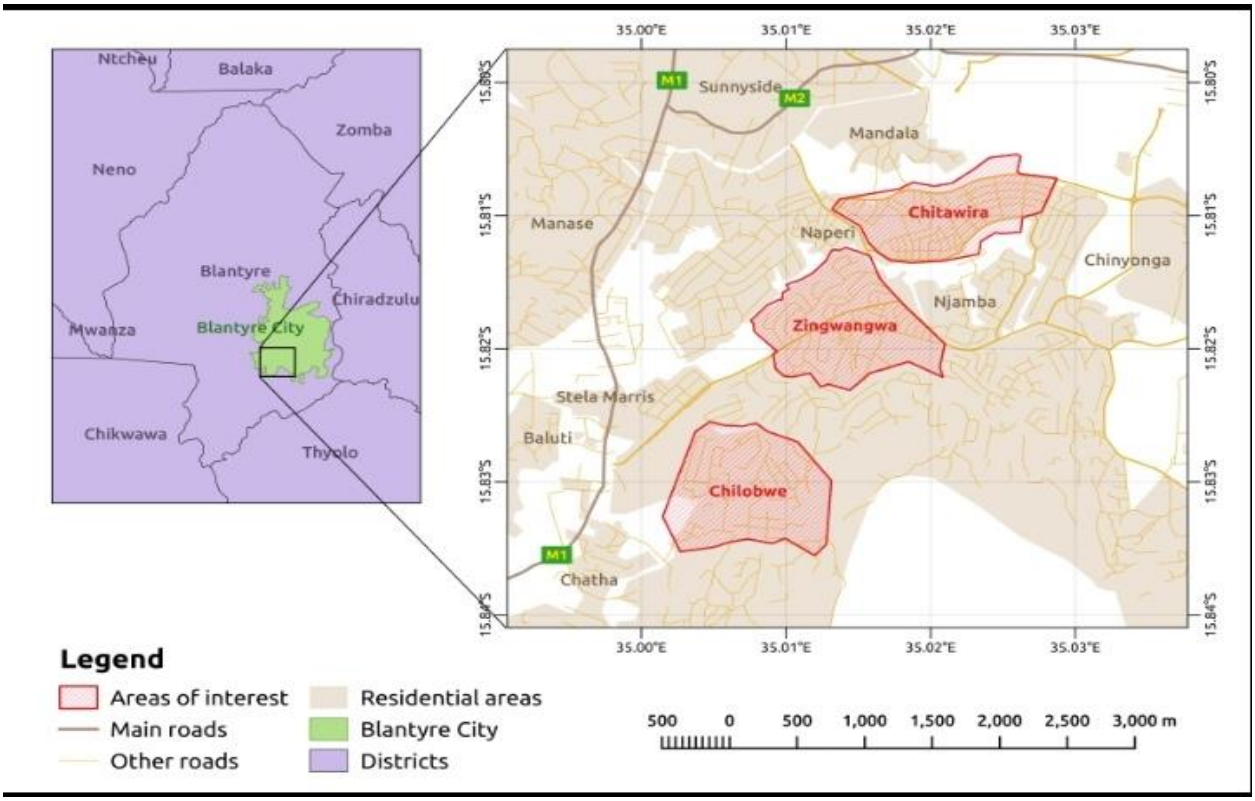


Figure 3 shows map of Blantyre showing areas of chilobwe, chitawira and zingwangwa.

Chapter 2

2.0 LITERATURE REVIEW

2.1. Introduction

A reliable and consistent procedure is required in order to establish and compare efficiency of fuels. In addition to that to assess the performance of cook stoves. According to Bailis et al. (2007), the performance of cook stoves does not only depend on the design but rather on other various factors such as altitude, capacity and material type for the pot used, moisture content of fuel (wood or charcoal), and type of fuel used. The altitude affects the local boiling point (Tb) of the water at a particular place, while the type, moisture and sizes of the fuels influence the burning characteristics of the fuel during the testing. Therefore, considerations should be taken into account when comparing the performance of fuels and cook stoves.

It should also be noted that conditions and factors were sent to be as close as possible to the local kitchen in order to simulate the practical setting in a normal kitchen. The most common method to assess performance of cook stoves and fuels is the standard cold start high power output water boiling test (WBT). The primary purpose of water boiling test is to quantify the heat transfer between the stove and the cooking pot.

2.2 Theoretical Bases of the Study

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

2.2.1 Energy Ladder Theory

The energy ladder model classifies household energies as traditional, transition and advanced energy sources. The model assumes that low-income households would use the traditional fuels until their socio-economic status improve and then they will rationally switch completely to the modern fuels. According to this theory, as household's income increase, they switched to the other advanced energy sources (Osiolo and Helen H, 2009). The energy ladder model considered as classic and traditional places heavy

emphasis on income (affordability) in both explaining and determining a household's energy choice (Masera, et al., 2000). Furthermore, this model has been criticized heavily for its lack of consideration of the intricate interactions that characterize energy transition, demographic factors, personal preferences, etc.

2.2.2 Energy stacking theory

The alternative models that have been proposed as consequent upon the observed weaknesses of the energy ladder model is the stacking model (Masera O et al., 2000). This model assumes that household energy use patterns depend on several factors (not only income) which could be social, economic, cultural, or even personal preferences. Therefore, rather than transiting linearly to cleaner fuels, households tend to increase the number of fuels used without actually abandoning the old ones. The fuel stacking model has been found to be true by many researchers who found fuel stacking to be practiced more by households with higher income (Schlag and Zuzarte, 2008; Kowsari, 2013; Puzzolo, 2013). In other words, households increased the number of fuels they used as their income increased.

2.2.3 Diffusion Theory

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

2.3 Household Income, Family Size and Age

Beyene and Koch (2013) found that household income and wealth are the most important determinants of adoption of clean fuel-saving technologies. Analyses determined that for

various clean stove adoption initiatives, income was positively associated with the stove adoption (Lewis, J.J. and Pattanayak, S.K., 2012).

Socio-economic measures such as income and household expenditure were important features of clean fuel (LPG) uptake (Rogers T, 2009). Bansal et al. (2013) in rural India and Nlom and Karimov (2014) in northern Cameroon found that household income is one of the main factors in choosing fuels for cooking. With regard to family size, Puzzolo et al. (2013) found inconsistency among findings. Gebreegziabher et al. (2010) found that family size was positive and statistically significant to the adoption of the stove. Lewis and Pattanayak (2012) found also household head's age were indicated to be a significant negative factor that determines the adoption of clean cook stoves across studies reviewed. Conversely, Gebreegziabher et al. (2010) found household head's age to be positive and statistically significant determinant factor of clean stove adoption decision.

2.4 Stove Cost

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

2.5 Sex and Marital Status

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

2.7 Liquefied petroleum gas in Africa

The largest African consumer markets for LPG are in North Africa. While the annual LPG consumption rate per capita in Sub-Saharan Africa is 2.3 kilograms (kg) compared to 55 kg per capital annual consumption in North Africa (Rockall, 2016).

The largest LPG markets in Sub-Saharan Africa per capital annual utilization in kilograms is Senegal (10.1 kg), Ivory Coast (8.6 kg), Angola (7.8 kg), South Africa (5.7 kg), Ghana (5.4 kg) and Sudan (5.3 kg) (Holmes, 2011).

The higher utilization of LPG in these countries is due to long-term government support and subsidies. Meanwhile, some of the biggest constraints to the growth of LPG markets are supply deficits due to low and erratic production capacity of refineries and increased cost for LPG resulting from inadequate transport, distribution, and storage infrastructure (LPG Business Review, 2016).

2.8 Use of liquefied petroleum gas in Malawi

In Malawi, there has been significant year-on-year growth of LPG importation from 200,000 in 2013 to 900,000 kgs in 2019. The main suppliers of LPG in Malawi are currently Afrox and Delta Gas. Based on best available and most recent information, this study estimates total household utilization of LPG to be 0.2% in Malawi (Malawi Housing and Population Census, 2018)). Much like the case in the rest of Sub-Saharan Africa, LPG consumption in Malawi is largely amongst middle to high-income urban households (PAC, 2018). Typically, LPG users in Malawi previously used electricity as their primary means for cooking supported by charcoal, and often switch to LPG due to the erratic supply and/or increasing cost of electricity.

