REPUBLIC OF KENYA

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POWERING FREEDOM

Ministry of Energy and Petroleum

State Department For Energy

HOUSEHOLD ENERGY AND INDOOR AIR QUALITY

THE IMPACT OF VARIOUS IMPROVED COOKSTOVES ON HOUSEHOLD ENERGY, HEALTH AND ENVIRONMENT IN SAGALLA LOCATION, TAITA-TAVETA COUNTY AND NAMANGA LOCATION, KAJIADO COUNTY, 2021

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FOREWORD

Energy is a basic and critical input in the production and consumption processes of economic productivity and industrial growth. Energy production and use is one of the single largest contributors to global warming. Globally, 2.4 billion people are estimated to rely on environment polluting solid biomass fuels such as fire-wood, charcoal or animal waste for cooking and heating. In developing countries, close to 90% of rural households rely on solid biomass for domestic use. The World Health Organization (WHO) estimates that 3.8 Million people globally die prematurely from illness attributable to household air pollution. This is mainly due to cooking with unclean fuels and traditional cooking stoves.

Kenya targets universal access to clean cooking by 2028 in line with the existing global and local commitments contained in Sustainable Development Goal (SDG) no.7, Sustainable Energy for All (SEforAll) and Nationally Determined Contributions (NDC). As it is, the use of improved cook stoves has a potential of supporting broader transitions from polluting fuels to cleaner forms of energy. As Kenyans, our focus on cooking solutions is pegged on Article 42 of the Constitution which guarantees all Kenyans “the right to a healthy and clean environment”. This makes access to clean cooking solutions, a human rights issue.

The overreliance on biomass as a primary source of energy has led to increased deforestation with resultant negative impacts on the environment. That being the case, solid fuels are typically burned indoors in poorly ventilated structures. These fuels are used on inefficient cook-stoves or open fire spaces which do not support complete combustion. More often than not, women and young children tend to get exposed to high levels of indoor air pollution leading to health complications and premature deaths from lung cancer and child pneumonia.

Inadequate awareness of the different types of improved cook-stoves in the market has deterred mass uptake and slowed progress in expanding clean cooking access. This is also likely to result in environmental degradation and widespread health challenges among users emanating from prolonged exposure to indoor air pollution. Similarly, households in both the rural and peri-urban set-ups continue to utilize biomass fuels leading to increased indoor pollution for longer periods of time in the foreseeable future. The Ministry has therefore found it imperative to promote improved and efficient cooking devices for energy conservation and reduction of indoor air pollution.

As a Ministry, I hereby present the findings from an intervention on the impact of using improved cook-stoves on household indoor air pollution. Findings from this study is a treasure trove of knowledge on indoor air pollution and the technological mix appropriate for communities still using biomass as their primary source of energy. I urge all stakeholders involved in supporting clean-cooking in the country to utilize the content of this study when addressing indoor air pollution.

Davis K. Chirchir
CABINET SECRETARY

PREFACE

Biomass still remains the main cooking fuel in the rural and peri-urban areas in Kenya where 68% reportedly rely on traditional biomass fuels. The need for increased adoption of improved biomass cooking stoves is urgently required to address energy, health and environmental conservation issues in our country.

The State Department for Energy through its Renewable Energy Directorate promotes and coordinates research on renewable energy, energy efficiency and conservation technologies. This is the premise on which the study on Kitchen Performance Tests and Indoor Air Quality was conducted in Kajiado and Taita-Taveta Counties. The follow-up study aimed to investigate the exposure to indoor air pollution and kitchen performance tests. Experts also measured fuel consumption in households transiting from traditional to improved cook-stove in a real life setting.

Results from the study established levels of major pollutants in households as compared to daily fuel consumption per person from the use of both traditional and improved cook-stoves. The study was carried out in real-life setting over a 24 hour period. It sought to expose the health risks from indoor air pollution. The households sampled were also transitioning from the use of traditional cook-stoves to the use of improved cook-stoves.

Findings from the study revealed that households sampled used firewood, charcoal and kerosene as fuel. This presented serious health issues to women and young children due to indoor air pollution. Further results gave insights into the environmental impact of using improved cook-stoves on the health of women and young children in the study areas as compared to the traditional cook-stoves.

The State Department for Energy therefore takes this opportunity to present the report on '**HOUSEHOLD INDOOR AIR QUALITY AND KITCHEN PERFORMANCE TESTS: *THE IMPACT OF VARIOUS IMPROVED COOKSTOVES ON HOUSEHOLD ENERGY, HEALTH AND ENVIRONMENT IN SAGALLA LOCATION, TAITA-TAVETA COUNTY AND NAMANGA LOCATION, KAJIADO COUNTY, 2021'***

From the foregoing, we continue to encourage all Kenyans to embrace the use of cleaner fuel options and affordable improved cook-stoves as a way of reducing exposure through modifications to the living environment.

Alex K. Wachira
PRINCIPAL SECRETARY

ACKNOWLEDGEMENT

The Renewable Energy Directorate, among other roles coordinates Renewable Energy Efficiency, Conservation and Integration of Climate Change. In fulfilment of its mandate, the Directorate undertook a study on Indoor Air Quality and Kitchen Performance Tests in Oloroi Village, Namanga Location in Kajiado County and Kirumbi Village, Sagalla Location in Taita-Taveta County. The study was on the impact of the use of improved cook-stoves on indoor air quality. Results from the follow-up study showed that Carbon Monoxide (CO) exposure levels were 29ppm in Sagalla and 59ppm in Namanga down from 77ppm and 95ppm registered during the baseline study respectively. Nevertheless, these findings revealed higher levels of Carbon Monoxide (CO) and Particulate Matter ($PM_{2.5}$) above the acceptable World Health Organization (WHO) levels of 6ppm and 25µg/m^3 respectively. The mean Carbon Dioxide (CO_2) concentration of 1157ppm recorded in Namanga and 1056ppm recorded in Sagalla within a 24 hour period were higher than the 1000ppm allowable in the WHO guidelines.

The average Particulate Matter of 1053µg/m3 registered in Sagalla and 1061µg/m3 registered in Namanga, were above the WHO recommended levels of 25µg/m^3. The results revealed that households in both locations were at health risk due to the high exposure. Households were therefore advised to use improved cook-stoves in well-ventilated environment.

I would like to express my deepest appreciation to the Cabinet Secretary (CS) Mr. Davis Chirchir for the immense support extended to the team of experts involved in the 'Indoor Air Quality and Kitchen Performance Tests' study. We relied heavily on the policy direction provided by the CS at all times.

In a very special way, I would like to thank our Principal Secretary (PS) Mr. Alex Wachira, whose day-to-day administrative guidance, support and technical input was the backbone of the assignment. Facilitation received from the PS made it possible for our teams to seamlessly implement the assignment.

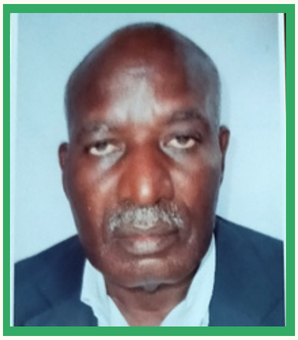
Specifically, special gratitude goes to the research team led by Prof. Jacob Kithinji, Lead researcher from the Chemistry Department of the University of Nairobi, assisted by his research assistants.

I am deeply indebted to the Renewable Energy Directorate team led by the Coordinator of the Kenya Energy Sector and Environment Social Responsibility Programme Fund (KEEP) Esther Wang'ombe, OGW. Tireless efforts by members of the team composed of: Eng. Benson M. Mwakina, HSC, Mr. Francis N. Nderitu, Mr. John Bakari, Mr. Dennis Mokaya, Lydia Baru, Viviene Simwa, Ibrahim Jaldesa, Elizabeth Odongo and Florence Vosena are highly appreciated.

Ultimately, much appreciation goes to the entire Energy family who in one way or the other have supported the production of this study. Results from this study will contribute to improving the quality of interventions aimed at improving the quality of life for all Kenyans.

Eng. Isaac N. Kiva, OGW
SECRETARY RENEWABLE ENERGY

RESEARCH TEAM



Jacob Kithinji, a Professor of Combustion and Energy at the University of Nairobi, Department of Chemistry, Chiromo Campus. He teaches and supervises students in the area of Fuel Science and Technology at both graduate and postgraduate levels. He is in charge of National Stoves and Fuels Knowledge Testing Centre and chairs the Committee on Development of Stoves' Standards.

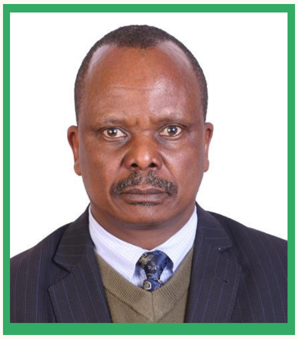
Esther Wang'ombe, OGW

A Senior Deputy Director, Renewable Energy at the State Department for Energy, Ministry of Energy and Petroleum. She is the Coordinator of Kenya Energy Sector and Environment Social Responsibility programme Fund (KEEP) and Climate Change activities. Her first Degree is in BSc. Forestry from Moi University, Kenya; Master's degree in Environmental Studies from Kenyatta University, Kenya and a Post Graduate diploma in Forestry for Rural Development from ITC, Netherlands. She has also undertaken Strategic Leadership Courses from Kenya School of Government as well as several courses on project management;

Mr Francis N. Ndertu: MSc. CBIS, BSc. Agric Eng.

Assistant Director, Renewable Energy, Ministry of Energy and Petroleum. Has 37 years' experience working in the agriculture and energy sector. Has a Bsc. degree in Agricultural Engineering and an Msc. in Computer Based Information Systems – CBIS and a Certificate in Green House Gas (GHG) Modelling using long range energy alternatives planning system – LEAP by Climate and Energy Advisory Kenya. He has proficiency Certificate in Energy Sector GHG Accounting using IPCC Guidelines 2006 from the GHG. Management Institute ,Korea

RESEARCH TEAM



Eng. Benson Mwakina, HSC is an Electrical Engineer with over thirty-three years post graduate experience in Public Service having graduated from the University of Nairobi-Kenya in 1990. He is trained both locally and internationally on renewable energy technologies, project formulation, feasibility study analysis, environmental impact analysis, contract management and funding. Eng. Mwakina is currently Director of Renewable Energy in charge of Alternative Energy Technologies in the Ministry of Energy & Petroleum.

Eng. Benson M. Mwakina, HSC handles a number of cross-cutting assignments in the Ministry of Energy as assigned by the Principal Secretary from time to time. He is currently the alternate Board Member at Kenya Power, the Chairman Board of Directors for East African Centre of Excellence for Renewable Energy & Energy Efficiency (EACREEE), the National Focal Point for the International Solar Alliance (ISA) among others.

Lydia Baru

A Principal Renewable Energy Assistant at the State Department for Energy, Ministry of Energy and Petroleum. She has 38 years' experience working on Farm Forest Management in gazetted Forests and energy saving, application and production of various energy sources and devices. She holds a Diploma in Forestry

Justus Muoki

Research Assistant in the area of reducing non-renewable biomass use for household cooking, heating and indoor air pollution. He has played a critical role in generating carbon finance used to subsidize the cost of efficient cookstoves to enable affordable access to clean energy for families throughout Kenya. He holds a Bachelor's degree in Environmental Studies (Community Development) from Kenyatta University. In the last 8 years, he has been researching on improved cookstoves, renewable household energy and indoor air pollution at the University of Nairobi.

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EXECUTIVE SUMMARY

The main objective of the Follow-up Survey was to assess the impact of the improved cookstoves to the general health of Households compared to the situation found during the Baseline Survey. Views from Households on the impact of the new cookstoves towards their health was collected while Indoor air concentrations (CO, CO_2 and $PM_{2.5}$) resulting from the use of the improved cookstoves were investigated and quantified. Kitchen Performance Tests (KPT) were also carried out to determine improvement in fuel consumption of the improved cookstoves as compared to the cookstoves in the Baseline Survey. Kenya Ceramic Jiko, the Maendeleo portable and Maendeleo Multipurpose stoves were used as improved cookstoves. The survey was carried out in April 2021 in Sagalla location, Taita-Taveta County and Namanga Location, Kajiado County.

