Domestic Energy Consumption Patterns of Households in Kaniga Area, Rwanda

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Abstract: **Most of Rwandan households depend primarily on traditional means as a source of energy. However, the consumption patterns and intensities remain poorly understood. The aim of the present study was therefore to provide a better understanding of households on renewable energy consumption. Stratified random sampling design was used in order to capture energy consumption patterns between rural, peri-urban and urban populations and across household wealth categories.**

Households in each randomly selected site were stratified into poor, low, medium and high wealth categories. Data were collected using pre-tested and pilot-tested questionnaires, direct measurements, direct observations, interviews and focus group discussions as the best research method that resulted to the dependable output in this primary study.

A total of 1 000 households were sampled: rural area (768); peri-urban area (183) and urban center (49). This is a good number to represent the whole population of the study area since each category of them were fully represented to avoid missing and misrepresentation. This sample was drawn from across all wealth categories: poor-39 household (3.9%), low-392 households (39.2%); medium-400 households (40.0%) and high-169 households (16.9%).

Several hypotheses were found to be true: (1) Socio-economic and demographic factors have effects on household energy choice; (2) There is significant household preference to Kaniga as source of energy. Factors which were found to be important in influencing choice of energy are: location of household, residence ownership, dwelling/house category, household income, and education level of household head; (3) Household survey revealed the insufficient electricity in Kaniga Sector.

Household dependency on traditional and hydro-electrical power sources of energy is irresistible and is likely to remain so for the foreseeable future. Promotion of improved renewable energy and improved electrification, and promotion of alternative sources of energy has been proposed to alleviate the available energy related problems.

***Keywords*: Domestic, Energy, Consumption Pattern, Alternative**

I. INTRODUCTION

1.1 An overview of energy consumption

Kaniga Area is a part of Gicumbi district and has variety of potential energy resources from biomass, hydro, solar, petroleum and gas sources of energy.

The analysis of supply and demand of energy in Rwanda indicates that today approximately 85% of primary energy still comes from biomass, in the form of wood that is used directly as a fuel (57%) or is converted into charcoal (23%), together with smaller amounts of crop residues and peat (5%). Of the 14% of non-biomass primary energy, petroleum products account for 11% (used mainly in the transport and industry sectors) and electricity for approximately 4%.

Due to increasing energy demand in the modern and developing sectors, the search is underway for other sources of energy. In addition to the option of expanding the capacity for hydroelectricity and solar energy, the government is supporting the development of methane gas of Lake Kivu, Geothermal exploration studies and other alternative sources of energy that could play a vital role in solving the problem.

Rwanda's potential for renewable energy, micro-hydro, geothermal and solar, is considered to be huge. Hydropower is the foremost energy resource in Rwanda utilized for power generation. The pivotal role played by energy in economic growth and improving livelihood has been highlighted by many authors including World Economic Forum. The most pervasive challenge associated with energy consumption is how to access energy on terms that facilitate economic growth while respecting environmental integrity norm.

1.2. Administrative characteristics

Kaniga is one Sector of Gicumbi District in Northern Province of Rwanda. It is a landlocked area, located a few degrees nearest to south of the Republic of Uganda, bordered by the Sectors of Rushaki in East, Cyumba in West and Mukarange in South. Total land area of Kaniga Sector is about 41,310 km^2 equivalent to 5% of the total area of Gicumbi District. It is located in the heartland of Rwanda and it is divided into five administrative Cells.

Based on Census survey, in 2014, Kaniga's population was 15 035 with density of 385/ km^2, this makes Kaniga to be in one of the most densely populated Northern Sectors. Kaniga's economy is primarily based on subsistence agriculture (30% of GDP), followed by Services (27%) and industry (10%), (NISR, 2014)

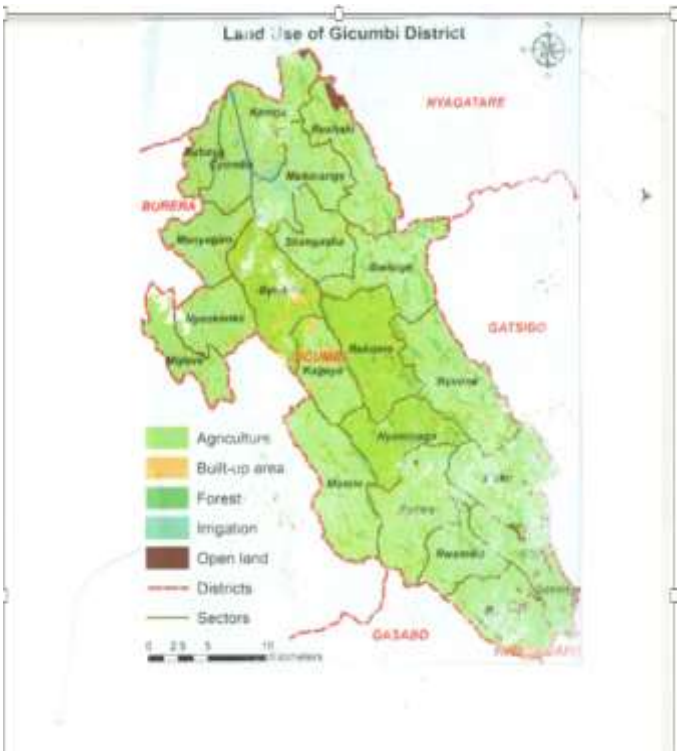
1.3. Geographic characteristics

Geographically, Kaniga Sector is located in one of the high mountains on the Rwanda-Uganda border. It lies on the high land of North of Rwanda in the Northern bearing along

Rukomo-Gatuna Road. Considered a tropical savanna climate typically with a pronounced dry season.

In order to understand clearly the location of Kaniga, it requires to understand its location and position on the map of Gicumbi District.

Figure 1: Localization of Kaniga sector in the map of Gicumbi District of Rwanda



Source: MININFRA, 2015

Based on the map shown in figure 1, It is now easier to study and understand Kaniga as one in 21 sectors that comprise Gicumbi District in Northern Province of Rwanda. It is highlighted on the described map.

The region lies at:

* Latitude: 1° 36' 59.3" (1.6165°) North
* Longitude: 30° 7' 15.7" (30.121°) South
* Elevation: 1,849 meters (6,066 feet)

Much of the Kaniga area is a plateau rising gradually from some 950 meters in Murindi Swamp to 2 000 meters above sea level in the highlands north of Gicumbi District. The annual rainfall ranges from 600 mm in lowlands to 1200 mm on the highland plateau. However, there are some areas that suffer from severe droughts (RMA, 2019).

In the biomass category, wood fuel dominates at 82.4%, charcoal 3.9% while agricultural waste and peat occupy 13.7%. On the other hand, electricity component is mainly hydro-based derived from both local and regional power plants (Bonfils S, 2010).