2.8.1 Challenges

According to the Government of Malawi's National Charcoal Strategy (2017), LPG is one of the most promising alternatives to urban charcoal use in the medium and long term. However, affordability, accessibility and acceptability of LPG are key variables that

determine adoption. All three of these variables must be clear to the potential customer otherwise adoption will remain limited. Explanations of each are as follows:

Affordability: MERA recommends the retail price of LPG per kilogram. As of March 2020, the cost was MWK 1,744.74 or $2.32 USD, significantly higher than the global average price of $0.63 USD per kg (Global Petrol Prices, 2019), and significantly higher than the South African Freight on Board price of 10.69 Rand (MERA, 2020). Affordability itself has numerous drivers including LPG regulation; proximity of Malawi from the LPG source; and resulting transport costs, storage, last mile distribution; market acceptability; and understanding of use. When considering (both accurately and inaccurately) perceived cost of viable alternatives, it is important to note alternative energy costs are often compared to charcoal prices. The cost of charcoal has an upward trajectory, a trend that is anticipated to continue due to large and increasing demand for charcoal and limited supply of biomass to produce charcoal. Furthermore, LPG in Malawi is extremely expensive relative to the global average and has potential to decrease with greater volume of LPG sales.

Accessibility: LPG safety regulation in Africa follows a European standard which is generally higher than that of South America and Asia. While this is good for maintaining safe distribution and use of LPG, it makes LPG even more expensive and limits its accessibility. Regional gas storage facilities are important for ensuring safe storage of large amounts of LPG for easy onward transmission to the consumer. Shorter distances from the storage facility to consumer's home is needed to create a denser network of distributors and consequently, users. The LPG value chain is complicated in any market, but in an underdeveloped market such as in Malawi, there are limitations on accessibility that are a function of storage and distribution, both of which limit supply because of the high storage costs and limited LPG supply from gas producers. Suppliers need to supply LPG at significant volumes in order to reduce cost.

Acceptability: The knowledge and understanding of LPG in Malawi remains low. A study by Practical Action Consulting highlighted limited knowledge of LPG efficiency and safety among potential users (PAC, 2018). Perceptions that LPG is unsafe and more expensive than other cooking fuels further hamper uptake.

2.8.2 LPG importation routes

There are standard importation routes Malawi which are applicable to importation of LPG.These include ports of Dar es Salaam, Tanzania; Nacala, Mozambique; Beira, Mozambique; and Durban, South Africa as well as Lusaka, Zambia.

2.8.3 Opportunities

Despite the challenges to LPG businesses, the opportunities remain vast. There are opportunities to incentivize LPG adoption, increase awareness of LPG's benefits, and introduce new and varying distribution approaches for LPG stoves, accessories, cylinders, and the on-going supply and sale of the LPG. However, it is important to note that LPG adoption is most likely to start with higher income households.

CHAPTER 3

3.0 METHODOLOGY

3.1. Research Design

The study was conducted in two phases, the first phase involved household fuel use survey conducted in Blantyre. In areas of chitawira, chilobwe and zingwangwa. The household survey captured data on fuel use pattern, time and cost of cooking fuels.

The second phase of the study involved conducting controlled laboratory experiments to measure the efficiency of the four cooking fuels done at Malawi bureau of standards.

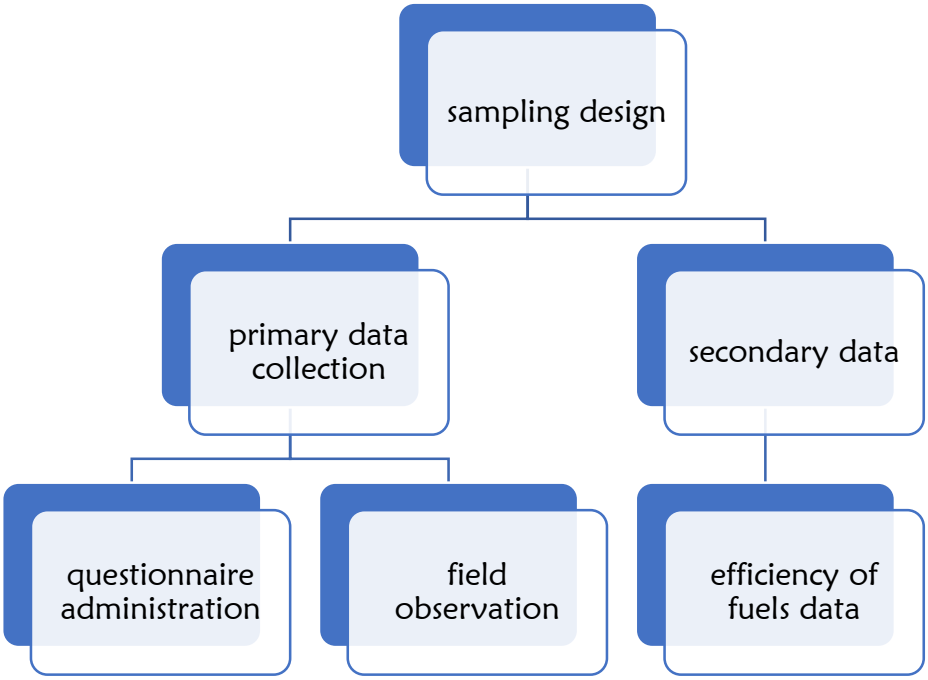


Figure 4 shows the sampling design of the research.

3.2.1 Theoretical Bases of the Study

As mentioned in the literature review that there are three theories that this study depends for instance energy ladder theory, energy stacking theory and diffusion of innovation theory.

The study depends on energy ladder theory in the sense that the area of study classified as tradition, transition, and advanced energy sources. The researcher assumes that low-income households would use tradition fuels for instance firewood until there social-economic status improve and they can switch to other fuels for instance LPG.

The energy stacking theory will be used in this study due to the weakness of the energy ladder model that concentrate only on income. The model assumes that there are several factors to use certain type of fuel not only income. The other factors could be social, cultural or personal preferences. This can be shown in the area of study that

some households tend to use electricity not abandoning cooking using firewood or charcoal.

Diffusion theory the researcher assumes that ideas, behavior or object spreads through a specific population or social system over time. For instance, people will know much better about LPG after a period as information about importance of LPG diffuses (spread)

As mentioned in the literature review, stove cost affects fuel choices. For instance, if LPG gas stoves are cheaper than any kind of cooking device i.e., charcoal stove, electric cooker. People will opt to use gas devices since they are cheaper.

3.2 Sample design.

The population of people in the study area is large and this requires a lot of resources in terms of money and time which is also the useful resources at school, as a result random sampling method was chosen to selected respondents to represent the entire population of the area (Ross, 2009).

The study used both primary and secondary data. The primary data was collected using simple random sampling in selected villages and the respondents respond to the questionnaires formulated, where 60 residential houses were visited and interviewed using the questionnaire. The sampling method provided an equal chance to every member in the sampling frame to be part of the sample independently of which other members of the population were chosen (Ross, 2009).

3.2 Household sample size and sampling framework

The researcher applied random sampling framework to select a total of 60 households in areas of chilobwe, chitawira and zingwangwa. The researcher purposively classified the urban communities of the study areas into low, middle- and high-income areas.

On random sampling the researcher used systematic sampling technique. With this technique the first sampling unit is selected from the sampling random and the rest of the units are sampled based on interval size.

With N as population size and n as sample size, the interval size is calculated as:

(N/n) where N = population size

n = sample size

For instance chitawira, chilobwe and zingwangwa had a population size of 3600. Then the researcher chose 60 as the sample size. To find sample

Sample = (N/n)

N = 3600 n = 60

Sample = 3600/60 = 60

Therefore sample = 60

The table below shows sample size per study area.

Table 1 shows sample size per study area.

study area	study area classification	total sample
chitawira	low income	7
	middle income	7
	high income	6
chilobwe	low income	7
	middle income	7
	high income	6
zingwangwa	low income	7
	middle income	7
	high income	6
	total sample	60

3.7 Data collection tool:

Data collection was conducted using a structured questionnaire administered at household level by Research Assistants and the researcher.