The survey adopted the following criteria: i) The respondent had to be the main cook of the family and had a child less than five years of age ii) the improved stove was designed to burn solid fuels (firewood, agricultural waste, or charcoal) iii) cooking took place in an enclosed place. A total of 47 households participated in the household survey which included 28 in Sagalla and 19 in Namanga. Emissions monitoring and Kitchen Performance Tests (KPT) was done in 8 households in Sagalla and 7 households in Namanga. Most of the respondents in both study areas were below 35 years of age at 57% in Sagalla and 62% in Namanga. The study also revealed that the average household size was 6 in Sagalla and 7 in Namanga which is above the national average of 3.9 (KNBS 2019 Census).

There was marked improvement in the health of the children under 5 years with the introduction of improved cookstoves in the survey area. In Sagalla 46% of the children experienced coughing down from 70% noticed during the Baseline Survey, while 35% of the children experienced coughing down from 61% in Namanga. Similarly, 21% of children experienced breathing difficulty down from 45% in Sagalla and 18% down from 33% of children in Namanga. Immense improvement was also witnessed in the health of women where coughing reduced from 68% to 14% in Sagalla and 49% to 26% in Namanga.

It can be deduced that the adoption of improved stoves as the main cooking device resulted in overall positive impacts on the health of daily users in both locations.

The survey revealed that Maendeleo improved cook-stoves were used in over 68% of the households in both study areas as their primary cooking devices. However, 11%

of the households in Namanga used both 3-stone and Maendeleo cookstoves as their main stove.

Majority of the households, 57% in Sagalla and 60% in Namanga generally used their stoves for cooking only. 32% of the households in Sagalla used stoves for both cooking and heating while 26% of the respondents' in Namanga used stoves for cooking, heating and lighting. Overall, the main purpose for using improved stoves was for cooking. The study revealed that majority of the households use fuel saving devices which includes thermos flasks, food covers, and hot pots.

Data considered in indoor air pollution covered Carbon Monoxide (CO), Particulate Matter ($PM_{2.5}$) and Carbon Dioxide (CO_2). Results showed 63% of households in Sagalla had CO concentrations above the acceptable limits of 6ppm over a 24 hour period while in Namanga it was 86% of households.

am was observed that the average indoor concentration of CO obtained over a period of 24 hours was highest in Namanga (at 59ppm) from a household that used firewood on the Maendeleo portable stove, while two households, one using Maendeleo multipurpose and the other Maendeleo portable recorded the highest amount of CO (of 29ppm) in Sagalla. Out of the 15 households sampled, three households, using Maendeleo portable stoves, the indoor CO concentrations was within the acceptable level (6ppm). In all the other households, CO concentrations were higher than the acceptable exposure. CO is produced by incomplete burning of carbon containing fuels and is highly toxic in poorly ventilated spaces. Therefore, it is advisable for people to use stoves in a well ventilated environment.

Indoor air quality analysis from the 15 households sampled in the follow up study revealed that there was a considerable reduction in the amount of CO(ppm), CO_2(ppm) and Particulate Matter($PM_{2.5}$) produced when improved cook stoves where used compared to baseline stoves. In spite of the improvement in indoor air quality attained by cooking with the improved stoves, the concentration averages of CO and $PM_{2.5}$ in the 24 hour monitoring period were still higher than the acceptable levels set out in the WHO guideline standards on exposure to these emissions in the same period of time, hence hazardous.

ABBREVIATIONS

CO	Carbon Monoxide
CO_2	Carbon Dioxide
EU	European Union
HH	Household
ICS	Improved Cook Stoves
IHME	Institute for Health Metrics and Evaluation
KCJ	Kenya Ceramic Jiko
KPT	Kitchen Performance Test
LPG	Liquefied Petroleum Gas
MoE	Ministry of Energy
MoEP	Ministry of Energy and Petroleum
PM	Particulate Matter
SDE	State Department for Energy
TCS	Traditional Cook Stoves
WHO	World Health Organization

KCJ

Maendeleo Portable

CHAPTER ONE

1. INTRODUCTION

Stack of Firewood

Approximately half of the global population and 90% of rural households, almost all in developing countries rely on solid biomass for cooking and heating. These solid fuels are typically burned indoors in poorly ventilated structures and mostly inefficient stoves or open fires with many products of incomplete combustion mainly Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Particulate Matter ($PM_{2.5}$). Consequently, women and young children are exposed to high levels of indoor air pollution everyday resulting in health complications like lung cancer and child pneumonia leading to their premature deaths. According to IHME, an estimated 3.5% deaths are attributed to high levels of household indoor air pollutants annually (IHME, 2015).

An insight into developed countries, reveals a mass shift from biomass fuels to cleaner fuels such as LPG, ethanol and electricity for domestic cooking purposes. On the other hand, a majority of households in developing countries continue to use biomass fuels notwithstanding the availability of cleaner fuels. This is attributed to high levels of household poverty in most of the developing countries, which prohibits the adoption of cleaner fuels in the households. The slow pace of energy infrastructure development, high cost of clean fuels and lack of policies to drive the mass uptake of clean fuels in developing countries, imply that biomass fuels will continue to be used by the poor for longer periods resulting in environmental degradation and widespread health problems among users. Kerosene, the common alternative to biomass fuels used predominantly by poor urban households in developing countries for cooking and lighting also emits high amounts of air pollutants because the kerosene stoves and lamps typically used are very inefficient.

CHAPTER TWO

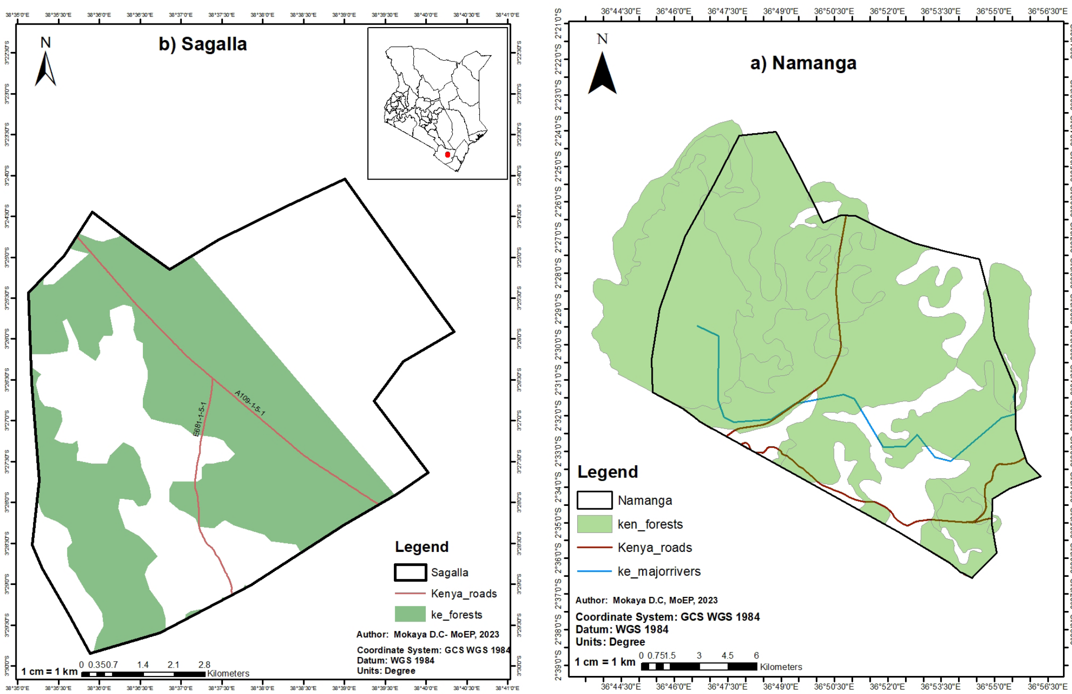
2.0 METHODOLOGY

2.1 Introduction

This section illustrates how the research study was carried out and outlines the step-by-step process used to achieve the results needed to draw conclusion and recommendations.

2.2 Location of the study

The study was conducted in April 2021 in Sagalla and Namanga Locations in Taita Taveta and Kajiado Counties respectively which was the same area as the baseline study.



2.3 Selection of households

The households used in this study were drawn from those that participated in the baseline study and who benefited from the issued improved cookstoves. Out of the 103 households who participated in the baseline study, 47 households participated in round two energy and health survey (19HH in Namanga and 28HH in Sagalla).


%MC


Air Quality Monitors

The survey also conducted emissions measurements and kitchen performance tests for 15 households (7HH in Namanga and 8HH in Sagalla) out the 30 households done in the baseline study. These households are the same as those who participated in the baseline based on the following criteria: - i) The respondent had to be the main cook of the family and had a child less than five years of age ii) the improved stove was designed to burn solid fuels (firewood, agricultural waste, or charcoal) iii) cooking took place in an enclosed place.

2.4 Administration of questionnaires

The questionnaires were administered to obtain the general information on health and energy utilization of the households including household size, age of the respondent, main type of fuel used and its source, type and condition of stove used and preference of improved cook stove. The study was also focused on gaining an insight about the effects of cooking using improved cook stoves on the health of women and children under 5 years. One on one interviews were conducted on female members who were active cooks in the households. Direct observation was also done by the enumerators to assess the physical conditions of the cook stoves. The choice of enumerators was particularly crucial for the study hence; all the enumerators had to be literate since the questions had to be read to the respondents verbatim. Additionally, at least one of the enumerators had to know the local language to ensure effective data collection.

2.5 Kitchen Performance Testing and Indoor Air Pollution Monitoring (IAPM)


KPT


Emissions

Out of the 47 households who participated in the follow up survey, 15 households participated in the kitchen performance tests and emissions measurement. Prior to the start of the 24-hour KPT, households were to have enough fuel to last more than twenty-four hours. At the start the fuel was weighed using a Digital Scale and recorded. Three pieces of fuel were sampled and average moisture content determined using pin type Moisture Meter. After 24 hours, the remaining fuel was weighed to determine the amount of fuel the household had used within the time. Questionnaires were administered to gather qualitative data on stove type used, physical appearance, type and amount of fuel consumed, type of food cooked, and number of people cooked for. During the KPT period the kitchen air pollution monitoring was undertaken to evaluate real time kitchen concentrations of Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Particulate Matter ($PM_{2.5}$). Using specialized equipment, Carbon Monoxide data was measured using the EL-USB-CO data logger at an interval of 1 minute; Carbon Dioxide (CO_2) concentration was measured at an interval of I minute using HOBO Teleire 7001 TEMP/RH/CO2 data logger combined with HOBO U12 to record and download the data. Particulate Matter ($PM_{2.5}$) was also measured at one-minute interval using the University of California, Berkeley Particle Monitor (UCB-PM Monitor).

Indoor air quality monitors were placed 1meter from the stove at a height of 1.5 meters from the ground to emulate the distance from which a person using the stove sits and the height simulated a person standing in the room. The main sources of indoor air pollution released is as a result of incomplete combustion of biomass fuels during cooking. Indoor air concentrations was analyzed using MS Excel to determine the average and maximum concentrations of CO, CO_2 and $PM_{2.5}$ emitted per household.

CHAPTER THREE

3.0 RESULTS AND DISCUSSIONS

3.1 Introduction

This chapter covers the respondents' general information, household health, energy (stoves and fuels), 24hr real-time indoor air emissions data and kitchen performance tests.

3.2 Respondents' General Information


KCJ


Maendeleo Portable

The survey was designed and administered only to households using firewood, charcoal or agricultural waste as fuel. A total of 47 households participated in this household study which included 28 in Sagalla and 19 from Namanga. KPT and emissions monitoring was done in 8 households in Sagalla and 7 households in Namanga.