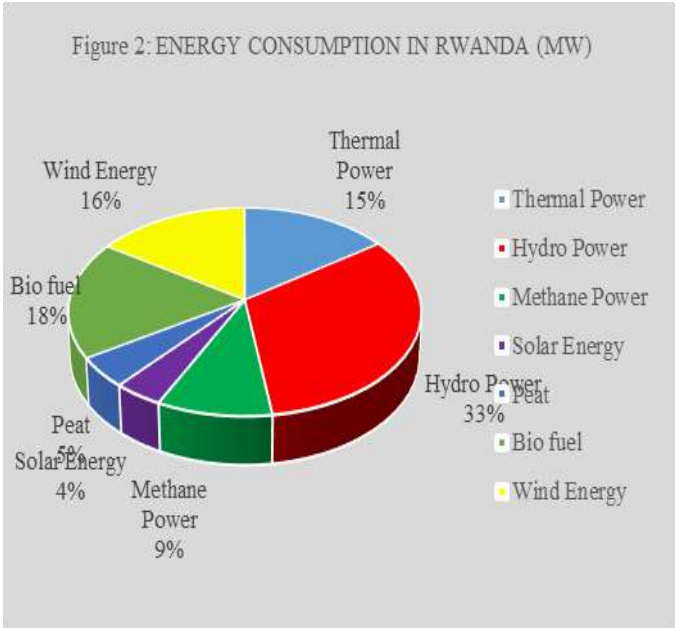
Table 2: Types of energy consumption in Rwanda

S/N	**Source of Supply**	**Capacity (MW)**	Contribution (%)
1	Thermal Power	47.8	15.12
2	Hydro Power	103.2	32.64
3	Methane Power	30	9.49
4	Solar Energy	12.8	4.05
5	Peat	15	4.74
6	Bio fuel	57.8	18.28
7	Wind Energy	49.6	15.69
	Total	**316.2**	**100.00**

Source: NISR.,2018

Table 2 indicates in summary the level of energy consumption in targeted site from the data collected. It revealed that a large number of the households depends on biomass as their major type of energy they consume (80.4%). This lead to deforestation and negative effects on environmental management.

Figure 2: Types of energy with level of consumption



Source: NISR.,2018

Figure 2 summarizes the types of energy and level of consumption at Kaniga area. It has been numerically shown that, among the energy types they consume, most of households use biomass (80.4%). This lead to deforestation and negative effects on environmental management.

Table 1: Climate data for Kaniga site

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Average High $^0C(^0F)$	24(75)	24(75)	24(75)	23(75)	23(75)	23(75)	23(75)	24(75)	24(75)	24(75)	23(75)	23(75)	24(75)
Average low $^0C(^0F)$	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)	13 (55)
Average precipitation mm (inches)	71 (2,8)	79 (3,1)	140 (5,9)	160 (6,3)	122 (4,8)	20 (0,8)	8 (0,3)	56 (2,2)	97 (3,8)	112 (4,4)	117 (4,6)	71 (2,8)	1,049 (41,3)
Average precipitation days	9	10	15	20	15	3	1	6	13	16	16	12	136

Source: RMA, 2019

1.4. Electrification

Currently, about 55% of the population lacks access to electricity. Steadily growing urban population, together with rising per capita income, the energy demand in Kaniga's area household has seen a constant increase in the last subsequent years.

With electricity being relatively expensive, biomass has remained households' main energy carrier for cooking. The cultural cooking habit, which is still biomass-based, only aggravates this problem. High use of biomass has led to deforestation in many parts of Kaniga Sector.

Additionally, biogas is a suitable option for the households at small level. Based on analysis, in the Kaniga area, the electrification rate shares much lower (45%), only under more than half of the households have electricity (NISR, 2014).

II. ENERGY CHARACTERISTICS IN KANIGA AREA

Currently, the energy balance in Kaniga Sector consist of Biomass at 80.4%, Electricity of hydropower 15,2%, Solar 2,4%, Fuel 1.3%, and Gas at 0.7%. Available electricity is therefore insufficient to meet both domestic and industrial needs required for sustainable economic development.

The demand for electricity, that continues to rise every year, has necessitated a projected expansion from the current 220 MW to 500 MW by the year 2025 at national level (MININFRA, 2015).

Understanding household energy consumption intensities is paramount in assessing energy efficiency in development.

The perceived government apathy in addressing household energy issues may be attributed to quality and amount of available data on household energy consumption, because poor quality and unavailability of baseline data on energy consumption seriously impedes energy planning and policy-related work and environmental protection insisted that in order to accomplish the MDGs, reliable and timely relevant information is pre-requisite.

The aim of the present study was therefore to analyze the patterns and intensities of household energy consumption in Kaniga region as study area.

III. PROBLEM STATEMENT AND JUSTIFICATION OF THE STUDY

3.1. Problem statement

Rigorous literature review reveals that in Kaniga, no detailed study has been conducted to establish patterns and intensities of household energy consumption. Rwanda per capita electricity consumption (30 kWh) is the lowest in East African Community when compared to Kenya (140 kWh), Tanzania 85 kWh) and Uganda (66 kWh); where about 25% of the imported petroleum products is used for electricity generation at the thermal power plants (Hakizimana et al., 2016).

This is underpinned by a number of studies: (Bimenyimana S., 2018) asserts that there was inadequate data on Kaniga rural energy consumption; little is known about economics of household energy consumption in Gicumbi district.

3.2. Justification of the study

3.2.1 Significance of the study findings:

The findings of this study will contribute to efforts towards development of efficient and modern energy services and consequently curb environmental problems and foster improved livelihoods of the poor households. Policy and decision makers will make use of the findings from this study to invent short-term, medium-term and long-term strategies for sustainable natural resource management. The public will also be made more aware of the situation on the ground and thus facilitate positive changes in their energy-related behavior and way of thinking and attitudes; and for prudent environmental management.

3.2.2 Why focus on the consumption side?

At a conceptual level, both economic and political emphases of any nation are on consumers as the ultimate target. While economics deals with the allocation of scarce resources among consumers' competing wants, people's welfare is the central concern of the political systems.

Thus, placing the consumer in the focus of interest sounds non-inconsequential as may contribute to a significant thrust on the side of politicians as far as energy issues are concerned, and many provide the common perspective-for experts from various disciplines as well as decision makers

and the wider public and other different stakeholders (Ed Ozdemir et al., 2012).

3.2.3 Why study the household sector?

In locations where electricity is available, households also use energy for running a number of household appliances for washing, preserving and conserving food, and beverages and entertaining the family and other uses.

In some countries, households also use energy for productive activities, including brewing beer, firing bricks, and cooking or drying food for commercial and other trading activities. The household sector consumes the greatest proportion of total energy across the globe. It accounts for 25-30% of total energy in developed countries in Africa and 30-95% of total energy across the globe (Anna B, Johanna H, 2014).

Energy supply in Rwanda is mainly from hydro and thermal sources where the former accounts for 26.74 MW and the latter contributes 29.57 MW against a skyrocketing national demand. Available electricity is therefore insufficient to meet both domestic and industrial needs required for sustainable economic development. (Rwanda Energy Situation, May 2020). The demand for electricity, that continues to rise every year, has necessitated a projected expansion from the current 69MW to 130MW by the year 2015 (MININFRA, 2014).

IV. CONCEPTUAL FRAMEWORK

Conceptual framework shows the salient factors affecting household energy consumption with consequent environmental impacts. The conceptual framework was used to determine the study variables. Detailed literature review from other previous authors, review of various consumption theories and researcher's personal Rwandan experience were used to determine the study variables. Consequently, a total of 63 variables were captured in this study.

In order to carefully address the objectives of this study, the focus of the study was on four key issues: choice of energy options, energy consumption, energy expenditure (cost implications), and environmental impact of household energy consumption.