3.8 Data analysis and quality assurance

As part of ensuring quality of data, the researcher was used to cross-check filled questionnaires before leaving each of the households and entities.

Data from instruments filled-in during data collection was entered on to the computer using Microsoft Excel. Protocols for compiling cleaned data sets that are readily accessed, merged and exported were followed.

This included, but not limited to: identifying and documenting missing data (incomplete information from households); eliminating redundant data observations (if data from the same household was entered more than once); ensuring that all components of data are correctly identified so as to ensure that data sets can be easily merged; ensuring that data reflects total sample size; completing inventory of database; completing electronic archiving of questionnaires and; computing tables, figures and statistics. Data recorded in Microsoft Excel was exported and analyzed in STATA package. This enabled the researcher to summarize and organize the data to answer the research questions.

3.9 Fuel Efficiency Tests

The Malawi bureau of standards conducted experiments on the efficiency and emissions tests for the four cooking fuels namely LPG, charcoal, firewood and electricity in a laboratory environment. The cold start high power water boiling test was used to assess the performance of the various types of appliances which included: an electric

hotplate; liquefied petroleum gas burner; charcoal stoves and 3 stone firewood. The following are the parameters that were measured.

a. Temperature, using a digital thermocouple thermometer.
b. Mass of the fuel before and after the test was measured, using a digital weighing scale.
c. Fuel moisture content. An oven was used to control moisture to the required levels from the fuel samples.
d. Time using a stopwatch.
e. Electric power consumption was assessed using a power quality analyzer.
f. Gaseous emissions, using gas detectors.

The researcher kept the following variables constant

- Type of the pot was the same for all cooking fuels
- Volume of water was the same
- When cooking for instance nsima the researcher used a digital thermocouple to know when to start cooking for all cooking fuels

This was done to avoid having bias in results

The researcher used natural firewood since it's mostly used according to 2018 population and housing census.



Figure 5 firewood used during the experiment.



Figure 6 shows a device used to measure emissions of cooking fuels.



Figure 7 taking mass readings for the pot.

3.9 limitation of the study

During the study some households withdrew during daily energy consumption monitoring despite having earlier consented to the process. To address this challenge

the researcher increased the number of households under observation by 3 to cover those dropping out and inconsistencies in provision of data.

CHAPTER 4

4.0 Results and discussion

This chapter presents the empirical results of the analysis of the data collected during the study using the methodology discussed in Section above. First, household fuel survey results are presented starting with the general descriptive socio-demographic statistics of the households under study. Then, results on time-efficiency and costs of a variety of cooking fuels are discussed. Finally, the chapter presents laboratory results on efficiency and emissions tests conducted by the Malawi Bureau of Standards.

4.1 Household Fuel Surveys

4.1.1 Response rate of the questionnaire

AREA	NO: questionnaires	NO: Accepted	Percentages
Chitawira	25	18	30%
Chilobwe	25	22	36.67%
Zingwangwa	25	20	33.33%
Total	**75**	**60**	**100%**

The response rate was calculated using the formula: $Respose = questionnaire\ accepted\ /declined * 100\%$, and 100% of the questionnaire formulated, 80% were accepted. Data was collected using the questionnaires from residents of chitawira, chilobwe and zingwangwa and total of 75 questionnaires were administered, 25 for

each area that were randomly selected; out of 75 questionnaires administered 15 were rejected to be interviewed as showed in the table above.

4.1.1 Demographic Characteristics

Before discussing the empirical results, there is need to briefly discuss features that characterize the data. Several socio-economic and other factors exert some degree of influence on the rate of fuel consumption and cost. Some of the major factors considered in this study are the number of people per households; average income level per household; education levels and who does most of the cooking at in the household.

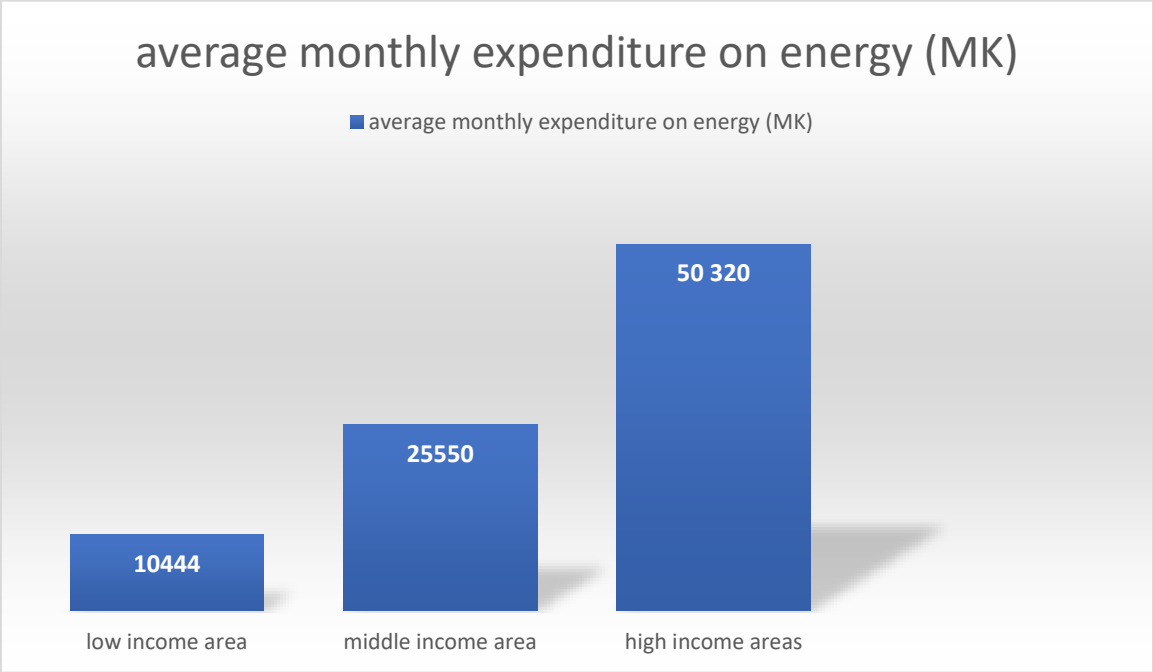
On education levels the researcher found that 15 % people had tertiary education, 30% had Malawi school certificate of education, 25 % had primary school education and 30% had no education.

About gender that does most of the cooking in the household. The researcher found that on percentage 95% is done by women.

4.1.2 Average household expenditure on fuels

Findings indicate that a reasonably good prediction of household's expenditure variation according to the location of the household. Variations also existed about monthly incomes and expenditures. The study found that on average high-income areas earns MK1, 900,000 and spends MK700, 555 per month. In the middle-income areas, average household monthly incomes were recorded to be MK300, 400 and average expenditures was MK180, 651. On average a household from low-income areas has an income expenditure of MK50, 000 and spends MK20, 667.