In Sagalla, 20 households used Maendeleo Portable, 2 used KCJ, one used RMS-2 (slightly improved 3 stone), 5 used the 3-stone as their primary stoves. 3 and 4 households that participated in the KPTs and emission monitoring used Maendeleo Multipurpose and Maendeleo Portable cookstoves respectively, while 1 used the KCJ stove and LPG cooker.

The table below shows the distribution of households by age in the two locations.

Table 1: Distribution of households by age

Age (Years)	Sagalla		Namanga	
	Number	Percent	Number	Percent
15-19	1	4	1	6
20-25	3	11	4	22
26-30	6	22	1	6

Age (Years)	Sagalla		Namanga	
	Number	Percent	Number	Percent
31-35	5	19	5	28
36-40	2	7	3	17
41-45	4	15	3	17
46-50	1	4	0	0
>=51	5	19	1	6
TOTAL	**18**	**100**	**27**	**100**

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The survey targeted persons who were responsible for cooking in the households. The findings revealed that over 50% of all respondents in Sagalla and Namanga were under 35 years of age. This implies that the population of both study areas are youthful and are receptive of adoption of modern cooking stove.

The table below shows the household members who regularly take meals from the same pot.

Table 2: Distribution of households by number of regular household members

Household Size	Sagalla			Namanga		
	Number of HH	Total Number of HH Members	Percent	Number of HH	Total Number of HH Members	Percent
3	3	9	11	1	3	5
4	5	20	18	1	4	5
5	5	25	18	5	25	26
6	2	12	7	3	18	16
7	5	35	18	2	14	11
8	5	40	18	3	24	16
9	1	9	4	1	9	5
10	1	10	4	1	10	5

Household Size	Sagalla			Namanga		
	Number of HH	Total Number of HH Members	Percent	Number of HH	Total Number of HH Members	Percent
11	0	0	0	2	0	11
13	1	13	4	0	0	0
Total	**28**	**173**	**100**	**19**	**129**	**100**

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The average number of household members was calculated using the following formula;

$$\text{Average} = \frac{\sum(\textit{regular household members})\sum(\textit{regular household members})}{\sum(\textit{number of households}) \qquad \sum(\textit{number of households})} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Average Number of HH Sagalla = Total number of HH Members/Total number of HH

= 173/28 = 6

Average number of HH Namanga = 129/19 = 7

These results shows that the households size for both study areas are higher than the National average which stands at 3.9 (KNBS: 2019).

3.3 Households' Health

The study was set out to explore the health of children under the age of five years as well as the health of the female respondents responsible for cooking. Further questions explored the relationship between smoke emanating from cooking stoves and children's health. Another question explored the perception of health (cough, breathing difficulties, burns, eye problem, ear discharge and headache) by respondents relating to children under the age of five years as shown in the figure below:

Households' Distribution by Children's Health

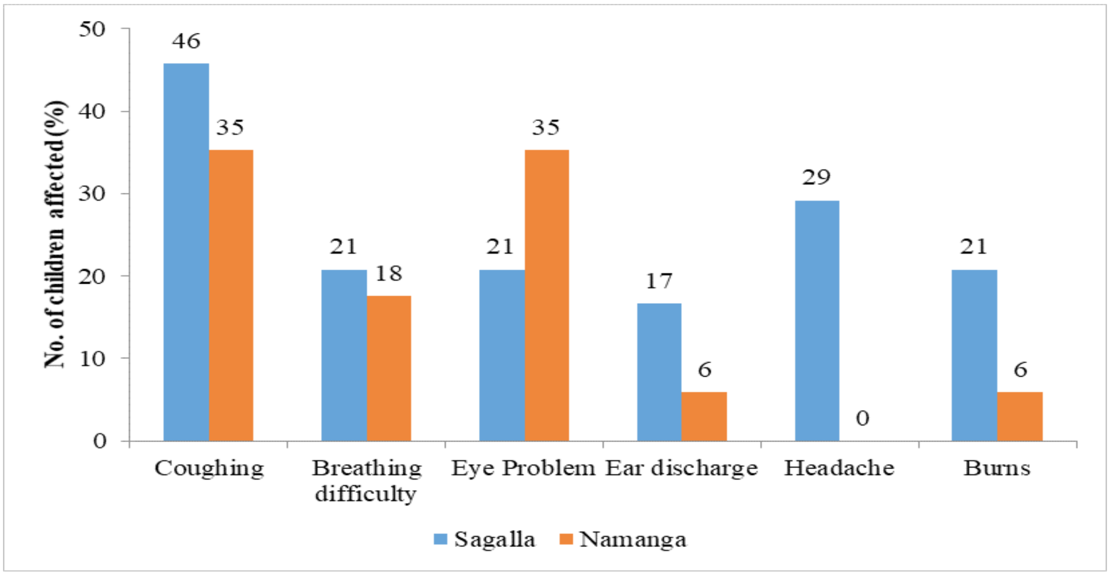


Figure 1: Distribution of households by health of children

Source: ***MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations***

The study explored the various health issues experienced by children below 5 years in the last one month, under improved stoves conditions. It emerged that, most children in this age group experienced coughing (46%), while (17%) experienced pus discharge from their ears as observed in figure 1. These results also indicated a substantial number of children in Sagalla had breathing difficulty, eye problem, headache and burns, at 21%, 21%, 29%, and 21% respectively. A similar trend was seen in Namanga where (35%) of the children experienced coughing, while 6% experienced ear discharge.

We see marked improvement in the health of the children under 5 years with the introduction of improved cookstoves in the survey area. In Sagalla 46% of the children experienced coughing down from the 70% noticed during the Baseline Survey, while 35% of the children experienced coughing down from 61% in Namanga. Similarly, 21% of children experienced breathing difficulty down from 45% in Sagalla and 18% down from 33% of children in Namanga.

The figure below shows multiple responses on distribution of households by children's exposure to smoke and its effects.

Exposure and effects of smoke to children

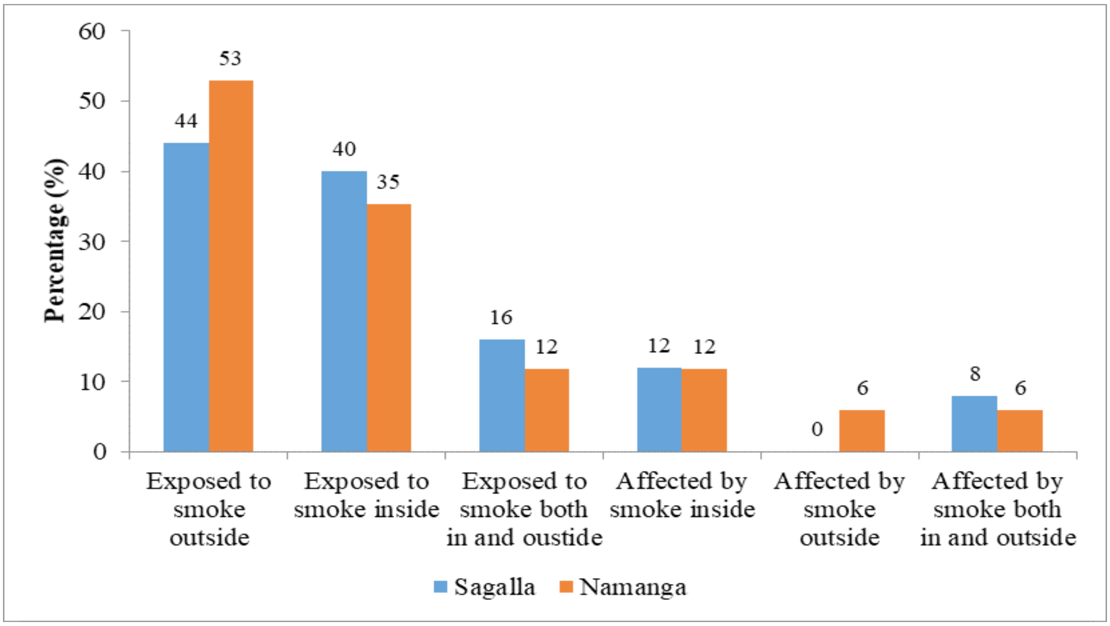


Figure 2: Distribution of households by whether children are exposed to smoke and if it affects them

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The effects of smoke on children below 5 years relative to where they are when cooking was done was examined. As can be seen in Figure 2, 44% and 53% of the children in Sagalla and Namanga respectively were not in the kitchen when cooking was being done using improved stoves. This implies that the children were not exposed to smoke. Of the children exposed to smoke outside in Sagalla, no household reported any observable effects of smoke on their under-fives. In Namanga, 6% of the respondents thought children under 5 years were affected by the smoke emitted by improved stoves when exposed outside. On the other hand, 40% of children under 5 years of age in Sagalla and 35% in Namanga were exposed to smoke while inside. 12% of these households said the smoke affected their children. The survey results also revealed that, 16% and 12% of the children in the two study areas were exposed to smoke both inside and outside. With regard to this exposure 8 and 6 percent of the children in Sagalla and Namanga respectively, were affected by smoke.

The figure below, the study endeavoured to establish the extent to which women coughed during the onset of cold/wet seasons

Question: Do women cough during the beginning of the cold/wet seasons?

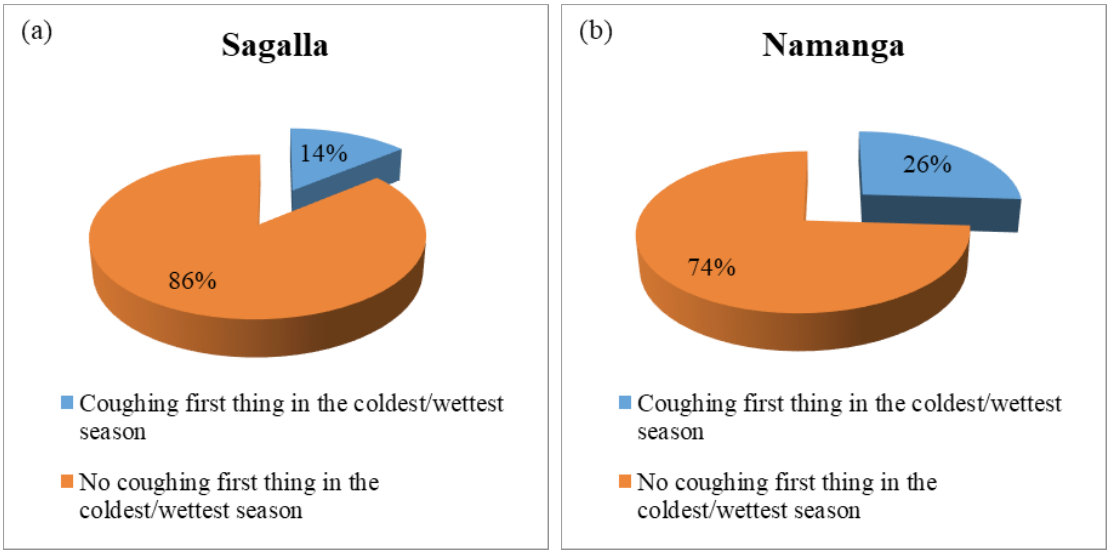


Figure 3: Coughing first thing in the coldest/wettest season among women

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

Figure 3a shows, 86% of women in Sagalla did not experience coughing during the onset of cold/wet seasons when using improved stoves. In Namanga, 74% of the women who adopted the improved stoves did not experience coughing.

Immense improvement was witnessed in the health of women where those who coughed reduced from 68% to 14% in Sagalla and from 49% to 26% in Namanga.

Based on these results, it can be deduced that the adoption of improved stoves as the main cooking device resulted in overall positive impacts on the health of daily users in both locations.

The figure below the study endeavoured to establish the occurrence of eye related problems experienced by the women

Question: How often do you experience eye problems?