According to (IOB, 2014), the conceptual framework acts as a basis for discussing the relationships between different groups, individuals or issues and can always be progressively revisited as further information becomes available.

The understanding of household energy consumption in developing countries is mainly built on the concept of energy substitution, commonly known as the energy ladder hypothesis (Rahut D, Abdul M, Prakash A.,2017). The hypothesis postulates that as household socio-economic status rises, the household in question abandons lower-level energy sources and switches to modern ones. Another hypothesis that tries to describe the household energy consumption is the "inverted-U hypothesis" (Lusambo L.P.,2021). This hypothesis postulates that household energy consumption varies proportionally with per capita income up to a certain level after which it starts decreasing, thereby making an inverted-U shape graph.

Energy consumption is also explained by a popularly used poverty environment hypothesis (Lusambo L.P.,2016) which claims that poor people rely heavily on biomass fuels and thus causing forest degradation and deforestation; and that addressing poverty issues is the key for sustainable forest resources management. When modeling household energy consumption, distinction should be made between direct energy use and indirect energy use (Jia Li and Richard E. Just., 2018**)**.

Direct energy use refers to the consumption of energy carriers purchased by the household itself (fuels and equipment) in order to cater for energy services. Indirect energy use refers to the energy used during various stages of production (and distribution) of commodities, also referred to as embodied energy or grey energy. The present study strives to address households' direct energy use.

Various studies (Bimenyimana.S,2018) have pointed out factors affecting household energy consumption current disposable income, household size, household type, fuel accessibility, fuel affordability, fuel reliability, energy flexibility, low-pollution, climatic conditions, effective household size, dwelling type and ownership, household power relation; tradition and customs, stock of liquid assets (wealth); future income expectation, urban-rural location differences, and level of consumer indebtedness (Lusambo L.P, 2016).

V. OBJECTIVES OF THE STUDY

The specific objectives of the study are to:

a. Determine and analyze patterns of household energy consumptions in Kaniga Area;
b. Identify and analyze factors influencing household energy choice in Kaniga Area;
c. Investigate households' preferences to wood fuel from natural forests in Kaniga Area,

VI. HYPOTHESES OF THE STUDY

This study puts forward the following two main hypotheses as priorities:

1. Households socio-economic and demographic factors have effects on fuel choice.
2. Households have significant preferences for natural forest for wood fuel.

VII. AIM AND SCOPE OF THE WORK

This paper aims to investigate the energy consumption across socio-economic classes across Kaniga area, in the context of environment protection. The case study area, Kaniga, has seen rapid rural area growth after the episode of Genocide came to an end in 1994. It has experienced high rates of migration, not only from within the country, but also from the neighboring country such as Uganda. Due to the demographic high density

and high energy consumption, Kaniga was chosen as a case study area. The households are divided into four categories based on their socio-economic background and the building type they live in with their description. Table 3 depicts different building types in Kaniga.

Table 3: Different building types in Kaniga

Number	Building	Descriptions
01	Rudimentary	Informal house
02	Local type/Apartment	Modern high-rise building
03	Basic Villa	Detached house
04	Luxury Villa	Luxury detached house

Source: RDB Report., 2017

VIII. METHODOLOGY

A preliminary survey was conducted in the Kaniga Sector to identify areas with different socio-economic groups. There is a Sector segregation of different classes in Kaniga, which is quite visible throughout the area. During the preliminary survey, with the help of local authorities and literature data, various test areas were identified. After the preliminary survey, five test areas were finalized for the consumption survey. These test areas have different buildings type and a socio-economic class. Table 4 shows the overview of household areas during survey 2020.

Table 4: Overview of household areas during survey 2020

Tested area	Majority type of building in area	Major socio economic class
Nyarwambu	Rudimentary	Low
Gatoma	Villa	Middle
Bugamba	Villa	Middle
Murindi	Luxury Villa	High
Rukurura	Rudimentary	Poor

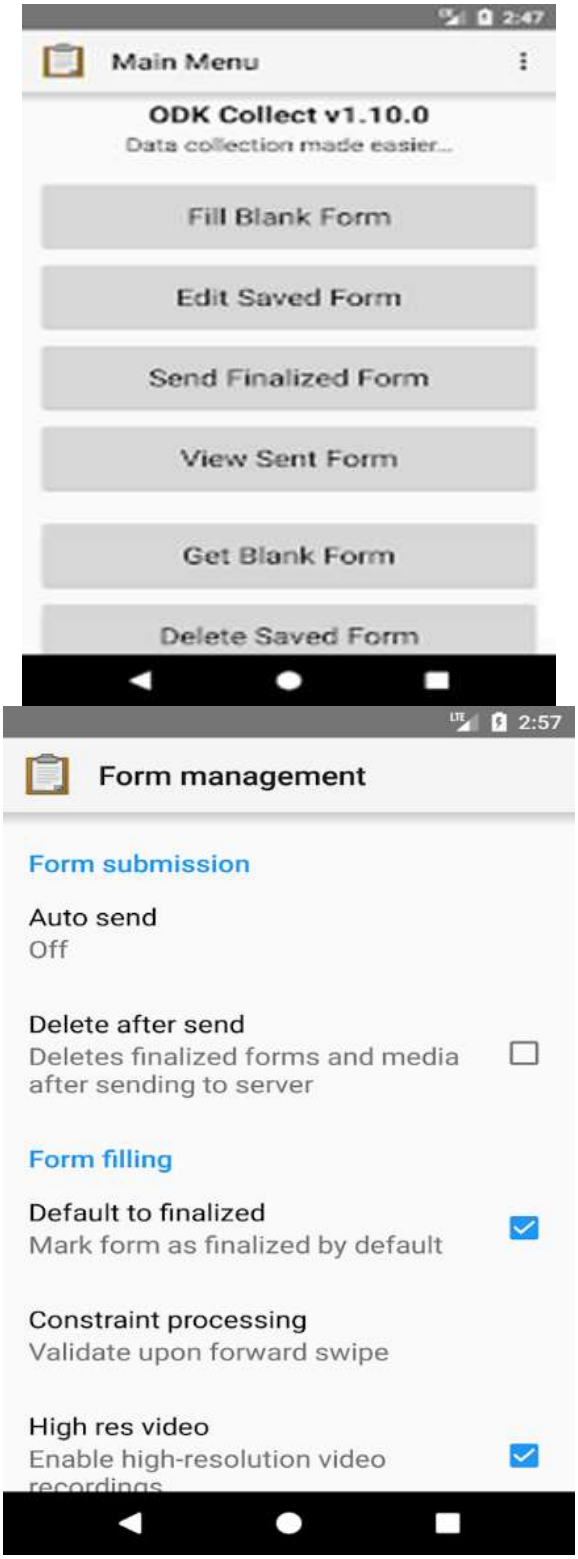
Source: Primary Data.,2020

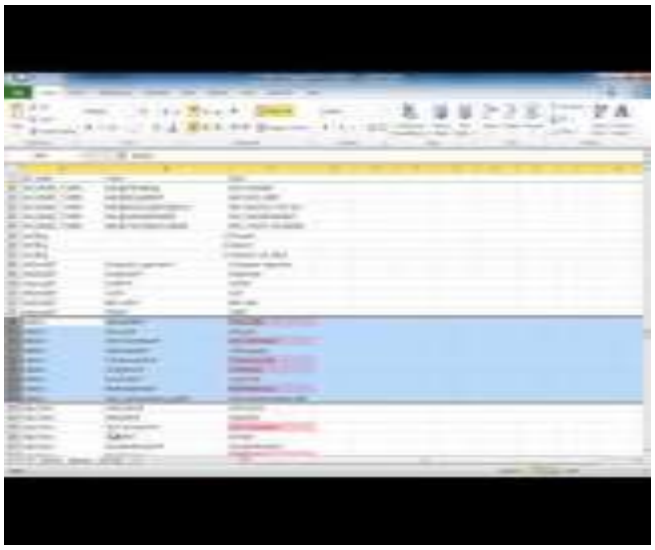
A questionnaire covering various usage types such as cooking, water heating, space heating and lighting was developed. In order to avoid manual error while transferring the data from paper to computer and save time, it was decided to conduct a tablet-based survey.