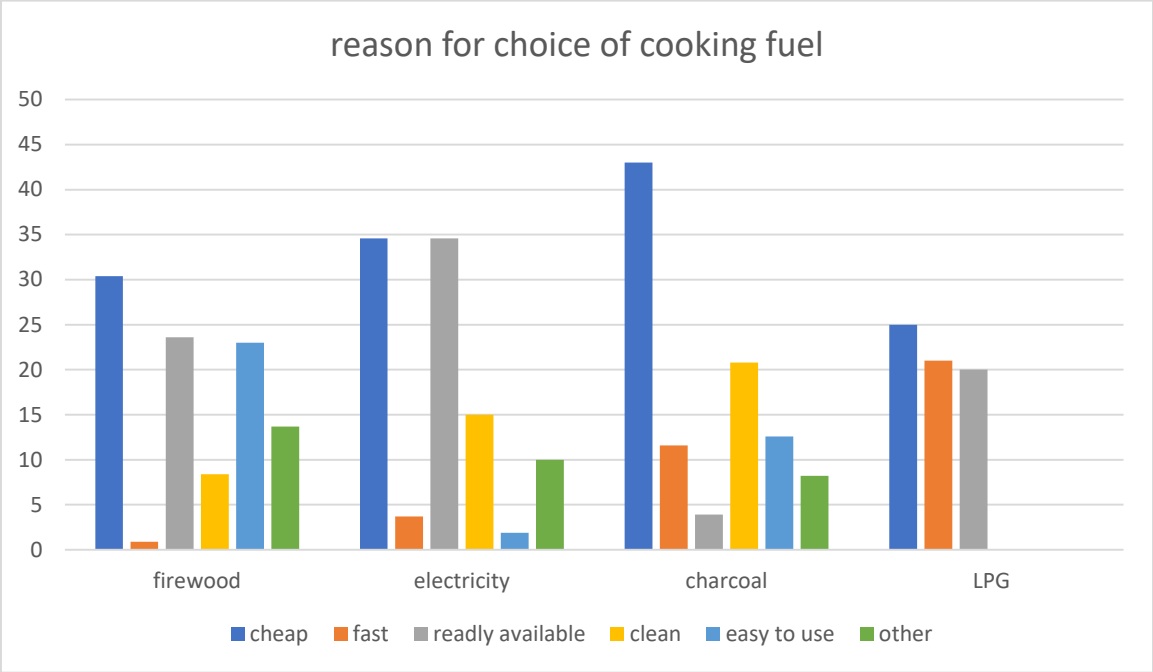
On average monthly energy expenditure on energy. Low income spends MK10, 444, middle income areas spend MK 25, 550 while high income areas spend MK50, 320 on energy.



4.1.3 Reasons for choice of cooking fuel

Income plays an important role in the explanation of inter-fuel substitution in a household. However, according to empirical evidence from a considerable number of households interviewed, household fuel choices are influenced by many other factors. It is also worth mentioning that a household may use a mix of energy sources rather than one source. Households interviewed primarily choose a particular fuel due to factors such as cost of the fuel, time taken to cook a meal, availability of the fuel in the area, cleanliness of the fuel, and ease of use.

On reason to prefer certain of fuel is based on percentage in the graph shown below



4.1.4 Average cooking time and cost of fuels

Below are the formulas the researcher used to find cost of cooking fuels. The study used a 3000 watts hotplate. Therefore converting it into kilowatt hour gives 3 kilowatt hour as power.

Formula to find cost of electricity;

$C_{av} = P * T*C$

Where C_{av} = average cost of electricity in Malawian kwacha

P = power in kilowatt hour

T = time in hours

C = cost per kilowatt hour in Malawian kwacha

Formula to find cost of charcoal, LPG and firewood

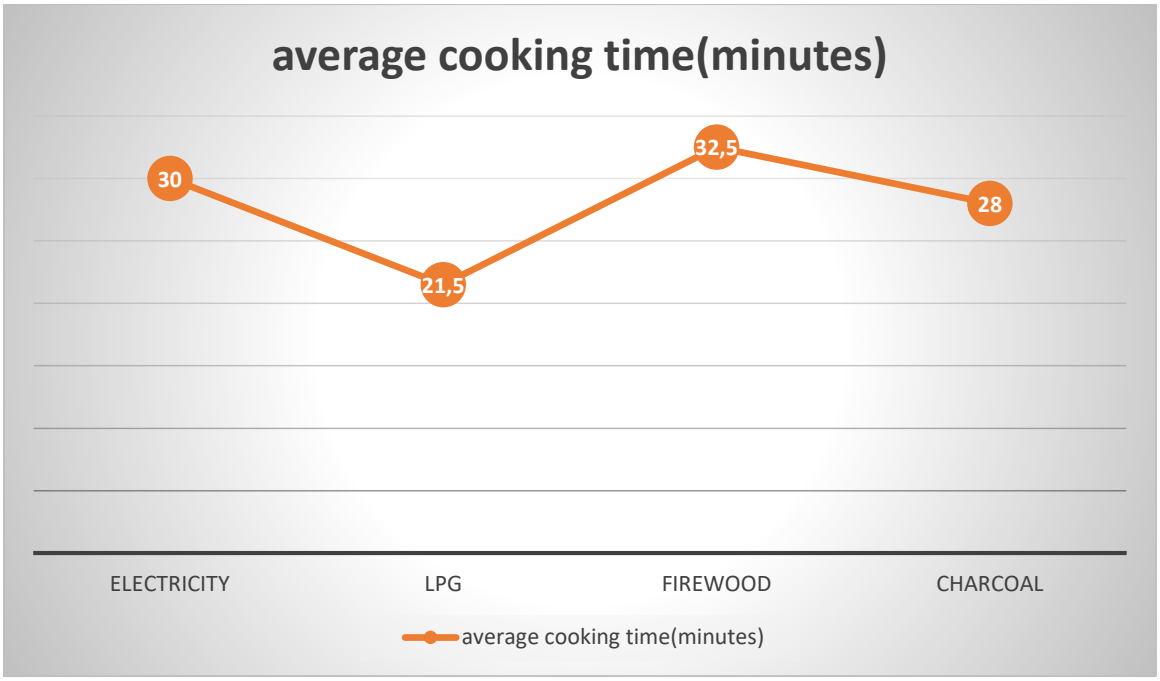
$C_{av} = (M_{bu} - M_{au}) * C$

Where M_{bu} = mass before use

M_{au} = mass after use

C = cost per unit mass

The researcher collected data on time and cost taken to cook a standard meal (Nsima; Potatoes; and rice) in Blantyre households. It was found that LPG is the most time efficient cooking fuel with an average of 21.5 minutes to cook a standard meal. The least time efficient fuel was found to be firewood with an average time of 32.5 minutes as presented in Figure below.



The time analysis results are like findings elsewhere such as Anozie et.al. (2006) who found that in Nigeria, fuel wood was the least time efficient fuel.

Table 2 shows type of fuel to boil water and cost of fuels

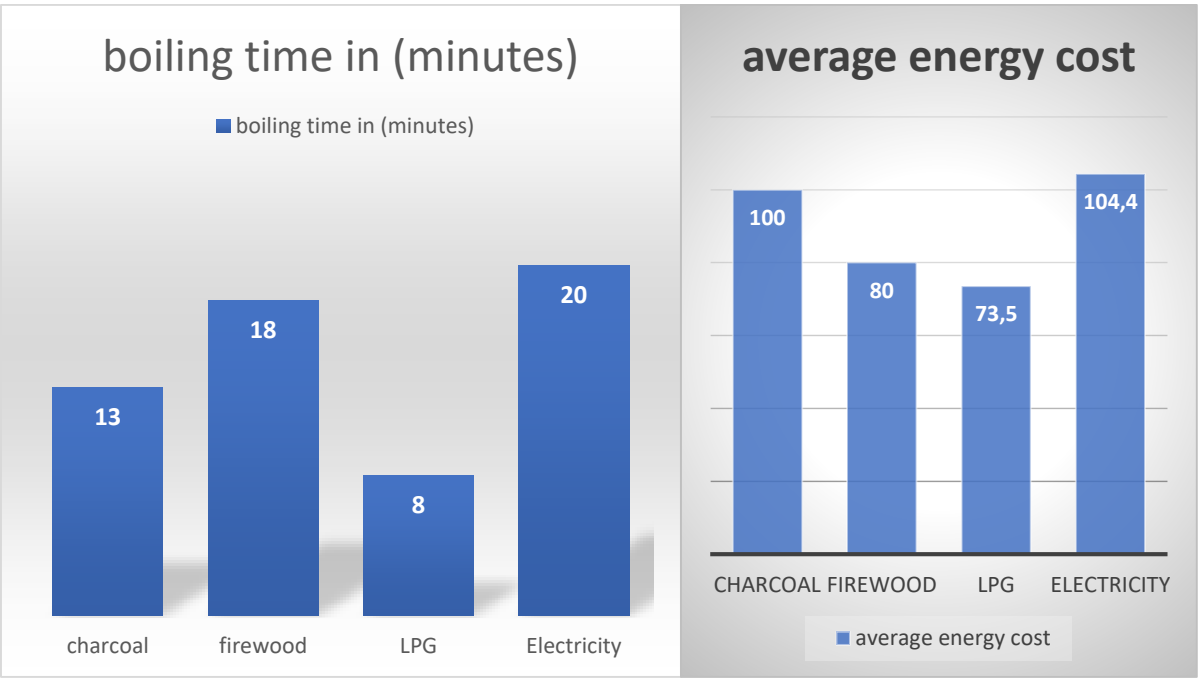
a.