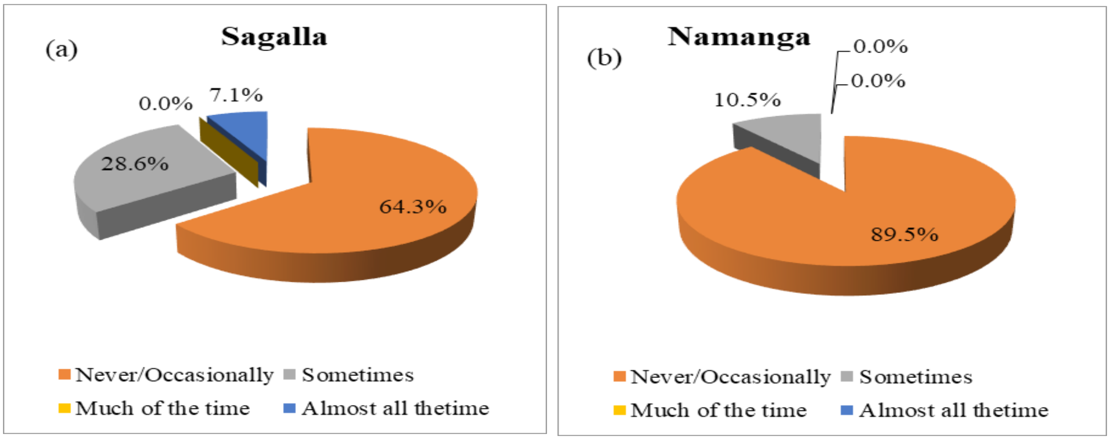


Figure 4: Prevalence of eye problems among women

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The survey findings demonstrated that when intervention stoves were used for cooking, 64% of women in Sagalla and 90% in Namanga never experienced eye issues as shown in figures 4a and 4b.

In the baseline study 39% of women in Sagalla never experienced eye problems which is 25% lower than those women who experienced eye problems after stoves replacement. Similarly in Namanga 57% of women never experienced eye problems which is 32% lower than those who never experienced eye problems (89%).

This scenario demonstrates that if adopted widely, improved cook stoves had the potential to mitigate eye complications brought about by exposure to emissions.

3.4 Energy: Cook-stoves and Fuel use

The table below shows distribution of households by which cook stoves the respondents are aware of.

Table 3: Distribution of households by type of stoves

Type of cookstoves mostly used	Sagalla		Namanga	
	Number	Percent	Number	Percent
3-stone	5	18	2	11
RMS-2 pots	1	4	1	5
Maendeleo	20	71	13	68

Type of cookstoves mostly used	Sagalla		Namanga	
	Number	Percent	Number	Percent
Charcoal stove	1	4	1	5
3-stone&Maendeleo	0	0	2	11
Improved charcoal stove (Jikokoa)	1	4	0	0
Total	28	100	19	100

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

Averaged results from both study locations revealed that Maendeleo improved cook-stoves were used in over 68% of the households as their primary cooking device as shown in Table 3 above. Despite being given improved cookstoves, 18% and 11% of households in Sagalla and Namanga respectively still used 3-stone stove as the primary cooking device. RMS-2 pots, which is a slightly improved version of the 3-stone was used in at least 4% of households in Sagalla and 5% in Namanga. 11% of households in Namanga used both the 3-stone and the Maendeleo cook-stoves for cooking. The continued use of conventional cooking devices in the households was attributed to loss or damage of whole or part of the improved stoves. These findings indicate that, the majority of rural households will readily switch to improved stoves as the main cooking device when they are easily available and affordable.

3.5 Distribution of households by the respondents' main cookstoves

The figure below shows the distribution of main cookstoves in the households

Question: What is your main cookstove?

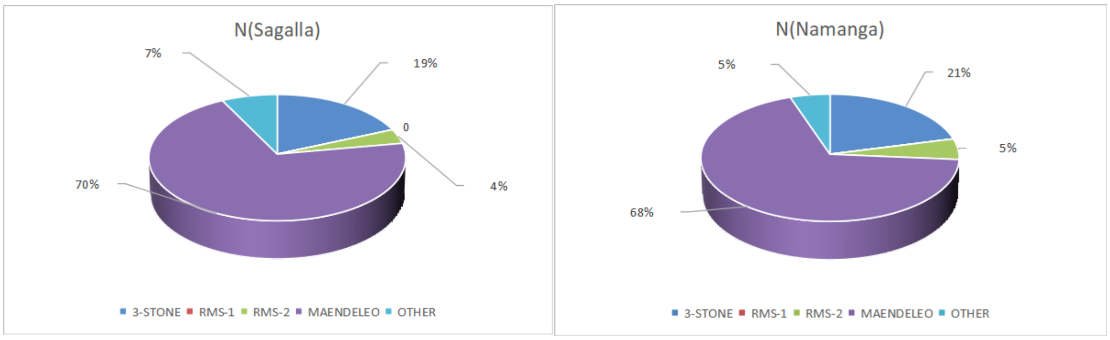


Figure 5: Distribution of main cookstoves in the households

The figure below shows the distribution of households by the main purpose of the cookstoves.

Question: What do you use cookstoves for?

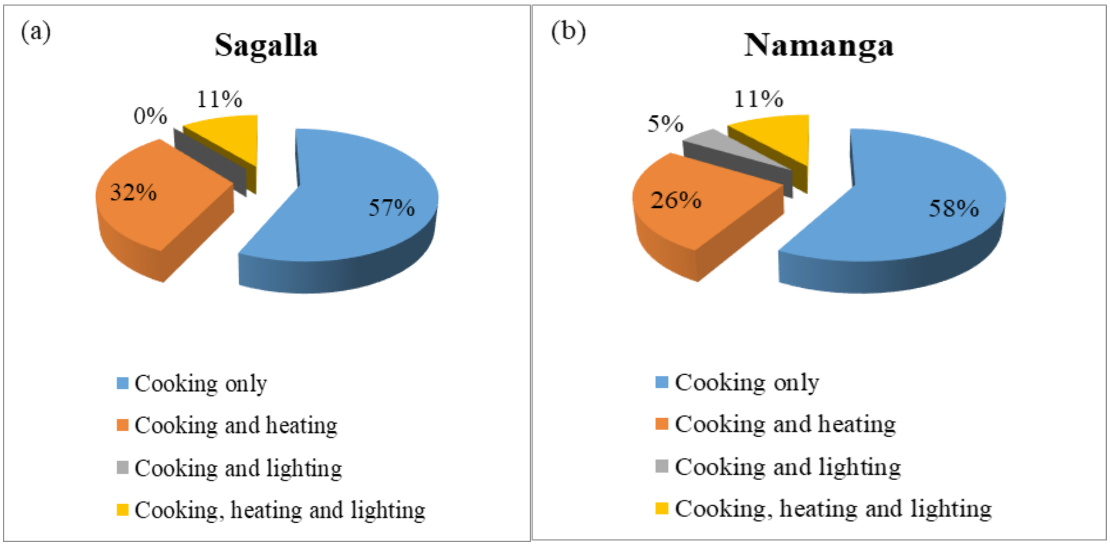


Figure 6: Distribution of households by main uses of improved cook stoves

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

Heating

Cooking

The study explored the main purpose of using an improved stove. Majority of the sampled households, 57% in Sagalla and 58% in Namanga generally used their stoves for cooking purposes only. In Sagalla, stoves were use for both cooking and heating by 32% of the households while in Namanga 26% of the respondents used stoves for cooking, heating of space and as a source of lighting at night as shown in Figure 6 above. Overall, the main purpose for using improved stoves in both study areas is cooking. However, there is need for introducing heating and lighting devices to complement the use of improved cook-stoves for lighting.

The table below shows the distribution of households by type of fuel used

Table 4: Distribution of households by type of fuel used

Type of fuel	Sagalla		Namanga	
	Number	Percent	Number	Percent
Firewood	15	54	13	68
Charcoal	3	11	3	16
Firewood and Charcoal	6	21	2	11
Firewood and Agriculture waste	4	14	0	0
Firewood, Charcoal, and Gas	0	0	1	5
Total	**28**	**100**	**19**	**100**

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

Agricultural Waste

The study explored the distribution of households by the type of fuel used. The most common fuel used by the households was firewood (54% in Sagalla and 68% in Namanga). 11% of the households in Sagalla used charcoal only while in Namanga, it was 16 %. 21% and 11% of households used firewood and charcoal in Sagalla and Namanga respectively as shown in Table 4 above. Combination of firewood and agriculture waste was used in 14% of the households in Sagalla while no household in Namanga combined the use firewood with agriculture waste. 5% households in Sagalla used firewood, charcoal and gas for cooking while in Namanga this combination was not observed in any of the sampled households.

These results can be attributed to the fact that firewood is easily accessible and mostly free of charge to most of the surveyed households.

8The figure below shows the distribution of households by sources of firewood

Households Distribution by Sources of Firewood

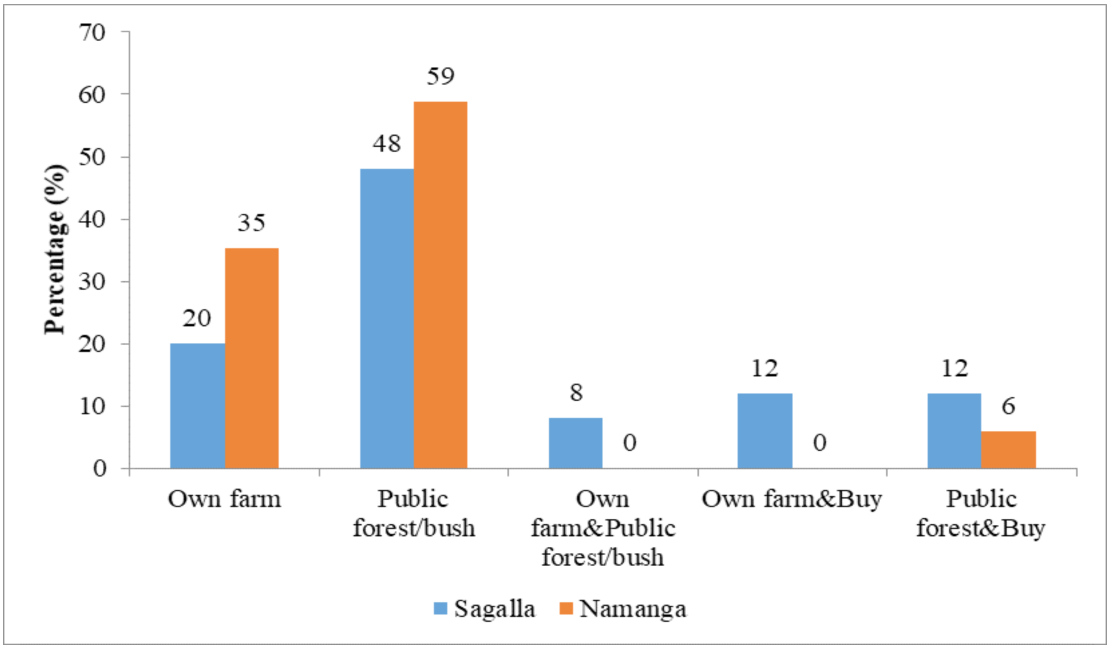


Figure 7: Distribution of households by sources of firewood

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the distribution of households by sources of firewood. According to the study findings, 48% of the sampled households in Sagalla and 59% in Namanga used firewood collected from public forests while 20% of the households in Sagalla and 35% in Namanga got firewood from own farms as shown in figure 7 above. These results imply that public forests/bushes are in danger of degradation if there is no regulation on firewood collection. The introduction of the improved stoves is expected to check this degradation by reducing the demand for firewood.

The figure below shows the distribution of households by whether respondents use fuel saving devices.

Question: Do you use any fuel saving devices?