8.1. Open Data Tool Kit Collect used in study

Open source software, Open Data Kit (ODK)-Collect was used for this purpose. This application can only be used for devices (tablet/laptop/mobile) equipped with Android system. ODK Collect is a replacement for paper forms with support for geo-locations, images, audio clips, video clips and barcodes, as well as numerical and textual answers. The screen shots displayed in figure 3 show at least three screens of the application during the data analysis and interpretations, the first screen shows various survey options and various options available to choose from, and the second screen demonstrate the section of platform where data was entered and manipulated during the research and the third screen shows us start of data analysis and interpretation of a household survey in Kaniga area (Primary data.,2020).

Figure 3: Open Data Tool Kit Collect in recording and analyzing data





Source: Primary Data.,2020

8.2. Study sites

This study was conducted with households around Kaniga sector (as highlighted on the map) in Gicumbi district. Sector was sub-divided into five strata:Nyarwambu, Gatoma, Bugamba, Murindi and Rukurura, peri-urban and urban areas; and sample households were drawn from each stratum.

Figure 4: Localization of Kaniga area on the map of Rwanda

Source: MININFRA.,2015

In Kaniga region the annual rainfall ranges from 600 mm in lowlands to 1200 mm on the highland plateau. However, there are areas which experience exceptional droughts (with less than 600 mm of rainfall). The mean annual temperatures vary with altitude from the valley bottom to the mountain top: between 18°C on the mountains to 25°C in river valleys. In most parts of the region, the average temperatures are almost uniform at 25°C.

The economy of the region is dominated by agriculture (80-90% of the region's labour force) and allied activities. The major activities include: (i) small scale farming; (ii) cattle production; (iii) plantations and so on. In Kaniga rainfall starts in September and ends in April. Total average annual rainfall is over 1,200 mm and the amount varies periodically. The major economic activities of the region are agricultural farming, livestock rearing, bee keeping and trading.

8.3. Study design

The design of the present study is a descriptive and analytic cross-sectional survey. It is a descriptive study because it sets out to rigorously describe household energy consumption patterns. It is an analytic study because it entailed testing a priori hypotheses related to household energy consumption in the study area. It is a one-time cross sectional study; it cannot therefore gauge the temporal variations or trends in the data collected. The overall objective was to have a study sample which is sufficient and representative of the target population (Primary data.,2020).

The target populations for this study were households in Kaniga Sector of the district. The sampling frame was in five types depending on the sampling phase. During sampling of cells in rural areas, the sampling frame was the list of cells bordering the selected sector. When sampling households for the study, the sampling frames that were used are the updated lists of households registers in the sampled cells. All executive secretary of cells in the selected study sites were asked to update lists of households in their respective areas by excluding households which no longer existed and/or adding those ones which were missing in their lists (Primary data.,2020).

Stratified random sampling design was used in the present study. Stratification was carried out at two levels: (a) stratification of study sites in the study sector into rural, peri-urban and urban areas, and (b) stratification of respondents into wealth categories: low, medium and high (Primary data.,2020).

8.4. Development of research instruments

The main research instruments used in the present study are questionnaires for household surveys (Maniraguha E.,2013) and checklists for focus group discussion and interview of key informants (Glesne C. 1999). Questionnaire development involve five sequential steps involved in questionnaire development: background, conceptualization, format and data analysis, establishing validity, and establishing reliability (Maniraguha E.,2013).

Questionnaire construction began by first defining the domain of information in order to obtain the required information

(Glesne C. 1999). This was achieved through an extensive and rigorous search of pertinent literature. As much as possible, the questionnaire was made to be: brief (keeping questions short, and asking one question at a time); objective (paying attention to neutrality of the words); simple (using language which is simple in words and phrase); specific (asking precise questions); and informative (covering all necessary information needed).

All three types of question formats (Glesne C. 1999) were used: multiple choice (closed ended) questions, numeric open-ended questions, and text open-ended questions. Attention was also given to issues such as opening questions, question flow, and location of sensitive questions.

8.5. Data collection

Based on the population Socio economic classes, the sample of 1 000 households were selected in Kaniga sector. The sample size is determined from Table 5, by considering 1 000 head of households and non-household heads of 1 000 households were selected in Kaniga sector. A varieties of data were collected and sample size were determined to facilitate the research to provide accurate and viable results to the users.

8.6. Rural area sample selection

The first step was to get the list of all households in each cell, from respective sector Office. The households were then stratified into 5 cells. Where applicable, cells were further grouped. One cell was randomly households in the selected village, as in the case of rural areas, stratified into wealth categories: low, medium and high. Respondent households were then randomly selected from each stratum. A random number table was used to select respondent households.

8.7. Sample size determination

Sample size determination: The reliable sample size for the present study was computed using the following formulae of the Taro Yamane formula (Pachauri S.,2018).

The Sample Size (n) is therefore calculated as:

$$n = \frac{N}{N(e)^2} \qquad Equation\ (1)$$

To determine the sample size, the Taro Yamane formula was used, where:

n: Sample size,

N: Number of population under study,

e: Margin of error (Which can be 0.10; 0.05;0.01), the most commonly used one is 5% or 0.05

The Taro Yamane formula developed in equation (1) helped to determine the sample size on different sites as it is demonstrated and summarized in the table 5 by randomly sampling method.