Type of fuel	Mass of fuel before(kg)	Mass of fuel after (kg)	Cost per unit mass(1kg) in MK

LPG	1	0.97	2,450
firewood	1	0.8	400
charcoal	1	0.8	500

b.

Type of fuel	Power (kilowatt hour)	Time (hour)	Cost per kwh in MK
electricity	3	0.33	104.46



The time to boil water was measured from the time the fuel was ignited to the time when the water started boiling at local atmospheric pressure. The Gas stove was the fastest to bring water to boiling point, followed by Chitetezo Cook stove. Electricity was the slowest, taking about 20 minutes to heat water to boiling point at local atmospheric pressure.

4.1.5 time cost analysis for cooking Nsima,potatoes and porridge

Performance of a fuel was measured in terms of time taken for a particular food item to be cooked using that fuel and the monetary cost of the fuel used in the process. To ensure comparability, performance was assessed for specific food items. Top 4 foodstuffs mostly cooked: Nsima, Rice, Potatoes, Porridge were considered. The results of individual time-cost analysis for cooking common meals in Malawi are presented in the figures that follow below:

Table 3 shows cost of each fuel when cooking nsima

a.

Type of fuel	Mass of fuel before (kg)	Mass of fuel after (kg)	Cost per unit mass (1kg)
LPG	1	0.96	2,450
firewood	1	0.7	400
charcoal	1	0.6	500

b.

Type of fuel	Power (kilowatt hour)	Time (hours)	Cost per kwh (MK)
electricity	3	0.5	104.46

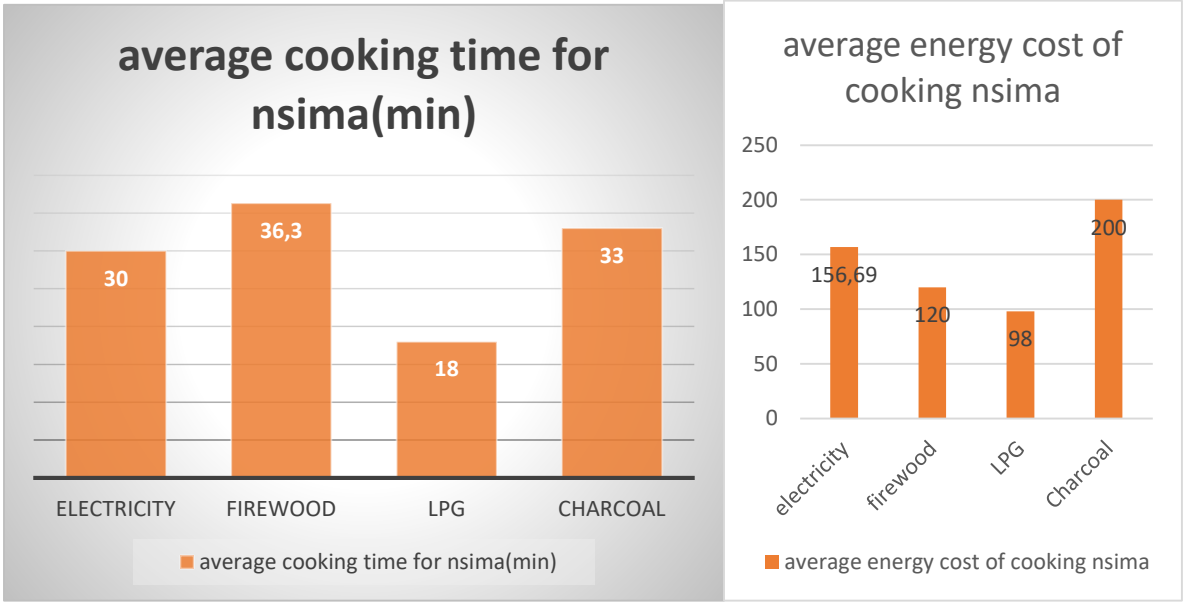


Figure above shows time-cost analysis for cooking Nsima by type of cooking fuel.

The same pattern of performance of the cooking fuel is repeated when we use, in turn rice, potatoes and porridge as shown below. LPG is consistently the most efficient fuel in terms of time and cost.

Table 4 shows cost of each fuel when cooking rice

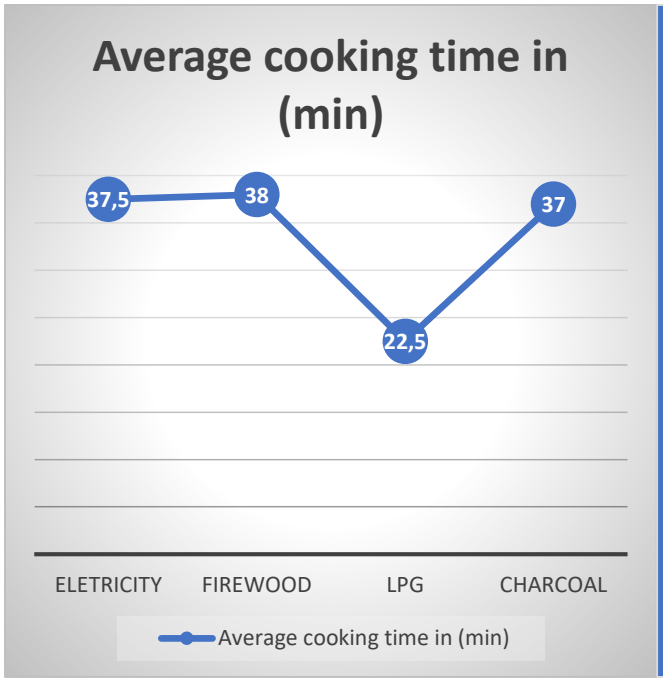
a.

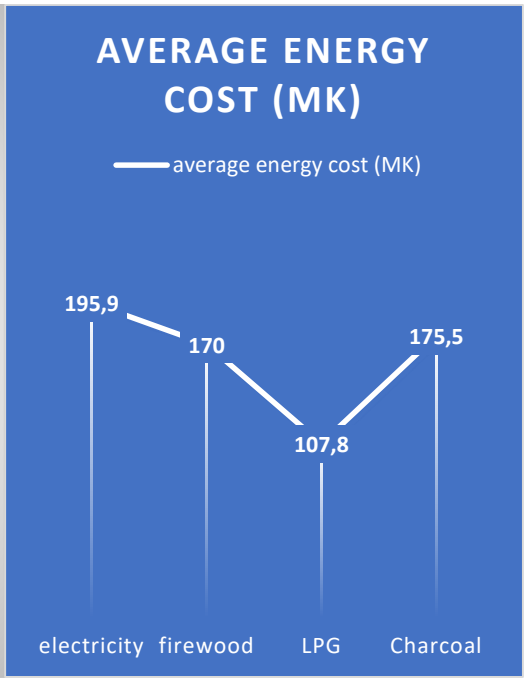
Type of fuel	Mass of fuel before (kg)	Mass of fuel after (kg)	Cost per unit mass (1kg) in MK
LPG	1	0.956	2,450

firewood	1	0.574	400
charcoal	1	0.649	500

b.