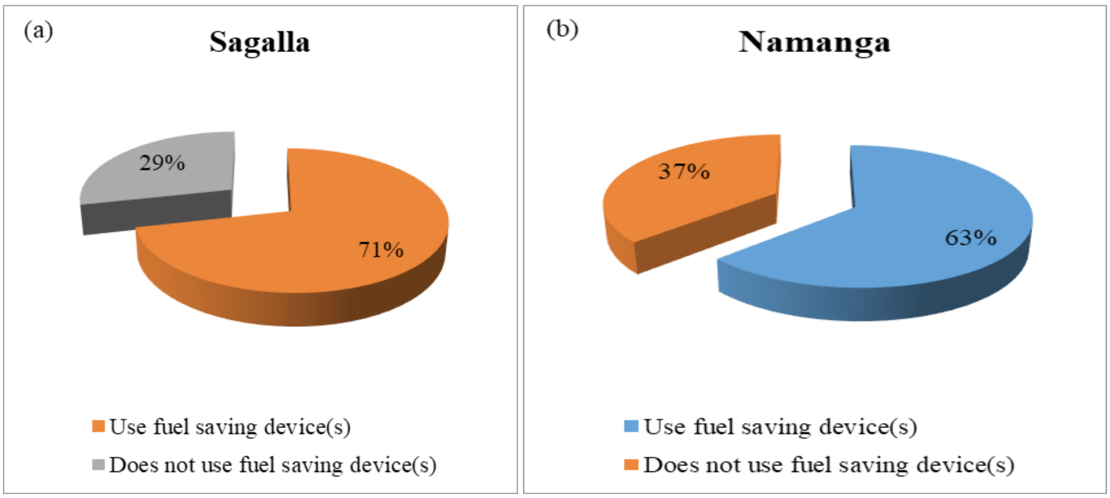


Figure 8: Distribution of households by use of fuel saving devices

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the distribution of households by the use of fuel saving devices. The study established that majority of the households in Sagalla (71%) and in Namanga (63%) used fuel saving devices as shown in Figure 8a & 8b above. Examples of fuel saving devices used include: thermos flasks; covering food while cooking and keeping food in hotpot. This demonstrates that the households in both locations are aware of fuel saving devices.

The table below shows the distribution of households by type of fuel saving devices used

Table 5: Distribution of households by type of fuel saving devices used

Type of fuel saving device used	Sagalla		Namanga	
	Number	Percent	Number	Percent
Fireless cooker	0	0	0	0
Thermos flask	3	11	8	42
Covering food while cooking	7	25	0	0
Thermos flask and covering food while cooking	10	36	3	16
Thermos, Covering food & Hotpot	1	3	0	0
Covering and Hotpot	1	3	0	0
Other (hotpot)	1	4	0	0
Did not use any fuel saving device	5	18	8	42
Total	**28**	**100**	**19**	**100**

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations


Fuel Saving devices

The study explored the prevalence of the various fuel saving devices in 28 and 19 households in Sagalla and Namanga respectively. 75% of households in Sagalla used thermos flask and/or covered food while cooking, while in Namanga it was 58%. 50%

of households in Sagalla used Thermos flasks while in Namanga the number was 58%. These results indicate that the fireless cooker is not used in either of the locations suggesting the need to create more awareness on the use of device. While 11% of households in Sagalla employed the use of hotpots no households in Namanga employed the use of hotpots which can be attributed to lack of awareness. There is need to increase awareness in all the location on the use of fire-less cooker.

The figure below shows the distribution of households by respondents' knowledge of improved cook stoves

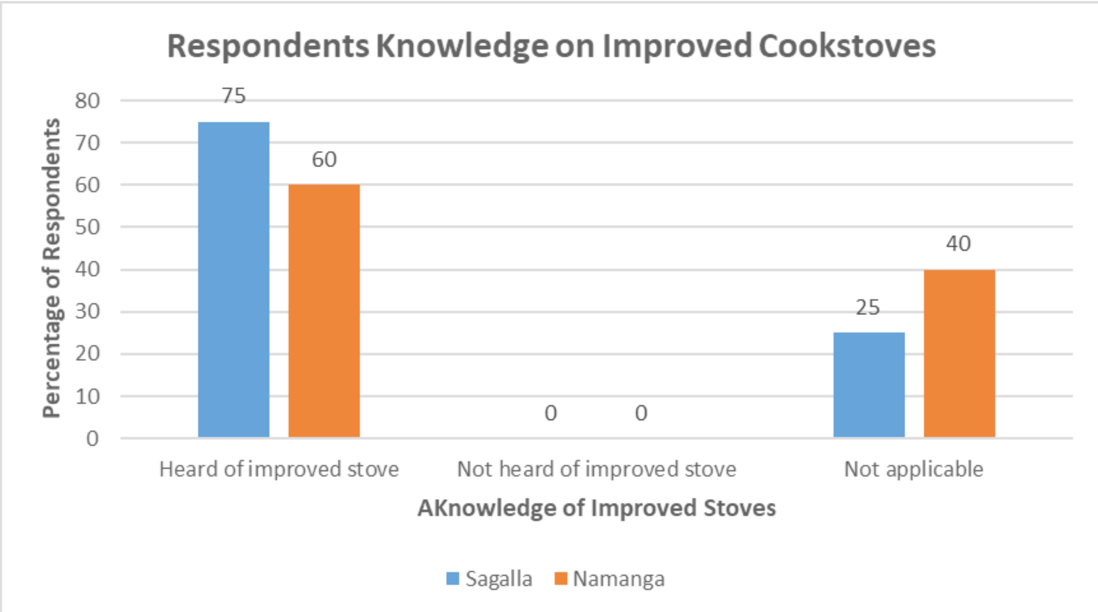


Figure 9: Distribution of households by respondents' knowledge of improved

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored whether the respondents were aware of improved cookstoves. Results demonstrated that most respondents in both locations had heard of improved cookstoves at 75% in Sagalla and 60% in Namanga but 25% and 40% respectively did not answer. This can be attributed to the fact that all respondents were issued with improved cookstoves.

The figure below shows the respondents' response on whether to continue using the old stoves after acquiring the improved stoves

Question: If you get the improved stove, would you continue to use the traditional stove?

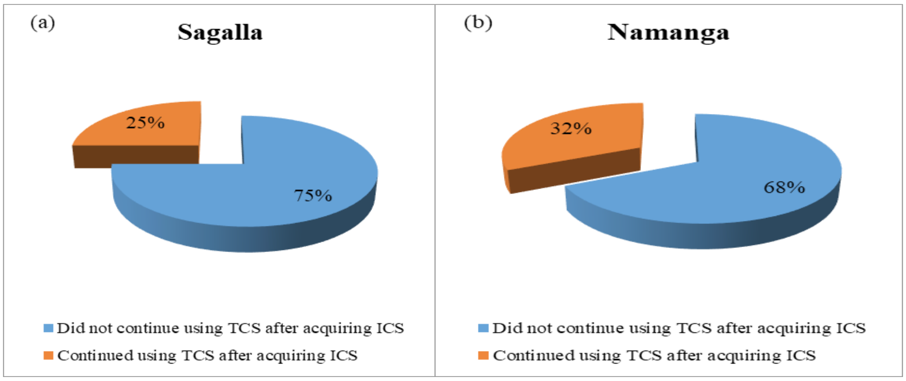


Figure 10: Distribution of households by continued use of Traditional Cookstoves after acquiring Improved Cookstoves

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the use of traditional stoves after acquiring improved ones. 75% and 68% of the sampled households in both locations did not continue using traditional stoves after acquiring improved stoves as shown in Figure 11 above. In Sagalla, 2 households explained that they continued using their old stoves despite having the improved stoves because firewood was easily available. In Namanga, 1 household could not use the improved stove because it made the house very hot during the day so they used 3-stone fire outside.

There is need to create more awareness concerning the benefit of improved cook-stoves such as better health and environmental conservation in addition to saving time for gathering firewood and other social-economic activities.

The figure below shows response to whether there are foods the households cannot cook using the improved stoves

Question: Are there foods you cannot cook using improved stoves?

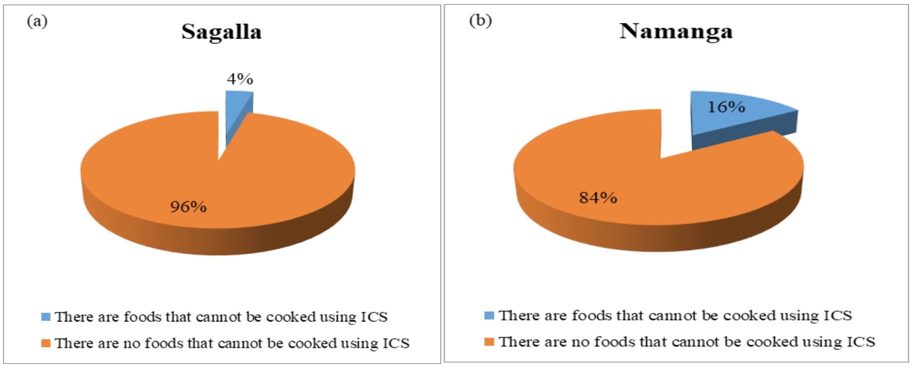


Figure 11: Distribution of households by if they could or not cook all foods using Improved Cookstoves

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

Only 4% of the households sampled in Sagalla reported inability to cook all foods using improved cook-stoves while Namanga had 16% as depicted in Figure 11 above.

Foods like githeri (mixture of maize and beans) are for instance known to consume a lot of time and fuel to cook. Therefore having more than 80% of the households using improved stoves to cook all their meals indicate that the stoves are efficient in terms of time and fuel consumption. Ability to cook most types of foods is a very important attribute in the acceptability of the intervention stoves.

The figure below shows the advantages of improved stoves

Advantages of Improved Stoves

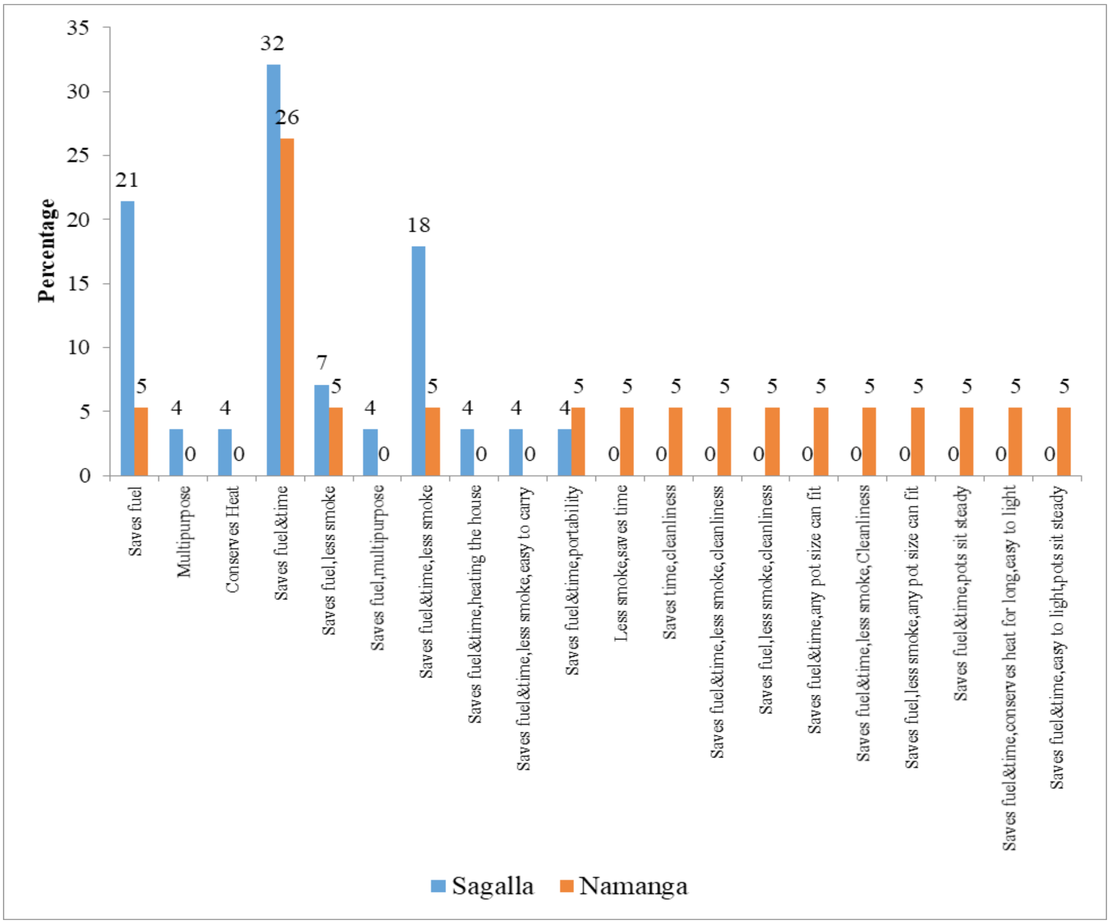


Figure 12: Distribution of households by advantages of using improved stoves

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the advantages of using improved stoves as viewed by the users in the two locations. As illustrated in Figure 12 above, most respondents in both Sagalla and Namanga gave saving time, fuel and reduced smoke as the major advantages of the improved stoves.