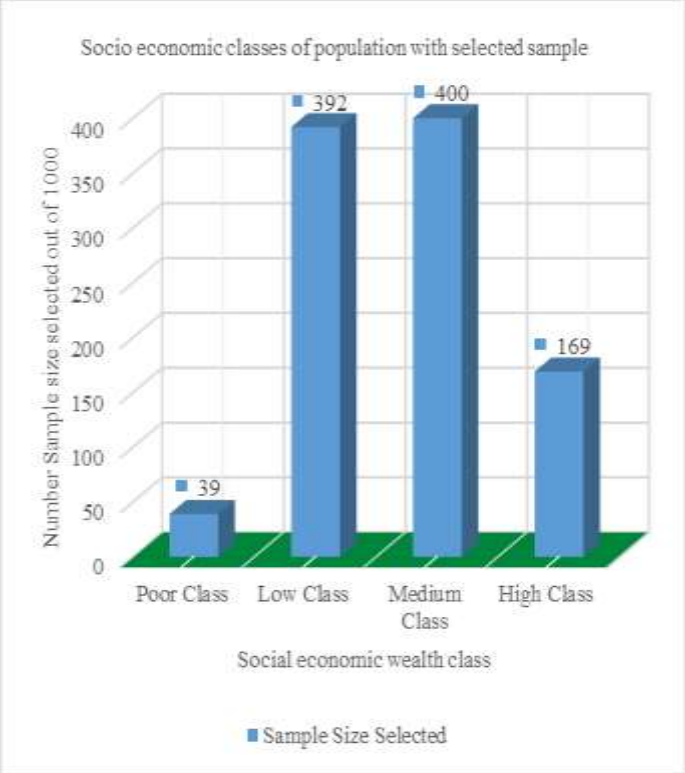
Table 5. Social economic classes of the respondents and sample size selection

No	Socio Economic Classes	Total number of Population	Selected Sample Size Selected	Selected Sample Size Selected in %
1	Poor Class	407	39	3.9
2	Low Class	5 909	392	39.2
3	Medium Class	6 584	400	40.0
4	High Class	2 135	169	16.9
	TOTAL	15 035	1 000	100

Source: Primary Data.,2020

Table 5 shows the socio economic classes of the respondents. It has been observed that a large number of respondents range in medium class with 40% of total sampled populations.

Figure 5: Social economic class and sample size



Source: Primary Data.,2020

Figure 5 shows the graphical representation of Socio economic classes of the sampled population. The findings have come up with the observation that the large number of population are in the category of medium class (40%) and low class (39.2%). This has the implication that their social life conditions and wealth level are approximately in the similar range. Each head of household was either given a questionnaire or interviewed after their responses were collected, analyzed, tabulated and interpreted to find out the Validity of the hypotheses that were supposed to be tested to find out the reliability.

8.8. Data collection and analysis

In this research both Primary data (data collected by a researcher from the field of study) and Secondary data (data collected from researchers, reports, journals, authors…) were used in order to find out dependable results of the research.

Data were collected using a number of techniques: household questionnaire survey, focus group discussion, key informant interview, and researchers' direct observation. Questionnaires were both pre-tested and pilot-tested before actual data collection. Data analysis was carried out using SPSS (Statistical package of social science Software) and Excel statistical computer programs. Prior to detailed analysis, data were arranged in such a way as to facilitate analyses. For example, some data were re-coded so as to fit a particular analysis (e.g. logistic regression analysis). Household income categories were collapsed from previous eight categories to four categories.

Descriptive statistical analysis was conducted. The general purpose of descriptive statistical method was to summarize, organize and simplify a set of data. In the present study, the central tendency (average or representative data) for numeric data (interval or ratio) was determined by mean. The central tendency determination for discrete variables was a mode. The measure of variability within the numeric (interval or ratio) data was standard deviation. The categorical variables were summarized using bar charts and pie charts; whereas numerical variables were summarized using histograms.

8.9. Factors influencing households' energy consumption choice

The first hypothesis which was tested in connection with households' energy consumption patterns concerned with the influence of households' characteristics on choice of cooking fuel. Since firewood and charcoal are the major cooking fuel in Kaniga Sector, they were used to test this hypothesis. Binary Logistic regression analysis was used to test this hypothesis. Also, other factors like education level of the population, Income level, government policy, population distributions, number of infrastructures facility have the great impact on the energy consumption.

IX. ANALYSIS AND INTERPRETATIONS OF RESULTS

9.1. Respondents' characteristics

The socio-economic characteristics for 1000 respondents who took part in the present study are summarized and presented in Table 6.

The findings reveal that both household heads and those who are not household heads participated in answering survey questionnaires. It is also evident from the findings (Table 6) that the study sample comprised of both male-headed households and female-headed households, although the former constitutes the majority.

Table 6: Socio economic characteristics of respondents

Characteristics	Number (N)	Percent (%)
Respondents		
Household head	641	64.1
Not household head	359	35.9
Total	1,000	100
Gender of the household head		
Male-headed household	718	71.8
Female-headed household	282	28.2
Total	1,000	100
Marital status of respondent		
Married	602	60.2
Never married/single	159	15.9
Widowed	87	8.7
Divorced	28	2.8
Separated	124	12.4
Total	1,000	100
Marital status of female-headed household		
Married	508	50.8
Not married	492	49.2
Total	1,000	100
Educational level of household head		
Illiterate	99	9.9
Primary education	382	38.2
Secondary education	423	42.3
Adult education	33	3.3
College education	15	1.5
University education	36	3.6
Others	12	1.2
Total	1,000	100
Main occupation of household head		
Employee	29	2.9
Formerly employed	24	2.4
Causal labourer	141	14.1
Artisan	9	0.9
Herder/cultivator	367	36.7
Trader/shop	216	21.6
Petty business	96	9.6
Firewood/charcoal vending	13	1.3
Housework	37	3.7
Others	68	6.8
Total	1,000	100
Ownership of dwelling		
Rented	73	7.3
Owned	927	92.7
Total	1,000	100

Source: Primary Data.,2020

Table 6 describes the characteristics of the respondents. The study attained a fairly good gender balance, the number of male respondents was comparable to that of female respondents. Different characteristics were considered to obtain enough information that helpful to draw the appropriate conclusion. Female-headed households can further be categorized into two groups: those who are married and those who are not.

The study attained a fairly good gender balance: the number of male respondents was comparable to that of female respondents. Household income distribution for the respondents (as recorded in the field) is presented in Table 6. Figure 5 shows the distribution of the collapsed household income categories (which was used during data analysis). Prior to actual data collection, the respondents were stratified into four wealth categories/ socio economic classes (based on the criteria developed during pilot study, using focus group discussion) poor wealth categories, low wealth categories, medium wealth categories, and high wealth categories.

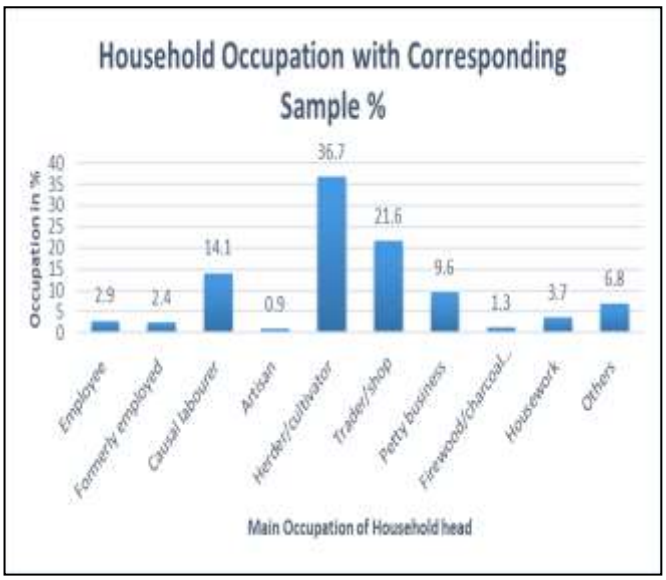


Figure 6. Main occupation of household heads

Source: Primary Data.,2020

Figure 6 indicates that in the respondents studied a large number of them are farmers it means they depend on agriculture (36.7%). During data collection, household assets were used as proxy for household wealth. Both animate (cattle, goats, sheep, pigs and chickens,…) and inanimate assets (land, motor cars, bicycles, hand hoes, sickles, machetes, and sprayers) were recorded for each respondent household and converted into monetary value to reflect the wealth status of a respective household. Table 8 shows the type and quantity of assets owned by the respondents in the study area. Besides, the study sought to determine wealth ownership equity by gender. The results (Table 8) suggest that there is fairly even household wealth (household assets) ownership.