Type of fuel	Power(kilowatt hour)	Time (hour)	Cost per kwh in MK
Electricity	3	0.625	104.46





Time cost analysis for cooking rice

Table 5 shows cost of each fuel when cooking potatoes

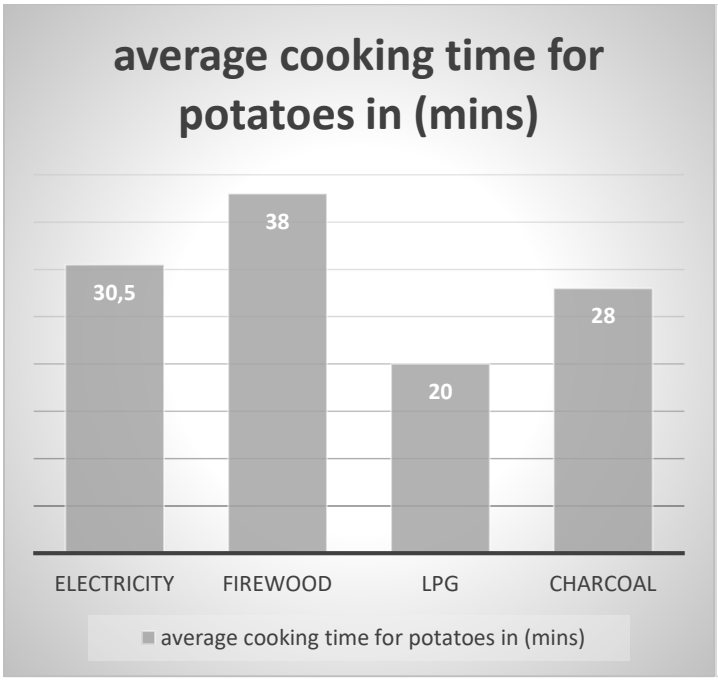
a.

Type of fuel	Mass of fuel before (kg)	Mass of fuel after (kg)	Cost per unit mass (1 kg) in MK

LPG	1	0.958	2,450
firewood	1	0.613	400
charcoal	1	0.7	500

b.

Type of fuel	Power (kilowatt hour)	Time (hours)	Cost per kwh (MK)
Electricity	3	0.508	104.46



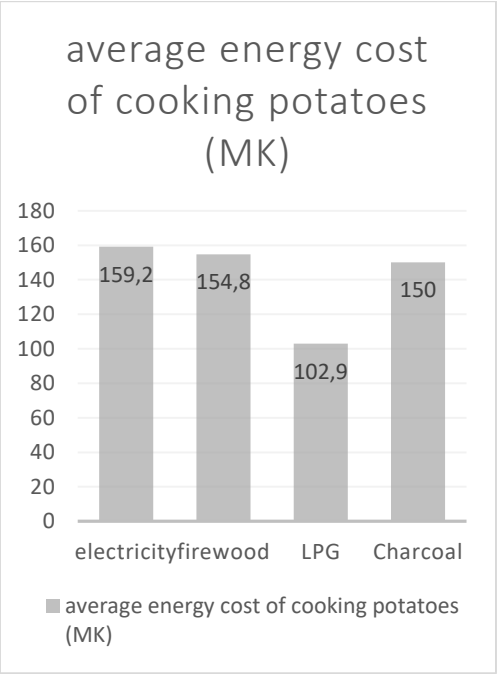


Table 6 below show cost of each fuel when cooking porridge

a.

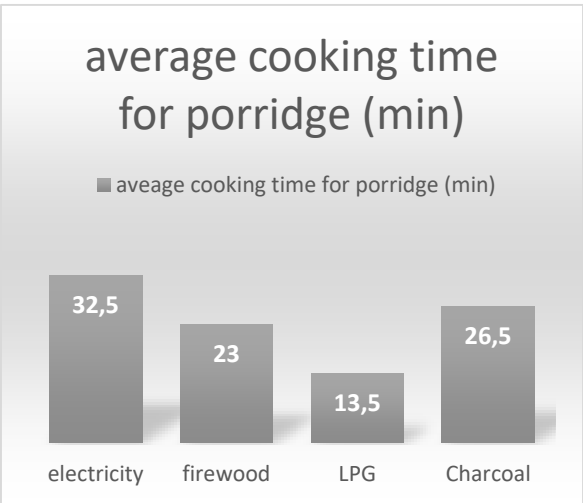
Type of fuel	Mass of fuel before(kg)	Mass of fuel after (kg)	Cost per unit mass (kg) in MK

LPG	1	0.967	2,450
firewood	1	0.65	400
charcoal	1	0.68	500

b.

Type of fuel	Power (kilowatt hour)	Time (hours)	Cost per kwh (MK)
Electricity	3	0.542	104.46

Time cost analysis for cooking porridge



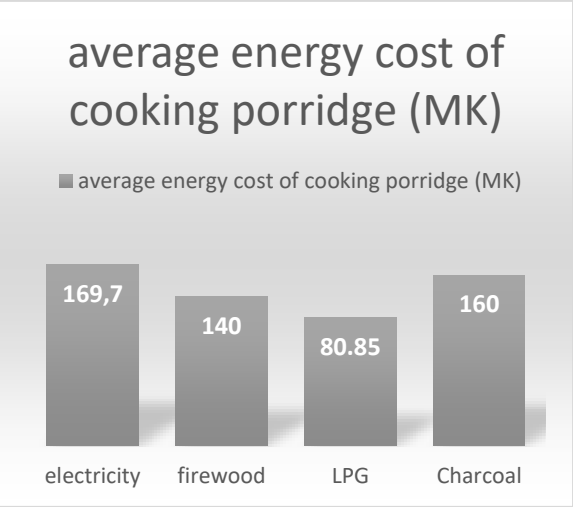


Figure above shows the time-cost analysis for cooking porridge.

4.2 **fuel efficiency**

4.2.3 Fire power of the stove

Firepower FPc is a ratio of the wood energy consumed by the stove per unit time. It tells the average power output of the stove (in watts) during the high power test. Fire power is given by the expression:

FPc = fcd*LHV/60*t

Where t is the time in minutes and LHV is the Net calorific value of the fuel (MJ/kg)

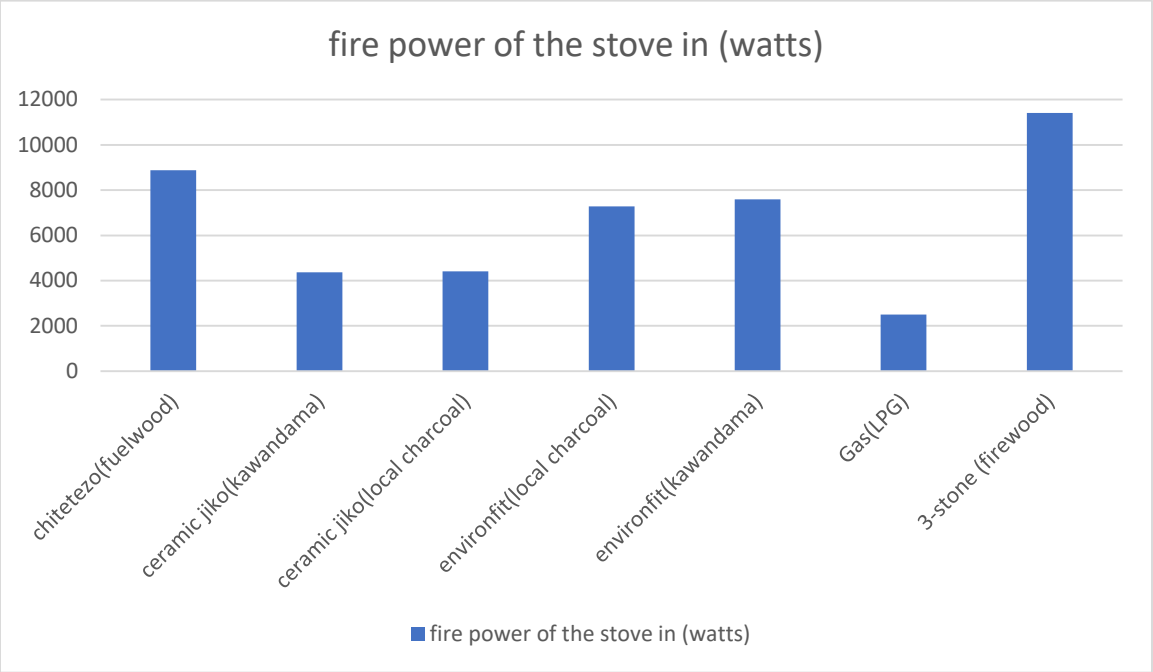
Lower heating value (LHV),also called net heating value ,is the theoretical maximum amount of energy that can be extracted from the combustion of the moisture-free fuel if it is completely combusted and the combustion products are cooled to room temperature but the water produced by the reaction of fuel bound hydrogen remains in the gas phase. The LHV values for the various fuels are listed below.