The figure below shows the disadvantages of using improved stoves

Disadvantages of Improved Stoves

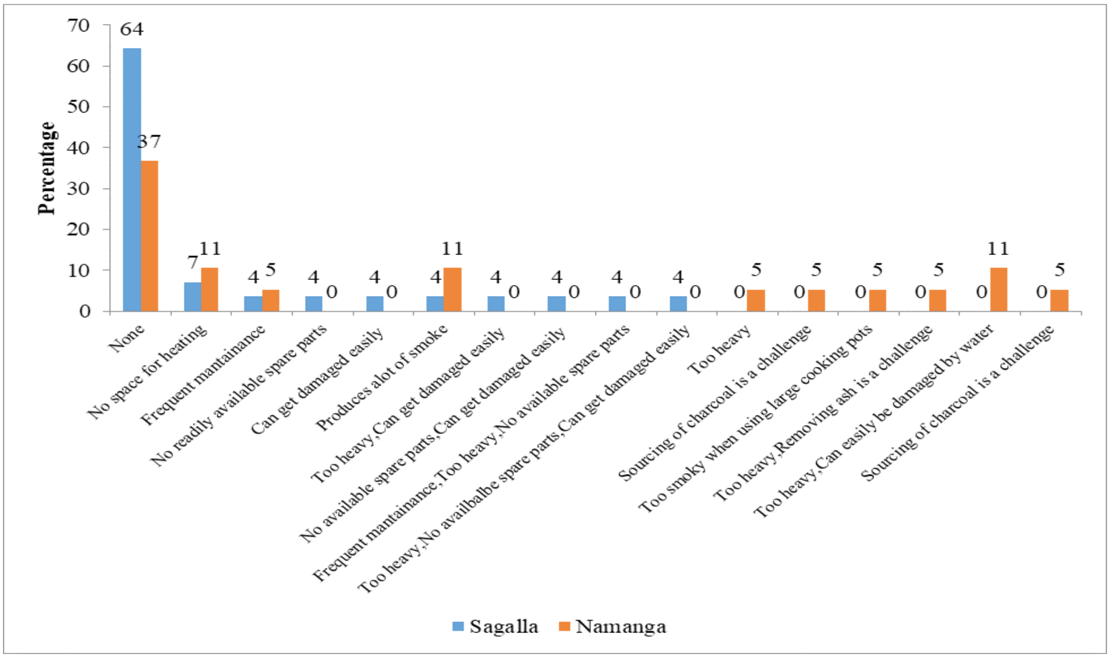


Figure 13: Distribution of households by disadvantages of using improved stoves

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the disadvantages of using improved stoves as viewed by the users in the two locations. As illustrated in Figure 13 above, only 11% of households in Namanga indicated that the stoves lacked capacity for space heating, produced a lot of smoke, was too heavy and removing ashes was a challenge.

The table below shows distribution of households by the time (hrs) spent in collecting firewood

Table 7: Distribution of households by time spent collecting firewood

Time spent collecting firewood (hours)	Sagalla		Namanga	
	Number	Percent	Number	Percent
0 – 1	10	40	1	6.7
1 – 2	9	36	7	46.6
2 – 3	5	20	7	46.7
3 – 4	1	4	0	0
Total	25	100	15	100

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the distribution of households by time spent when collecting firewood. As shown in Table 7 above, 40% of the households in Sagalla and 6.7% of HH in Namanga spent 1hr or less to collect firewood. It is also clear that more households in Namanga spent more time collecting firewood than in Sagalla. This implies that firewood is less available in Namanga forcing people to cover longer distances in search of firewood.

Comparing the above results with the baseline findings the number of HH requiring less time (under 1 hour) to collect firewood has more than tripled with 10% in Sagalla, and 2% in Namanga. This can be attributed to the fact that less wood was required while using improved cook-stoves therefore less time was required to collect firewood allowing more households to meet their firewood demand within the homesteads. As a result, there is need to encourage the use of improved cook-stoves, promotion of wood lots and use of clean energy (e.g. Electricity, LPG, Biogas and Bio-ethanol) as alternative fuels.

The figure below shows distribution of households by the general physical condition of the improved cookstoves

General physical condition of the improved stoves

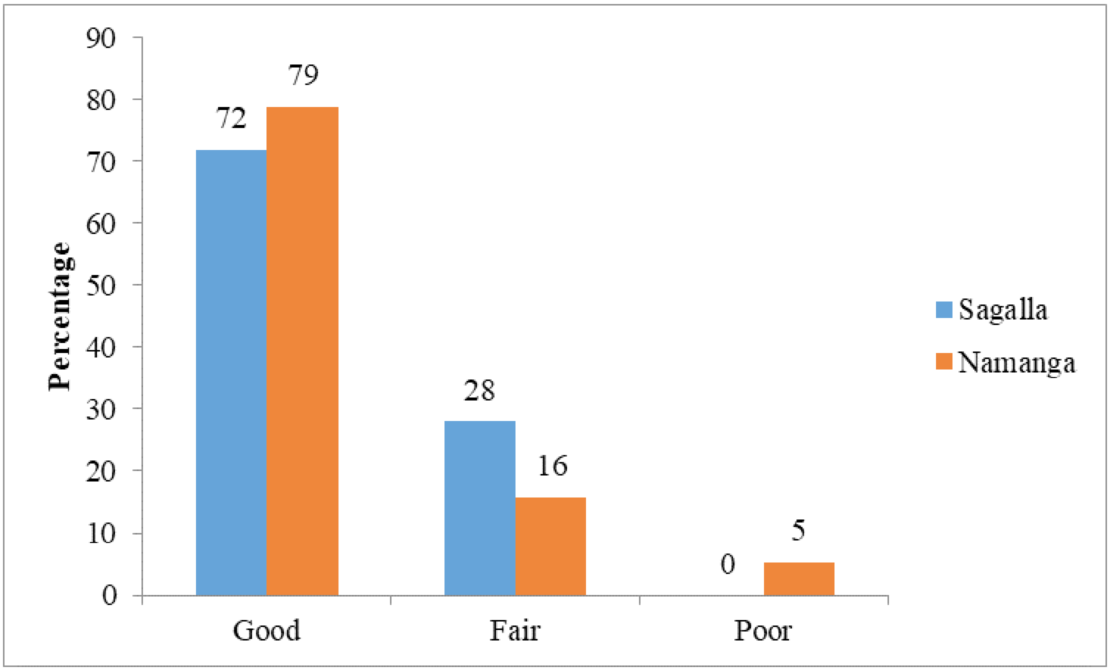


Figure 14: Distribution of households by general physical condition of improved stoves

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the general physical condition of the improved cook-stoves found in the households of the respondents during the study period. Over 70% of the improved stoves were found to be in good condition after being used for over a year as seen in Figure 15 above. These results reveal that the stoves are durable and that the households were taking care of the stoves. Durability is an important factor in the full adoption of improved stoves by households countrywide. Further research is required to ensure durable and quality standards of the cook-stoves are maintained.

The figure below shows the distribution of households by future plans for kitchen improvement

Question: Do you plan to improve your kitchen in future?

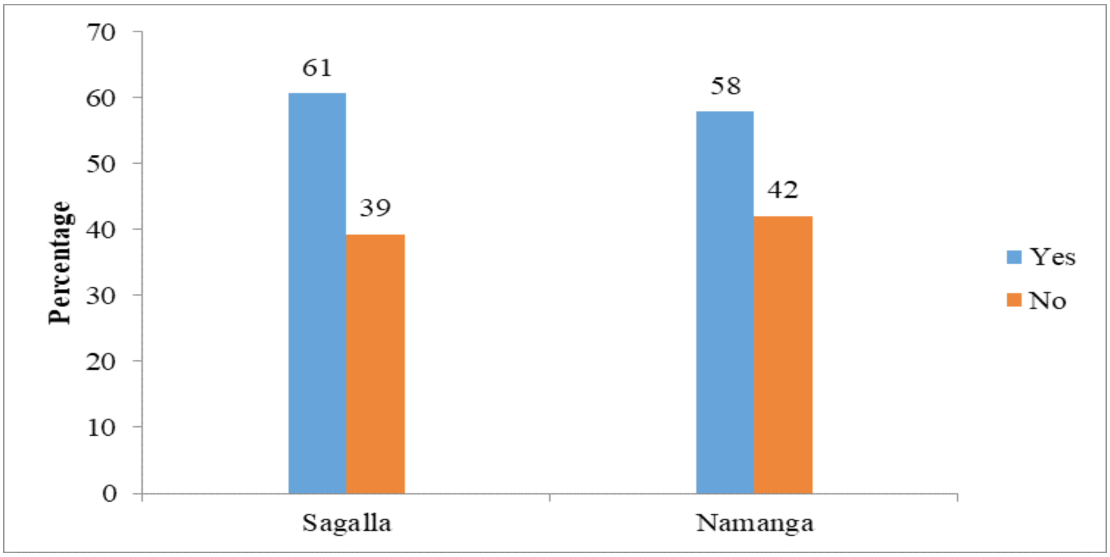


Figure 15: Distribution of households by having future kitchen improvement plans

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the importance of a good kitchen in the household setup. Majority of the households in Sagalla (61%) and Namanga (58%) had plans to improve their kitchens in future as illustrated in Figure 15 above.

The table below shows distribution of households by type of kitchen construction required.

Table 8: Distribution of households by type of kitchen construction required

Type of Kitchen Construction	Sagalla		Namanga	
	Number	Percent	Number	Percent
Brick/Permanent walled	12	43	0	0
Iron-sheet walled	0	0	8	42
Mud-walled	2	7	2	11
Renovation of existing kitchens	1	4	1	5
Others	13	46	8	42
Total	**28**	**100**	**19**	**100**

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

Iron Sheet Kitchen

The study sought to know the type of kitchen improvements the households intended to undertake. 43 % of households in Sagalla considered the construction of permanent/ brick walled kitchens while 42% of households in Namanga opted to construct iron-sheet walled kitchens. 7% of households in Sagalla and 11% in Namanga said they will renovate their old kitchens. The choice of types of kitchens to construct are dictated by the availability of construction materials in the localities. However, there is need to sensitize the community in Namanga to embrace the use of alternative materials other than iron sheets. There is a need for further research to establish why the communities prefer certain materials and not the others.