Table 7: Distribution of Household monthly income

Income month-1 Frw)	Number (N)	Percent (%)
Income < 30,000	36	3.6
31,000 – —-60,000	86	8.6
61,000 —— 90,000	107	10.7
91,000 – --120,000	265	26.5
121,000 – 150,000	310	31.0
151,000 – 180,000	20	2.0
181,000 – 210,000	35	3.5
Income > 210,000	141	14.1
Total	1,000	100

Source: Primary Data.,2020

Table 7 describes the economic life and the average income ranges generated by the households in the study area based on the survey conducted. It shows the number of sampled population and their equivalent percentage of their population.

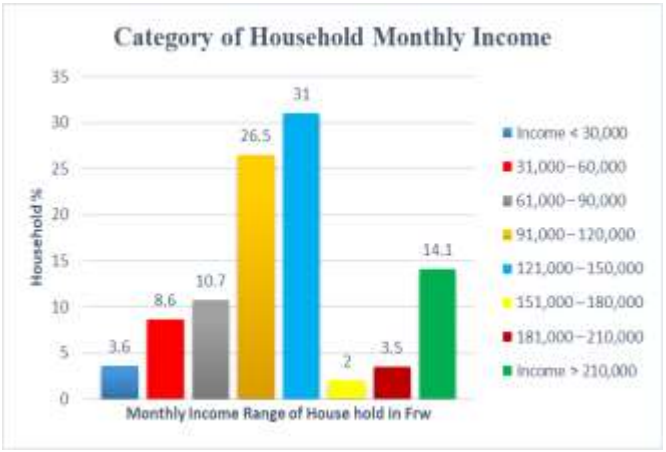


Figure 7: Categories of household monthly income

Source: Primary Data.,2020

Figure 7 represents the category of household income generated by the sampled population. It has revealed that the large number of people in Kaniga earm the income range from 121 000 to 150 000 of about 31 % (the high range of the sampled population) while the low range of sampled population in income is from 151 000 to 180 0000 with the approximated value of 2.0%.

The purchasing power of the respondents can be studied based on the average house hold incomes since it demonstrates their ability to manage their expenditures.

Therefore; it was suggested that individuals tend to increase consumption of energy as their income increases, but to a moderate consumption extent.

This has demonstrated that as the level of income increases, the difference between income and consumption increases as well. So there is a strong correlation between income level and households' energy consumption.

Table 8: Household assets endowment in the study area.

Type of assets	Household Owning		Number of Household	
	Number (N)	Percent %	Min	Max
Animate				
Cattle	39	6.7	1	250
Sheep	8	1.4	2	30
Goats	84	14.8	1	37
Pigs	53	9.3	1	18
Chicken	294	51.8	1	180
Ducks	19	3.3	2	15
Others (e.g. Pigeons)	20	3.3	1	200
Inanimate				
Sprayers	6	1	1	2
Hand hoe	347	61	1	13
Machete	190	33.5	1	6
Sickle	28	5	1	5
Bicycle	211	37	1	26
Land	343	60.4	0.25 acre	56 acre
Cars	22	3.9	1	2
Motor cycle	70	0.9	1	2

Source: Primary Data.,2020

Table 8: indicates that during data collection, household assets were used as proxy for household wealth. Both animate (cattle, goats, sheep, pigs and chickens,…) and inanimate assets (land, motor cars, bicycles, hand hoes, sickles, machetes, and sprayers) were recorded for each respondent household and converted into monetary value to reflect the wealth status of a respective household. It also shows the type and quantity of assets owned by the respondents in the study area. Besides, the study sought to determine wealth ownership equity by gender. Therefore its results suggest that there is fairly even household wealth (household assets) ownership.

9.2 Household size

Figure 3 shows the average household size per building type and Cell in Kaniga. Luxury villa building type has the largest household size of 5 persons per household, whereas local type building has the smallest household size with only 2.5 persons.

The large variations in the household size may be due to the socio- economic status of the households. The average for our sample size in Kaniga is 3-6. According to a recent study in Rwanda, the average household size in Kaniga was 4, 5 (NISR, 2014).

9.3 Research Model and Philosophy Used in the Study

Models are key components of the study. In this research, different models were used in order to reach on a reasonable and valid conclusion. Some of them are described and explained as follow:

- **Scientific Model** (Jia L. and Richard.,2018)**:** it is described as a representation of a particular

Phenomenon in the World using something else to represent it, making it easier to understand. Scientific model adopted are but not limited to diagrams, pictures and other physical models as used in the research. This explains the reason why this study has a number of diagrams, maps and tables with the findings.

 Mathematical Model or Computer model (Jia L. and Richard E.,2018)**:** In this model mathematics was used to describe a particular phenomenon. The sample size determination formula we have used is a critical example. Like Taro Yamare method used in sampling to determine the sample size of the sampled population.

 Visual Models (Jia L. and Richard E.,2018)**:** These are things like flow charts, pictures and diagrams that describe and clarify the nature, characteristics and behavior of sample or population. Where different observations were carried out at the study site to investigate and getting the physical and visible characteristics of the populations.

 Qualitative and quantitative models (Jia L. and Richard E.,2018)**:** These are models that include quality and quantity that the research has considered to come up with feasible decisions and conclusion. Interviews and summarized results from questionnaire were used to get accurate and reliable data (Glesne C., 1999).

Table 9: Average annual energy consumption in different building types in Kaniga area (kWh/Capital)

Building	**Electricity**	**Solar**	**Fuel**	**Gas**	**Biomass**	**Total**
Unit (kWh)						
Rudimentary	79	12	16	21	1,290	1,418
Villa House	380	15	195	290	520	1,400
Luxury Villa	689	59	419	533	49	1,749
Local Type	342	9	121	219	922	1,613

Source: Sibomana G. and Nkunda F.,2014

9.4. Share of different energy carriers used

Table 3 shows the average annual energy consumption for electricity, solar, fuel gas and biomass per capital in four building types in Kaniga. Electricity usage in rudimentary building type is exceptionally low. The electricity usage in luxury villa is almost ten folds than that in rudimentary. Gas usage is the dominant energy carrier in the local type buildings with an average annual usage of mono and triphase

2, 26 kWh per house. Except for luxury villa, biomass is the dominant energy carrier in all other building types. The amount of biomass used in these three building does not have a large variation.

Figure 7 illustrates the share of expenditure on energy carriers (Biomass, Gas and electricity) in the total expenditure by households. The rudimentary households spend almost biomass 40% of their spending on energy services, followed by local type, which spend almost 30 % on energy Households living in luxury villas have the least share of energy expenditure, 1,6% of their total spending. The results are compared with literature data to assess the change of consumption patterns as a result of urbanization and migration.

9.5 Households' preferences to wood fuels from natural forests

The second hypothesis to be tested was concerned with the households' preference for Kaniga woodlands/natural forest wood fuel. The chi-squared ($\chi 2$) test was used to determine whether the households' preference for natural forests (Kaniga woodland) as a source of wood fuel is statistically significant.