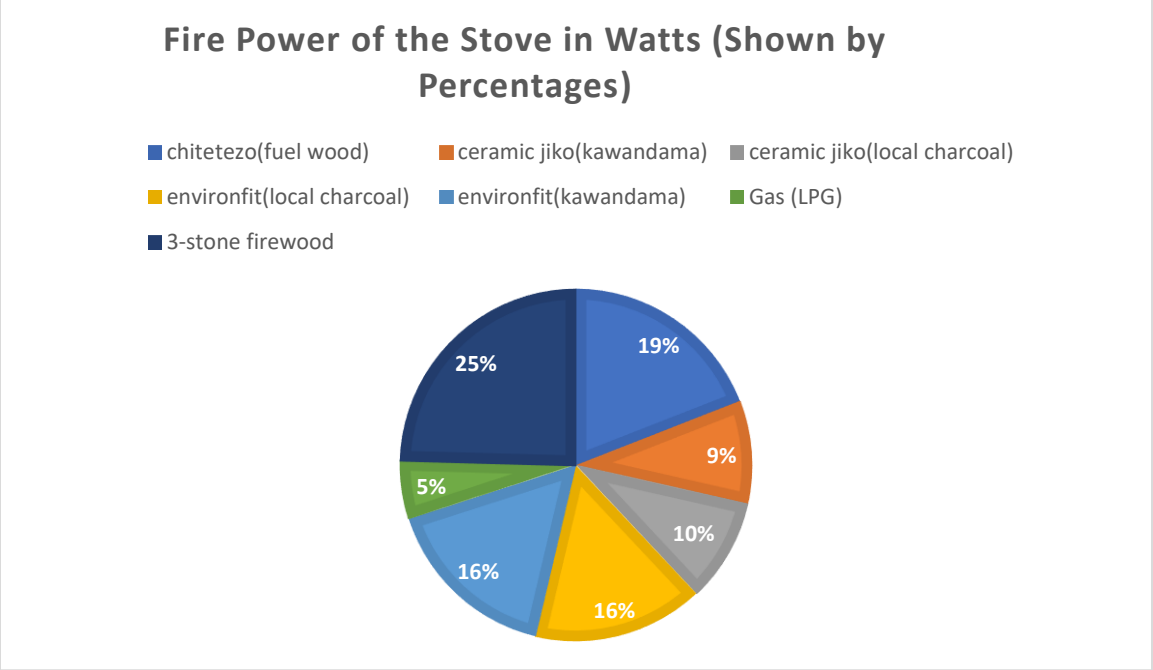
Fuel wood 17.6 MJ/kg

LPG 47.1 MJ/kg

Charcoal 27.6 – 31.5 at 5% MC_{wet}

The average power output of the stove was assessed by determining the ratio of the fuel energy consumed per unit time expressed as fire power. The 3-Stone Fire had the highest fire power seconded by the Chitetezo Cook stove. The Environ fit Stove was third followed by the Ceramic Jiko Stove. The LPG stove gave the lowest fire power values comparatively as presented in Figure below.





4.2.5 Fuel Emission Tests

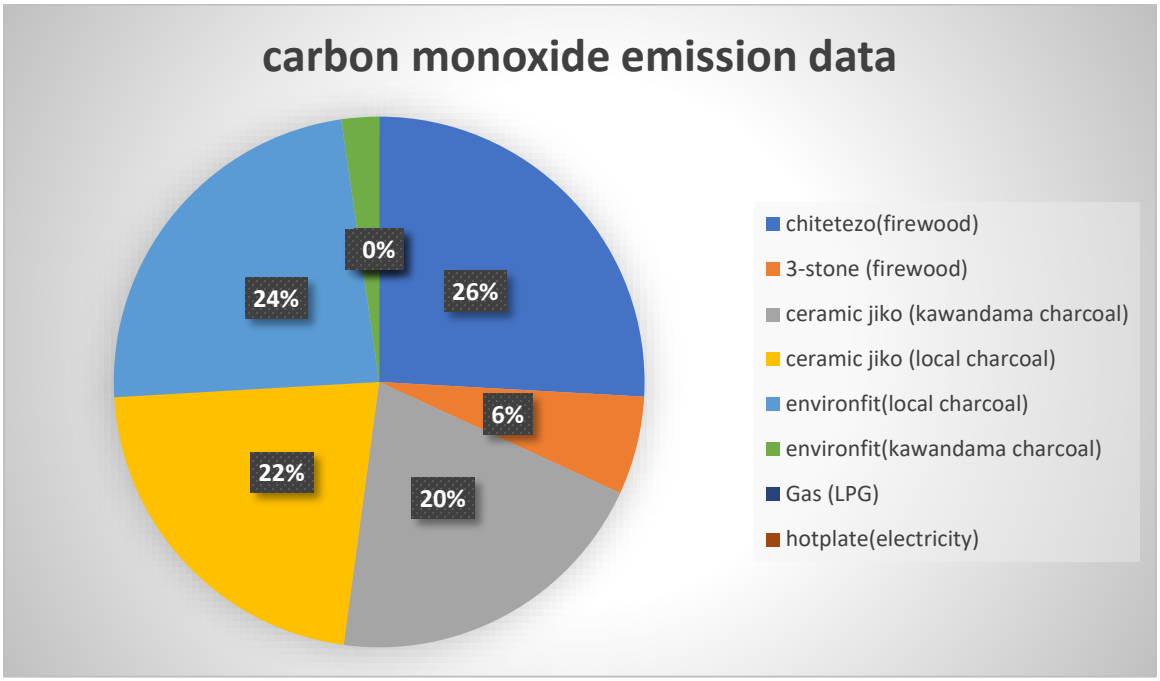
The values for Carbon monoxide (CO) varied with height/distance from the Cook stove as in Table below. The higher the distance of the stove from the fire, the higher

the level of emissions recorded. It should be noted that firewood gave the highest CO values compared to charcoal while no CO emissions were detected in LPG and Electricity cook stoves.

The table below shows carbon monoxide emission data.

Fuel	At 30cm (ppm)
Chitetezo(firewood)	690
3-stone (firewood)	160
Ceramic jiko (kawandama charcoal)	540
Ceramic jiko (local charcoal)	585
Environfit (local charcoal	630
Kawandama charcoal	61
Gas (LPG)	0
Electricity	0

Analysis of carbon dioxide emission data (percentage)



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4.2.6 Discussion of the results

4.2.6.1 Household income and energy expenditure

The scenario of household income show that as a family earns a lot of money there socio-economic changes as a result change to other fuels, for instance the researcher found that most household that uses electricity to cook food were the ones that earns a lot of money since they have capability to buy electric cooker.

On average monthly expenditure on energy the researcher found that a household spend according to their income for instance high income household spend a lot of money on energy, seconded by middle income households. Low income areas have the least average monthly expenditures on energy. This is according to the energy ladder model that explain that income plays a role in usage of fuels.

4.2.6.2 Who does most of cooking

On question about which sex does most of the cooking in the house. Results show that cooking is done mostly by women. This is not surprising as traditionally in Malawi

most household chores are done by women. This has an implication in understanding the population group that is at the highest risk of exposure to unhealthy fumes from cooking fuels. In low income areas around chilobwe, chitawira and zingwangwa the fuel choice is firewood which is known to emit larger amounts of fumes hence exposing women to considerable health hazards.

4.2.6.3 Role of education

Education plays a big role in adopting clean cooking fuels. In the sense that if an individual is educated can be employed hence start using modern technologies when cooking due to money he/she earn. Education is intertwined with health literacy, which is the ability of individuals to obtain and understand health information to make health-related decisions (Nutbeam, 2000)

4.2.6.4 Firepower of the stove

On percentages the 3-stone firewood consumes almost 25% of energy per unit time which means more energy is lost when heating or cooking something. Liquefied petroleum gas burner shows on percentages that it consumes less energy almost 5%. As compared to firewood, LPG saves 20% of the energy per unit time consumed by firewood. This 20% energy can be used to cook other meals.