The table below shows distribution of households by the devices used for lighting

Table 9: Distribution of households by devices used for lighting

Device(s) used for lighting	Sagalla		Namanga	
	Number	Percent	Number	Percent
Tin lamp	2	7	1	5
Solar lamp	12	43	17	90
Tin lamp & Solar lamp	0	0	1	5
Flash light	2	7	0	0
Electricity	3	11	0	0
Phone	1	4	0	0
Firewood	1	4	0	0
Hurricane lamp & Flash light	1	4	0	0
Solar lamp & Flash light	1	4	0	0
Solar lamp & Electricity	4	14	0	0
Hurricane lamp, Tin lamp & Solar lamp	1	4	0	0
Total	**28**	**100**	**19**	**100**

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The study explored the types of devices used for lighting in the 2 locations. In Table 9 above, 43% of the households in Sagalla used solar lamps as their primary lighting device while a total of 65% used solar lamps in one way or the other. 11% used electricity as their primary source of lighting, while 14% had solar lamps and electricity connections. In Namanga, 90% of households exclusively used solar lamps for lighting while 5% used tin lamps and the remaining 5% used both solar and tin lamps.

These results indicate high acceptance of solar energy and the general acceptability of new technologies in the 2 locations. It was observed that though there was high penetration of solar lamps, most were of low quality. There is need for government to create awareness of reliable solar lighting systems through piloting of good quality solar lamps. Increased use of solar lamps in place of kerosene lamps results in overall reduction of indoor air pollution.

3.6 Real-time Indoor Air Emissions and Kitchen Performance Tests


IAQ Monitors

In this study, 15 households using the improved cook-stoves (Maendeleo multipurpose, Maendeleo portable, Maendeleo liner and the Kenya Ceramic Jiko - KCJ) were monitored of indoor air pollutants released for 24 hours. Maendelo multipurpose and Maendeleo portable stoves used firewood, while the Kenya Ceramic Jiko used charcoal as fuel. The pollutants considered in this report includes: - Carbon Monoxide (CO), Particulate Matter ($PM_{2.5}$) and Carbon Dioxide (CO_2). The emission was captured directly by specialized equipment placed in the kitchen for a 24 hour period. Out of the 15 households sampled, 8 were in Sagalla location in Taita Taveta County and 7 were in Namanga location in Kajiado County. The levels of CO, $PM_{2.5}$ and CO_2 released from cooking and heating was quantified and compared to the WHO and EU Guidelines for indoor air quality. There were no adjustments made to account for other potential sources of indoor pollutants like concurrent use of stoves with tin or hurricane lamps.

The stipulated WHO guidelines states that the permissible average indoor air concentrations' exposure in a period of 24 hours are as follows:-

- CO <6ppm
- CO_2 < 1000ppm
- $PM_{2.5}$ <25µg/m^3

3.6.1 Indoor Air Pollution Concentrations

The figure below shows the distribution of households' fuel source by mean concentration of CO (ppm) over 24hrs.

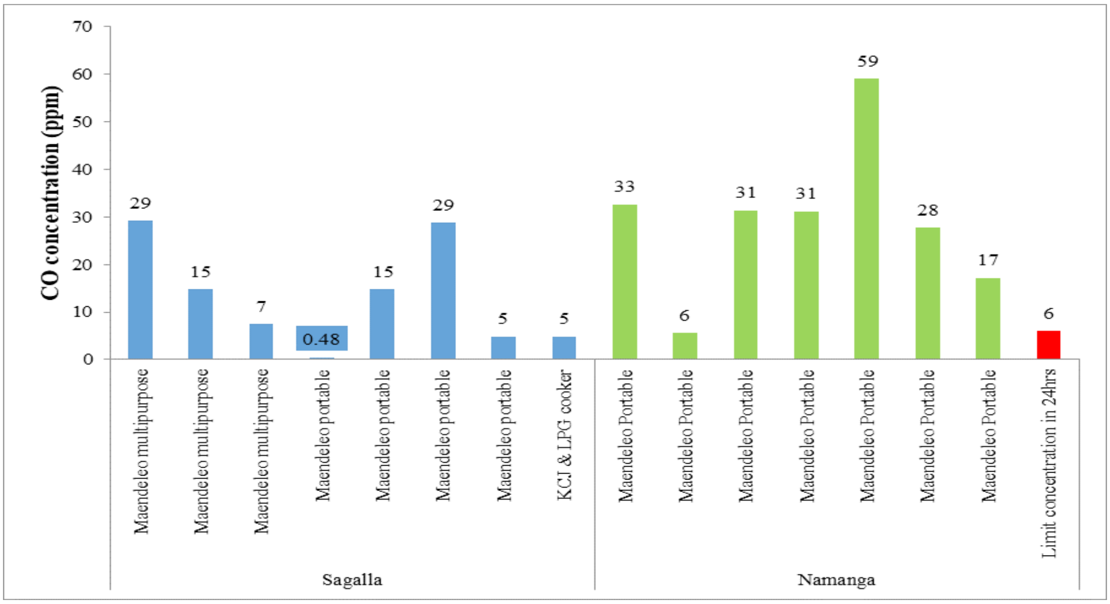


Figure 16: Mean indoor concentration of CO (ppm) in 24 hours

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

In Figure 16 above, it was observed that the average indoor concentration of CO obtained over a period of 24 hours was highest in Namanga (at 59ppm) from a household that used firewood on the Maendeleo portable stove, while two households, one using Maendeleo multipurpose and the other Maendeleo portable recorded the highest amount of CO (of 29ppm) in Sagalla. Out of the 15 households sampled, three households, using Maendeleo portable stoves, the CO concentrations was within the acceptable level (6ppm). In all the other households, CO concentrations were higher than the acceptable exposure. CO is produced by incomplete combustion of carbon containing fuels and is highly toxic. Therefore, it is advisable for people to use stoves in a well ventilated environment.

Comparing the indoor CO concentrations from the Baseline study with the results from the follow up study (improved cookstoves), the percentage of households above the acceptable WHO limits were nearly same at 76% and 80% respectively. However considering the average CO concentrations from both studies, we notice a 2ppm drop with the improved cookstoves. In addition the follow up study shows that the highest CO exposure levels was less at 29ppm in Sagalla and 59ppm in Namanga from 77ppm and 95ppm in the baseline, respectively. Although the reduction in CO concentration was not very pronounced, the study considers concurrent use of other potential sources of indoor pollutants like open flame kerosene lamps or hurricane lamps to have affected the results.

Table 9 Maximum permissible CO levels

Exposure time	Concentration
15 minutes	90ppm
30 minutes	50ppm
1 hour	25ppm
8 hours	10ppm
24 hours	<6ppm

Source: WHO guidelines on CO exposure

The figure below shows the distribution of households' fuels by mean concentration of CO_2 (ppm) over a period of 24hrs.

Carbon dioxide (CO_2)

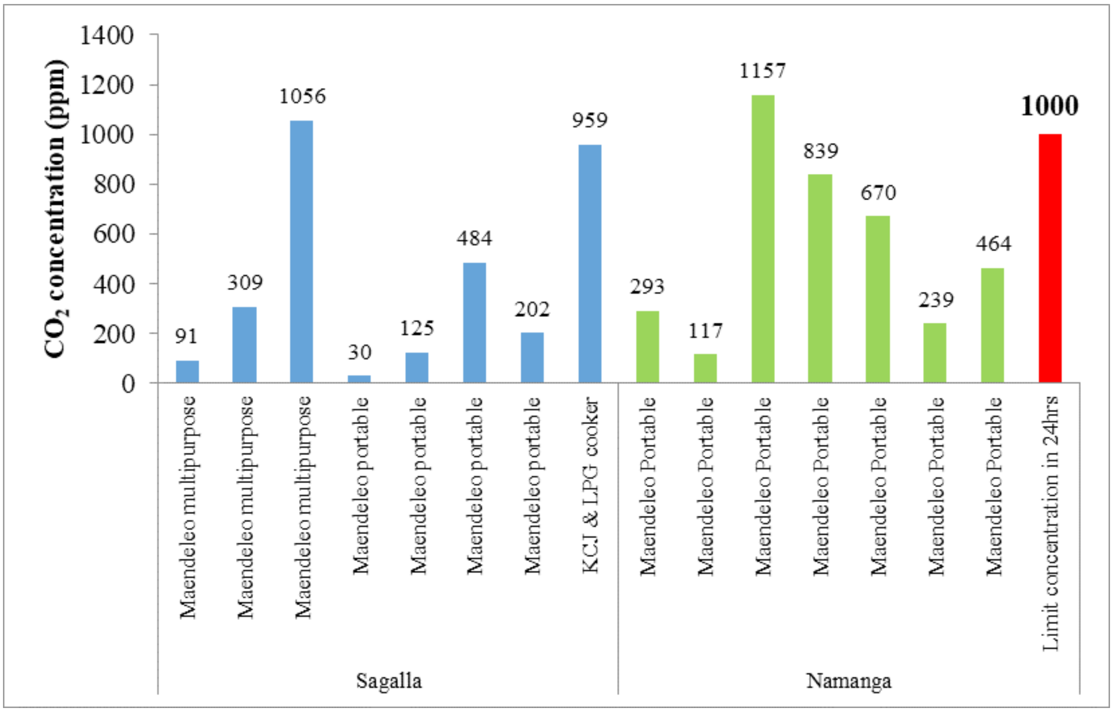


Figure 17: Mean indoor concentration of CO_2 (ppm) in 24 hours

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The Mean CO_2 concentration of 1157ppm was the highest recorded in 24hrs in Namanga while Sagalla recorded 1056ppm as seen in figure 18 above. These concentrations were higher than the 1000ppm allowable in typical occupied indoor spaces with good air exchange. In the other 13 households, indoor CO_2 concentration were within the acceptable limit of 1000ppm. A high indoor carbon dioxide concentration displaces available oxygen for humans leading to headaches, drowsiness, restlessness, and sweating among other health problems. The high CO_2 concentration is partly as a result of poor ventilation which can be improved by opening doors, windows, eaves' spaces or cooking outside

Considering the average CO_2 concentrations from the followup study at 469ppm the 362ppm from the baseline study it was apparent there was an increase in CO_2 with introduction of improved cookstoves. There is need for further research to be done in a controlled environment where other CO_2 emitting sources can be controlled.

The figure below shows distribution of household fuel by mean concentration of $pm_{2.5}$ ($\mu g/m^3$) over 24hrs period

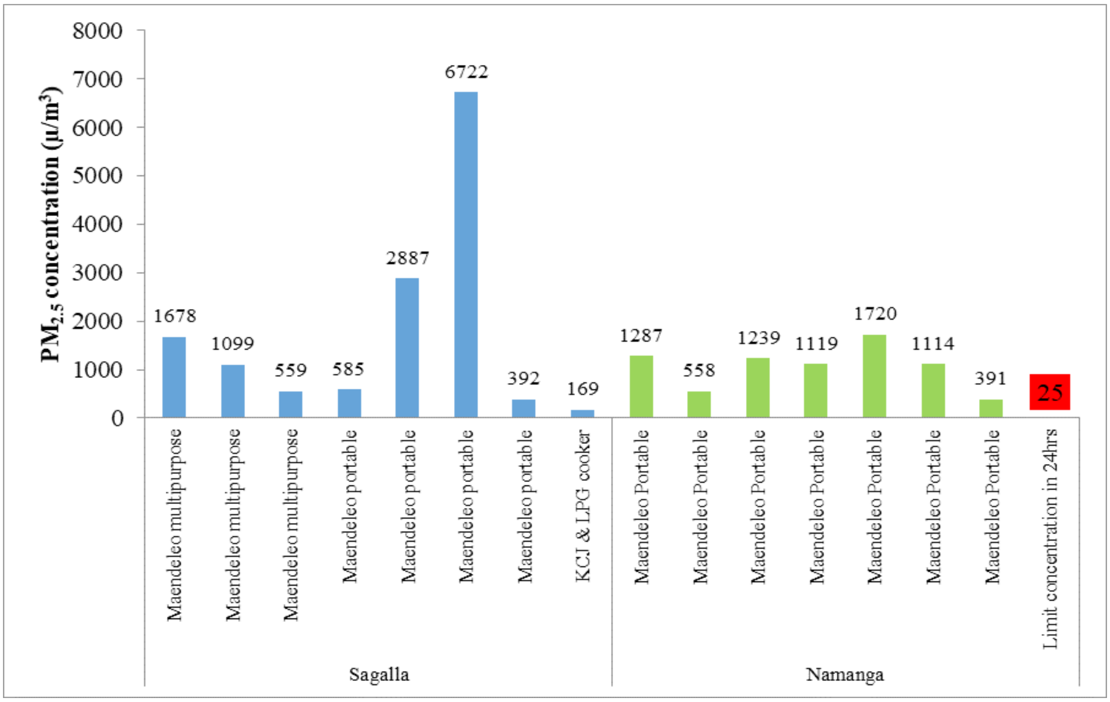


Figure 18: Mean indoor concentrations of PM $_{2.5}$ (µg/m^3) in 24 hours

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

$PM_{2.5}$ is the sum of solid and liquid particles suspended in air many of which are hazardous. Figure 19 above indicates that all the households in both locations had $PM_{2.5}$ concentrations way above the acceptable 24 hours WHO exposure limit (25µg/m^3). For instance in Sagalla, the highest $PM_{2.5}$ recorded was 6722µg/m^3 and the lowest was 169µg/m^3 while in Namanga the highest $PM_{2.5}$ recorded was 1720µg/m^3 and the lowest was 391µg/m$^{3.}$