Respondents were asked to indicate their preferences between wood fuel from the natural forests (Kaniga woodlands) and that from the plantation forests. Results as presented in Figure 10 indicated that majority of respondents (60% of wood fuel users) prefer wood fuel from Kaniga woodlands (natural forests) to that from plantation forests.

Some of the respondents were able to give reasons for their preference as indicated in Table 10.

9.6. Reasons for households' preference for Kaniga woodlands

Table 10: Reasons for preference to wood fuel from Kaniga woodlands.

Category label	Code	Count	Percent of responses
Catch fire easily	1	25	8.8
Burns longer	2	191	67.5
Easily available	3	29	10.2
Produces less smoke	4	32	11.3
People are traditionally used to	5	5	1.8
Collection from field is easy	6	1	0.4
	Total	283	100.0
233 valid cases			

Source: Primary.,2020

A number of 283 sampled households were put under consideration in studying populations preferences. It was found that 233 responses equivalent to 82.3% were valid.

Table 11: Table Of Cohen's Standards And Chi-Squared Test Results

For df*=1	0.10 < V < 0.30	Small effects
	0.30 < V < 0.50	Medium effects
	V > 0.50	Large effects
For df*=2	0.07 < V < 0.21	Small effects
	0.21 < V < 0.35	Medium effects
	V > 0.35	Large effects
For df*=3	0.06 < V < 0.17	Small effects
	0.17 < V < 0.29	Medium effects
	V > 0.29	Large effects

Source: Lusambo L.P.,2016

Table 11 shows different df values and different interpretations to be concluded based on the results found. After computing the value of df the decision and interpretations are made accordingly to the obtained df value.

Table 12: Investigation of fuel preferences for Kaniga and results table for Kaniga area

Variables	Preference to Kaniga Woodlands	Preference to Kaniga plantation Forests	Indifferent Users	Total
Observed Frequency Number (n)	600	340	60	1,000
Observed Frequency Percentage (%)	60	34	6	100
Expected Frequency Number (n)	370	520	110	1,000
Expected Frequency Percentage (%)	37	52	11	100

Source: Primary Data.,2020

Table 12 of investigation of fuel preferences and results for Kaniga details the observed frequencies and expected frequencies where it project the corresponding level of effect interpreted using chi-squared test of independence.

It is clearly described in table 12 that the respondents have asked and their answers were tabulated to get the summary of observed frequencies of the samples and it's corresponding expect number in terms of the percentages. The table 11 was used to classify the level of effect of each result obtained based on the value of df analyzed.

- In 37% of the population expected to prefer Kaniga woodlands, the study revealed that about 60% prefer to be the users of Kaniga woodlands.
- In 52% of the population expected to prefer Kaniga plantation forests, the study revealed that about 34% prefer to be the users of Kaniga plantation forests.
- In 11% of the population expected to be indifferent users on both woodlands and plantation forests, the investigations and assessments made revealed that only 6% are indifferent users between Kaniga

Woodlands and Plantation forests.

Table 12 shows the observed and expected frequencies which were used to for the chi-squared ($\chi 2$) test.

Using the values in statistical tests conducted from tables 10 and 12, the chi-squared statistic ($\chi 2$) was then computed as follows:

$$x^2\% = \sum \frac{(f_o - f_c)^2}{f_c} \qquad Equation\ (2)$$

$$x^2\% = \sum \frac{(f_o - f_c)^2}{f_c} = \sum \frac{(60-37)^2}{37} + \frac{(34-52)^2}{52} + \frac{(6-11)^2}{11}$$

$$x^2\% = (0.621)^2 + (0.346)^2 + (0.454)^2$$

$$x^2\% = 72.1\%$$

The degree of freedom (*df*) for chi-squared is C-1, where C is the number of columns in the chi-squared frequency table. For *df*= 2 and $\alpha = 0.05$, the table of critical value for chi-squared indicate that the critical $\chi 2$ has a value of 5.99. Therefore, the respondents in the study area showed statistically significant preference between sources of wood fuel, $\chi 2$ (2, n = 1000) = 72.1, p <0.05

The strength of preference was subsequently determined using Cramer's V

$$V = \sqrt{\frac{x^2}{n(df^*)}} \qquad \text{Equation (3)}$$

Where χ^2 is chi-squared, *n* is the sample size, *V* is the effect size, *df** is a smaller of either *(R-1)* or *(C-1)*: R and *C* are the number of rows and columns respectively, in the frequency table. Consequently, the value of Cramer's V is:

With X^2=72.1, df=1 and n=1000, the effect size is given by:

$$V = \sqrt{\frac{72.1^2}{1000(1)}}$$

$$V = 2.28$$

According to Cohen's 1988 guidelines presented in Table 11, the obtained value of V (2.28) suggests that the effect size of natural forest/woodlands preference is large.

The empirical evidence from the present study has revealed several household fuels: kerosene, firewood, charcoal, grid electricity, crop residues, natural gas, solar electricity, and diesel

9.7. Discussions of the results

The study didnot encounter any household that was using coal and LPG. Of the above-mentioned energy sources, the main ones are biomass (used by 80.4% of the respondents), electricity of hydropower (used by 15.2% of the respondents) solar energy (used by 1.4% of the respondents), gas used by 0.7% of the respondents and other fuel used by 1.3% of the respondents. Firewood and charcoal are the main cooking fuels in the study area. The households use a fuel mix-empirically supporting the energy stack model.

The majority of the households (51.4%) collect firewood, mainly from the natural forest (73.6% of the firewood collectors). About 46 % of respondents reported that firewood collection is mainly undertaken by women, and nearly 15% of the respondents posited that firewood collection is the task carried out by women and children. This is the evidence that women suffer disproportionately in the event of wood fuel scarcity

When analyzed using the chi-squared ($\chi 2$) test, the preference of households for natural forest-wood fuel was found to be statistically significant, $\chi 2$ (2, n = 1000) =72.1, p <0.05 and effect size of the preference was large: Cramer's V = 2.28

Multiple binary logistic regression analysis was carried out to find out factors affecting choice of cooking fuels (firewood and charcoal) in the study area. It was found that the statistically significant factors are: residence ownership ($p < 0.001$): households with owned residence prefer firewood to charcoal, dwelling category ($p < 0.001$): households with modern dwellings prefer charcoal to firewood, education of household head ($p < 0.05$): the higher the education level of the household head the more is the preference of charcoal to firewood, household income ($p < 0.01$): households with higher income prefer charcoal to firewood; and location of the household ($p < 0.001$): households in urban areas have more preference to charcoal than their counterparts in non-urban areas.

Households' dependency on wood fuel as a source of energy in the study area is overwhelming. Empirical evidence suggests that there are a number of factors which influence this situation.

The main factors are poor availability of alternative sources of energy and escalating prices of the available non-wood fuels. The findings of this study support the energy stacking model, suggesting that while efforts to avail other sources of fuels alternative to wood fuel to the population in the study area are highly recommended, existing sources of energy should concurrently be increased and used more efficiently.

The support towards the energy stacking model (Van der Kroon et al.,2013) coupled with high household dependency on wood fuel, is sufficient evidence that biomass fuel in general and wood fuel in particular will remain the major and in many cases the only – source of household cooking and/or heating fuel.