4.2.6.5 Carbon monoxide emission

The chitetezo firewood emits 26% of carbon monoxide. This emission is slightly dangerous to the health of an individual and to the climate. If a family cooks 3 times per day using chitetezo firewood can emits 2070 ppm of carbon monoxide in the atmosphere. Per month this household can emits 62100 ppm of carbon dioxide. This family per year can emit 745200 ppm of carbon monoxide. Imagine there are 60 households using chitetezo as a cooking fuel. This means there will be 44712000 ppm emissions of carbon dioxide which can heavily affect the environment and the health of people since carbon monoxide is dangerous to the health of people. Carbon monoxide can cause death

4.2.6.6 Reasons to prefer certain type of fuel

It was observed by the researcher that some reasons to prefer certain type of fuel are availability of the fuel, for instance the area that has a lot of people that sells charcoal like zingwangwa, people prefer to use charcoal. The other reason was fastness of the fuel. This reason was being said by the people that uses gas. These people prefer gas since its fast when cooking rice, nsima even potatoes. The other reason being told was cleanliness of the fuel, for instance some household hate firewood because it's not clean due to its ash particles that can fall in the food being cooked when it's windy.

Chapter 5

5.0 Conclusion and Recommendations

5.1 summary of the findings

The study has investigated the cost and efficiency of four cooking fuels (electricity, LPG, firewood and charcoal) using household surveys and laboratory experiments. Household surveys were conducted in areas around Blantyre. A sample of 60 households were interviewed during household surveys and 3 laboratory tests (water boiling; fire power and emissions test) were conducted.

Time and cost analysis of the four cooking fuels at household level revealed that LPG was the most efficient. Out of 3 fuel efficiency tests (water boiling, fire power, and emissions level) conducted in at laboratory setting for the four cooking fuels, LPG gas was found to be the most efficient fuel in terms of time, fuel consumption and level of emissions. Firewood and Charcoal produced more CO than any other type of fuels, making them unsuitable choices as they exposed women to hazardous

fumes. This quantitative study has found that LPG is a competitively cost-efficient cooking fuel in comparison to other common fuels available in Blantyre. LPG ranked first in the water boiling test and took less time to cook a standard meal at household level.

5.2 Recommendations

The following recommendations are made based on the household survey and laboratory experiments conducted on the four cooking fuels:

- The study revealed low uptake of LPG as a cooking fuel across Blantyre despite household survey data on time and cost efficiency showing that the fuel is the most efficient. There is therefore needed to increase access to knowledge on the advantages of LPG and implement strategic initiatives such as subsidies and credit facilities for acquisition of gas cylinders, especially for urban based households.
- Fuel efficiency laboratory tests established that LPG is the most efficient fuel in terms of time, fuel consumption and cleanliness. It is therefore recommended that these benefits should be effectively communicated to the general population. Behavioral change activities would be recommended to change perceptions, attitudes and practices of Malawian households in relation to LPG use.

5.3 future studies

Demand and supply study are recommended to understand the impact of supply chains on the cost and uptake of different cooking fuels, especially identification of barriers to adoption of LPG.

5.4 conclusion

The objective of this study has been achieved through efficiency of cooking fuels data obtained at Malawi bureau of standards (MBS) and questionnaires administered at household level in areas of chitawira, zingwangwa and chilobwe. For instance the

objective about cooking time and cost of fuels. This objective have been achieved through the cooking and boiling time of water that have been converted into money through the formulas shown under discussion of results where by firewood took 18 minutes, LPG 8 minutes and electricity took 20 minutes during boiling experiment. These when converted into money found that LPG was cheap which cost k73.5, seconded by firewood which cost k80, charcoal k100 and electricity k104.4.

The second objective which determines reasons to prefer certain type of cooking fuel has been achieved through the reasons the researcher collected in the study area that people choose certain type of fuel due to how cheap, fast ,readily available, easy to use and how clean a certain type of fuel.

Fuel efficiency objective has been achieved through the fuel emission tests where by other fuels emit a lot of carbon monoxide parts per million. For instance kawandama charcoal stove emit 540 ppm of carbon dioxide while LPG doesn't emit.

Researcher's opinions suggest that if Malawi wants to promote use of liquefied petroleum gas need to address the following challenges: affordability, accessibility and acceptability.

The issue of affordability need to be sorted in the sense that low income household can't afford to buy LPG cylinders and cook stoves since its very expensive. Hence there is a need of LPG subsidies by government.

The challenge of accessibility need to be handled in the sense that remote areas have no access to shops they can buy gas for cooking. So there is need to create shorter distances from the storage facility to consumers home to create a denser network of distributors and users

The challenge of acceptability. The researcher observed in the field that people in areas of zingwangwa, chilobwe and chitawira, their knowledge and understanding of LPG remains low and there are perceptions about unsafe of LPG that it can cause accidents.

This challenge can be solved by doing LPG uptake campaign to sensitize people on the importance or benefits of LPG.

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6.0 Appendices

6.1. Appendix 1

HOUSEHOLD QUESTIONNAIRE

Hello, my name is CHARLES MACHESO, I am student at Malawi University of science and technology. Your household has been randomly chosen to participate in this study. We are trying to learn more about how families using different fuels for cooking. The survey is a confidential exercise, and your name will not be disclosed anywhere. Please feel free to answer these questions as they will help in future community development. Would you be willing to have a discussion with me?

If NO, mark here  and end the interview.

If YES, mark here  to acknowledge that consent for respondent was give

BACKGROUND INFORMATION

1. **What is your name?**

   _____

2. **Is your age below 30 or above 30?**

   _____

3. **Gender**

Male female

4. **Marital status**

   1. Single 2. Married

5. **How many children do you have?**

   _____

   _____

6. **Age and Education of Adults and children**

	Age	Education Level		Age	Education Level
Adult 1 ()		( )	Child 1 ( )		( )
Adult 2 ()		( )	Child 2 ( )		( )
Adult 3 ( )		( )	Child 3 ( )		( )
Adult 4 ( )		( )	Child 4 ( )		( )
Adult 5 ( )		( )	Child 5 ( )		( )

1=Primary; 2 =Secondary; 3 =Tertiary; 4 =No education

7. **Name of the area for which a person is interviewed.**

   _____

8. **Energy access and use at household.**

   a. **Do you have access to or use the following (circle as many choices)**

      1. Grid electricity (yes/no)
      2. 3-stone fire (yes/no)
      3. Gas (yes/no)
      4. Improved cook stove (yes/no)
      5. Other (specify)

9. Which type of fuel does your household usually use (select one)

a. Electricity

b. LPG

c. Firewood

d. Charcoal

10. Give two reasons why you prefer the selected fuel type above

_____

_____

_____

11. Roughly how much money do you spend in the month on the following cooking fuel?

a. Charcoal (MWK)

b. Firewood (MWK)

c. LPG (MWK)

d. Electricity (MWK)

12. How many times on average do you cook in your home?

a. 1 up to 3 times

b. 2-4-5 times

c. 3-above 5 times

13. What cooking device/appliances do you use? Please tick the one applicable

a. improved cooking stove

b. Open fire (3 stone fire)

c. Gas cylinder

d. Electric cooker

e. Charcoal stove

14. Who does most of the cooking in the house?

a. Male

b. Female

15. Source of charcoal

a. Government Forest

b. Private/commercial seller

c. Fam

d. Woodlots

e. Purchase from market

16. **Source of firewood**

1. Government Forest

2. Private/commercial seller

3. Woodlots

4. Purchase from market

DAILY ENERGY CONSUMPTION AT HOUSEHOLD LEVEL

1. **Type of Cooking Fuel** (1=Electricity; 2=LPG; 3 =Firewood;4=Charcoal)
2. **State what item was cooked or heated (food, water) using the fuel**

   _____

   _____

   _____ _____

3. **Time taken (minutes) for each item.**

_____

_____

3. **Quantity/Units of fuel used for each item.**

   _____

   _____

   _____

4. **Unit Cost of the Fuel Used.**

   _____

   _____ _____

5. **Total Cost of Fuel Used**

_____

_____

_____

7. Frequency of cooking or heating the listed items per day

_____

_____

_____

_____ _____

END OF QUESTIONNAIRE