The $PM_{2.5}$ results above (On average 1053µg/m^3 for Sagalla and 1061µg/m^3 for Namanga) compared to the baseline results (On average 596µg/m^3 for Sagalla and 1290µg/m^3 for Namanga) did not give a noticeable trend.

The $PM_{2.5}$ results shows that the households in both locations are at health risk due to the exposure and hence there is need for further research in a controlled environment to observe the character of $PM_{2.5}$ indoor emissions.

3.6.2 Kitchen Performance Tests (KPT)

The table below shows the distribution of household by the type of primary stove they use.

Table 10: Distribution of household by the type of primary stove

Primary Stove Type	Sagalla	Namanga
Maendeleo Multipurpose	3	0
Maendeleo Portable	4	7
KCJ	1	0
Total	**8**	**7**

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

Table 10 above indicates that all households had adopted the improved cookstoves as their primary cookstoves. Sagalla had Maendeleo multipurpose, Maendeleo portable and KCJ while all the stoves in Namanga were Maendeleo portable. Table 11 below shows the distribution of households by the number of people cooked for in 24hrs and the amount of fuel used to cook

Table 11: Distribution of households by the number of people cooked for in 24hrs and the amount of fuel used to cook

People/Fuel	Sagalla	Namanga
Number of people cooked for	63	63
Amount of firewood used	47.42kg	58.37kg

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The table below shows the distribution of households by primary stove and average firewood consumption for persons cooked for.

Table 12: Distribution of households by primary stove and average firewood consumption for persons cooked for

Primary Stove	Average firewood consumption per capita (kg per person)	
	Sagalla	Namanga
Maendeleo Portable	1.02	0.93
Maendeleo Multitpurpose	0.64	-
KCJ	0.36	-

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations

The results of KPT showed that in Namanga the average fuel consumed per day was calculated to be 8.34kg for wood while in Sagalla it was 6.77kg for wood, 1.78 for charcoal and 0.24kg for LPG.

The table below shows the average firewood consumption in Kg/stove for the primary improved stove used singly for 24 hours in both Sagalla and Namanga

Table 13: The average firewood consumption in Kg/Stove for the primary improved stove used singly for 24 hours in both Sagalla and Namanga

Stove/Location	Sagalla	Namanga
Baseline Survey (3Stone)	4.2	7.4
Follow-up Survey (Maendeleo Stove)	4.1	6.7

Source: MoEP, State Department for Energy Baseline Survey Data 2019 and Follow-Up Survey Data 2021, Sagalla and Namanga Locations

From table 13 above, we notice that the average 24hrs firewood consumption per stove is less in Sagalla (at 4.2 and 4.1 Kg/stove for baseline and follow-up Survey data respectively) than in Namanga (at 7.4 and 6.7 Kg/stove for baseline and follow-up Survey data respectively). It is also evident that the improved stoves resulted in reduction in average 24 hrs consumption per stove in both survey areas.

3.6.3 The Fuel Moisture Content and the Amount Consumed during KPT

The study explored the amount of fuel consumed and its moisture content during a 24 hour Kitchen Performance Test (KPT).

The table below shows the moisture content and amount of fuel consumed during the 24-hour KPTs

Table 14: Moisture content and the amount of fuel consumed during the 24-hour KPTs

Stove used during KPT	Sagalla			Namanga		
	Average fuel consumed		Average fuel moisture	Average fuel consumed		Average fuel moisture
	N	kg (SD)	% (SD)	N	kg (SD)	% (SD)
Maendeleo Portable	4	6.89 (2.70)	8.76 (2.90)	7	8.34 (4.85)	10.47 (2.83)
Maendeleo Multipurpose	3	6.62 (2.27)	9.25 (1.81)		-	-
Kenya Ceramic jiko	1	1.78	6.20 (1.21)		-	-
LPG	1	0.24				

Source: MoEP, State Department for Energy Follow-up survey data 2021, Sagalla and Namanga Locations


%MC measurement

On average, the sampled households in Sagalla used 6.9kg of firewood with mean moisture content of 8.8% on the Maendeleo portable improved stoves. The households that used Maendeleo multipurpose stoves in Sagalla consumed an average of 6.6kg of firewood with a mean moisture content of 9.3 %.One household in Sagalla used the Kenya Ceramic jiko and LPG cooker consuming 1.8kg of charcoal and 0.2kg of gas in 24 hours. In Namanga, households that used the Maendeleo portable stoves consumed an average of 8.3kg of firewood with an average moisture content of 10.5%. Table 12 above and Table 13 below clearly shows average fuel consumption by stove type and corresponding fuel moisture content.

Moisture content as a measure of dryness of firewood in the two locations is quite low at 9% and 10% for Sagalla and Namanga respectively making the fuel suitable for cooking, energy saving, and emits less smoke. The per capita fuel consumption for Sagalla was 0.96 kg/person, while in Namanga it was 1.24kg/person. This can be attributed to the difference in the firewood moisture content.

CHAPTER FOUR

4.0 CONCLUSIONS AND RECOMMENDATIONS

1. Respondents' General Information

The result showed that the household sizes was 6 and 7 in Sagalla and Namanga respectively, which is higher than the National average of 3.9

2. Households Health

The follow-up survey revealed a remarkable reduction of incidences of coughing, eyes, and ears problem in both women and children. It can therefore be deduced that the adoption of improved stoves as the main cooking device resulted in the overall positive health impact.

3. Energy: Cook-stoves and Fuel Use

This survey revealed that a majority (over 68%) of the rural households adopted the use of the improved cook-stoves, this implies that the rural households will readily switch to improved cook-stoves as their main cooking device when they are easily available and affordable.

The survey found out that majority of the households used their stoves for heating and cooking purposes. It is clear that the main purpose of cook-stoves is cooking in both locations. However, there is a need for introducing lighting device to complement the use of improved cook-stoves.

The survey found out that over 50% of the households in Sagalla and Namanga used firewood as their main source of fuel. The study has shown that firewood are collected from public forests at 48% and 59% in Sagalla and Namanga respectively. This result implies that the public forests/bushes are in danger of degradation. Improved cook-stoves are expected to check this degradation by reducing the demand for firewood. This can be attributed to the fact that firewood is easily accessible and mostly free of charge. There is therefore need for a firewood collection regulation to stem public forest degradation in the two locations.

The most commonly used fuel saving device is thermos flask and covering of food, and fireless cooker was unknown to all respondents. There is need for community sensitization on fuel saving devices especially fireless cooker.

A majority (96% and 84%, for Sagalla and Namanga respectively) being able to cook all foods using the improved cook-stoves, it is imperative that improved cook-stoves can be used to cook all foods.

4. Time Spent to Collect Fuel wood after issuance of improved cook-stoves

The follow-up survey found out that the HH requiring less time (under 1 Hr) to collect firewood has more than tripped which can be attributed to the fact that less wood was required while using improved cook-stove and allowing more HH to meet their firewood demand within their homesteads. As a result, there is need to encourage use of alternative sources of energy (LPG, electricity, biogas and Bio-ethanol) and promotion of woodlot establishment.

5. Improved cook-stoves Standards

The survey found out that the stoves are durable and the HHs were taking care of the stoves. Durability is an important factor in the full adoption of improved stoves by HHs countrywide. Further research is required to ensure durable and quality standards of the cook-stoves are maintained.

6. Distribution of HHs by Devices used for Lighting

These results indicate high acceptance of solar energy and the general acceptability of new technologies in the 2 locations. It was observed that though there was high penetration of solar lamps, most were of low quality. There is need for government to create awareness of reliable solar lighting systems through piloting of good quality solar lamps. Increased use of solar lamps in place of kerosene lamps results in overall reduction of indoor air pollution.

7. Indoor Air Pollution Concentrations

The survey revealed that the percentage of HHs above the acceptable CO WHO limits were nearly the same with that of the baseline study at 76% and 80% respectively. However considering the average CO concentration from both studies, we noticed a 2ppm drop with the improved cook-stoves. In addition, the follow-up study shows that the highest CO exposure levels was less at 29ppm in Sagalla and 59ppm in Namanga from 77ppm and 95ppm in the baseline respectively. Although the reduction in CO concentration was not pronounced, there were no adjustments made to account for other potential sources of indoor pollutants like open flame kerosene lamps and hurricane lamps to affect the results. Therefore it is advisable for the households to use the stoves in a well-ventilated environment.

The follow-up study shows that the mean CO_2 concentration of 1157ppm was the highest recorded in 24hrs in Namanga while Sagalla recorded 1056ppm. These concentrations were higher than the 1000ppm allowable in typical occupied indoor spaces with good air exchange. In the other 13 households, indoor CO2 concentration were within the acceptable limit of 1000ppm. Considering the average CO_2 concentrations from the follow-up study at 469ppp, and 362ppm from the baseline study, it was apparent there was an increased in CO_2 with introduction of improved cook-stoves. There is need for further research to be done in a controlled environment where other CO_2 emitting sources in the houses can be controlled.

The follow-up study shows that the $PM_{2.5}$ results on average 1053µg/m3 for Sagalla and 1061µg/m3 for Namanga, way above the WHO recommended levels of 1000 $\mu g/m^3$, compared to the baseline results, on average 596$\mu g/m^3$ for Sagalla and 1290$\mu g/m^3$ for Namanga did not give a noticeable trend. The $PM_{2.5}$ results shows that the households in both locations are at health risk due to the exposure and hence there is need for further research in a controlled environment on the character of $PM_{2.5}$ indoor emissions.

8. Kitchen Performance Tests (KPT)

The result of KPT showed that in Namanga the average fuel consumed per day was 8.34kg for wood while in Sagalla it was 6.77kg for wood, 1.78kg for charcoal and 0.24kg for LPG. The study noticed that the average 24hrs firewood consumption per stove is less in Sagalla, at 4.2 and 4.1 Kg/stove for baseline and follow-up Survey data respectively, than in Namanga at 7.4 and 6.7 Kg/stove for baseline and follow-up Survey data respectively. It is also evident that the improved stoves resulted in reduction in average 24 hrs consumption per stove in both survey areas.

The study showed that the fuel moisture content in the two locations is quite low at 9% and 10% respectively, making the fuel suitable for cooking, energy saving, and emits less smoke. The per capita fuel consumption for Sagalla was 0.96 kg/person, while in Namanga it was 1.24kg/person. This can be attributed to the difference in the firewood moisture content.

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