It is reasonably plausible to argue that since (according to the findings of this study) at any point in time a household will use a fuel mix, efforts targeted at reducing pressure on natural forests should explicitly aim at reducing the share of wood fuel in household total fuel mix.

Clear in rural area like Kaniga household energy practices are apparent. In many of the developing regions, close to 100% of

rural dwellers rely nearly exclusively on gathered wood, dung, or crop waste. Biomass fuels are still widespread in urban areas but often need to be purchased, which helps drive progression toward replacement by another higher quality of energy.

9.8. Reliability and validity of the results

Based on all data collected from difference sources and different technique used in the data collection. Considering different results obtained in different analysis and interpretations made, followed by hypothesis tested in this research, analysis, and interpretation conducted from SPSS, It can be concluded that the data gathered are reliable and the hypotheses are valid. Therefore, Household survey on "Domestic Energy Consumption Pattern in Kaniga" revealed the insufficient electricity in Kaniga Sector.

X. CONCLUSION AND RECOMMENDATIONS

10.1. Conclusion

This research has analyzed household type of Domestic Energy Consumption Pattern in Kaniga, with special focus on the Energy Consumption Patterns of households.

Based on the information collected from the respondents using different mentioned methodology, followed by deep analysis on data that were analyzed using different techniques as have been mentioned, by considering different interpretations conducted to find out the validity of the hypotheses that were supposed to be tested to find out the reliability, the research proved that the available data are valid and reliable.

The findings indicated that majority of the households are dependent on biomass being their source of energy. This has practical implications that the most appropriate strategies for improving household energy services in the study area should be those targeted at improving the household Renewable energy mix proportions as opposed to those aimed at exclusively replacing biomass by Renewable Energy.

Thus issues of rural electrification and biomass should be facilitated by renewable energy should go in tandem with the improvement in Socio economic situation, standard of living of the population as well as the improvement of sustainable natural forest and environment management.

10.2. Recommendations

10.2.1. To the Government of Rwanda

1) Promote, disseminate and scale-up the uptake of improved renewable energy. The renewable energy should be affordable, sustainable and consider the safe environment. It would be prudent for the Government to institute a body responsible for quality control of the improved renewable energy.
2) Regularly and consistently provide adequate and well-targeted extension education services to the community so as to change their habits, way of thinking and attitudes towards environmental protection issues.

10.2.2. To the Kaniga local authority

Environmental protection committees from local population surrounding the climate change management should be involved in all steps of sustainable energy undertaken at Village, Cell and Kaniga Sector level.

They should have both sense of ownership of forest resources and responsibility for its management. If the local community is not dedicated towards management of their surrounding renewable energy resources, no amount of efforts from higher levels will bring about a sizeable change towards a desired outcome. It is with this understanding that the following recommendation is tasked to the village-level leaders:

1) Village level leaders should be made to ensure that all energy using households use improved stoves;
2) The forests should be monitored by the Village and the Cell leaders or environmental management committees to ensure that all should be required to use improved energy production technology;
3) Local authority leaders should devise a mechanism which will ensure that households have individual wood lots for energy purposes.

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ANNEXURE

FORM THAT SHOW THE ENERGY TYPES AND THEIR CONSUMPTION LEVEL

Date: 31/5/2020

NORTHERN PROVINCE

GICUMBI DISTRICT

KANIGA SECTOR

National Identity Number:…….

Hello, I am ……,

I worked at …….....

I would like to ask you to participate in this research related to " **DOMESTIC ENERGY CONSUMPTION PATTERNS IN KANIGA AREA**" This research do not specify respondent by name and all questions are not compulsory, you are free to express your ideas. All your ideas will be kept confidentially. The answer of the following research questions are intended to do the advocacy to the concerned part to improve the underserved sectors of household Socio-economic welfare.

PART I.PERSONAL IDENTIFICATION

1. How old are you? (Circle the best choice that represent your position/experience)
   a. From 11 years to 20 years
   b. From 21 years to 30 years
   c. From 31 years to 40 years
   d. From 41 years to 50 years
   e. From 51 years to 60 years
   f. From 60 years and above
2. What is your gender?
   a. Male
   b. Female
3. What is your education level?
   a. Illiterate
   b. Primary Education
   c. Secondary Education
   d. Adult Education
   e. College Education
   f. University Education
   g. Others
4. What is your Marital Status
   a. Single
   b. Married
   c. Divorced
   d. Widows/Widower
   e. Separate

5. Underline the Cell where you live.

a. Bugamba cell

b. Gatoma cell

c. Murindi cell

d. Nyarwambu cell

e. Rukurura cell

6. Based on your family organization, Choose your Social Responsibility

a. Household Head

b. Not household Head

PART II. RESIDENCE CONDITION OF THE RESPONDENT

1. Does your dwelling/residence house ownership owned or rented?

a. Rented

b. Owned

PART III. SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENT

1. What is your Socio-economic class?

a. Poor Class

b. Low Class

c. Middle Class

d. High Class

2. What are main day-to-day occupation of household?

a. Employee

b. Formerly employed

c. Casual labor

d. Artisan

e. Herder/ Cultivator

f. Trader

g. Petty business owner

k. Firewood/charcoal vending

3. What is the Building Types represent your Building

a. Rudimentary

b. Local type/Apartment

c. Basic Villa

d. Luxury Villa

4. What are the income range does a household generate in a month?

a. We generate amount ranging from 0 Frw to 30 000 Frw

b. We generate amount ranging from 31 000 Frw to 60 000 Frw

c. We generate amount ranging from 61 000 Frw to 90 000 Frw

d. We generate amount ranging from 91 000 Frw to 120 000 Frw e. We generate amount ranging from 121 000 Frw to 150 000 Frw f. We generate amount ranging from 151 000Frw to 180 000 Frw

g. We generate amount ranging from 181000 Frw to 210 000 Frw

h. We generate amount ranging from 210 000 Frw and above

5. What are the assets and materials does your household own? Specify

…….

PART IV. TYPES OF ENERGY AND THE LEVEL OF CONSUMPTION

1. Choose the type of energy you currently use

a. Biomass

b. Electricity of Hydropower

c. Fuel

d. Gas

e. Solar

2. What is the Building Types represent your Building

a. Rudimentary

b. Local type/Apartment

c. Basic Villa

d. Luxury Villa

3. What factors affect household energy consumption in Kaniga Sector?

a. Education level

b. Income level and financial ability

c. Availability of Infrastructure (Energy types)

d. Cultural and inheritances'

e. Government policy

f. Population distribution

4. What are the purpose of household energy consumption you experience?

a. Energy consumption are needed for domestic consumption only

b. Energy consumption are needed for domestic consumption and trading activity

c. Energy consumption are needed for domestic consumption and educational activity

d. Energy consumption are needed for domestic consumption and Health activities

e. Energy consumption are needed for domestic consumption and others (Specify others)……

5. Based on experience, what level of satisfaction derived from available energy types in Kaniga Sector?

……

6. Based on your personal experience, What types of resources in your area that could be used to generate additional sources of energy to satisfy domestic energy consumption in Kaniga?

    a. Waste

    b. Lakes and water body

    c. Fuel

    d. Gas

    e. Solar

    f. Wind

Thank you to take a time to express your valuable idea and personal experience in this Survey questionnaire!