Republic of Botswana
MINISTRY OF MINERALS & ENERGY

NATIONAL ENERGY USE SURVEY

MAIN REPORT 2022/23

Ministry Of Minerals & Energy
Department Of Energy
Tel: 3640200
Fairground Office Park

BITRI
BOTSWANA INSTITUTE FOR TECHNOLOGY RESEARCH AND INNOVATION

STATISTICS BOTSWANA

@minerals_energy mmebotswana

National Energy Use Survey 2022/23

Published by

STATISTICS BOTSWANA

Department of Energy

Ministry of Minerals and Energy

Private Bag 00378, Gaborone

Tel: +267 3640200

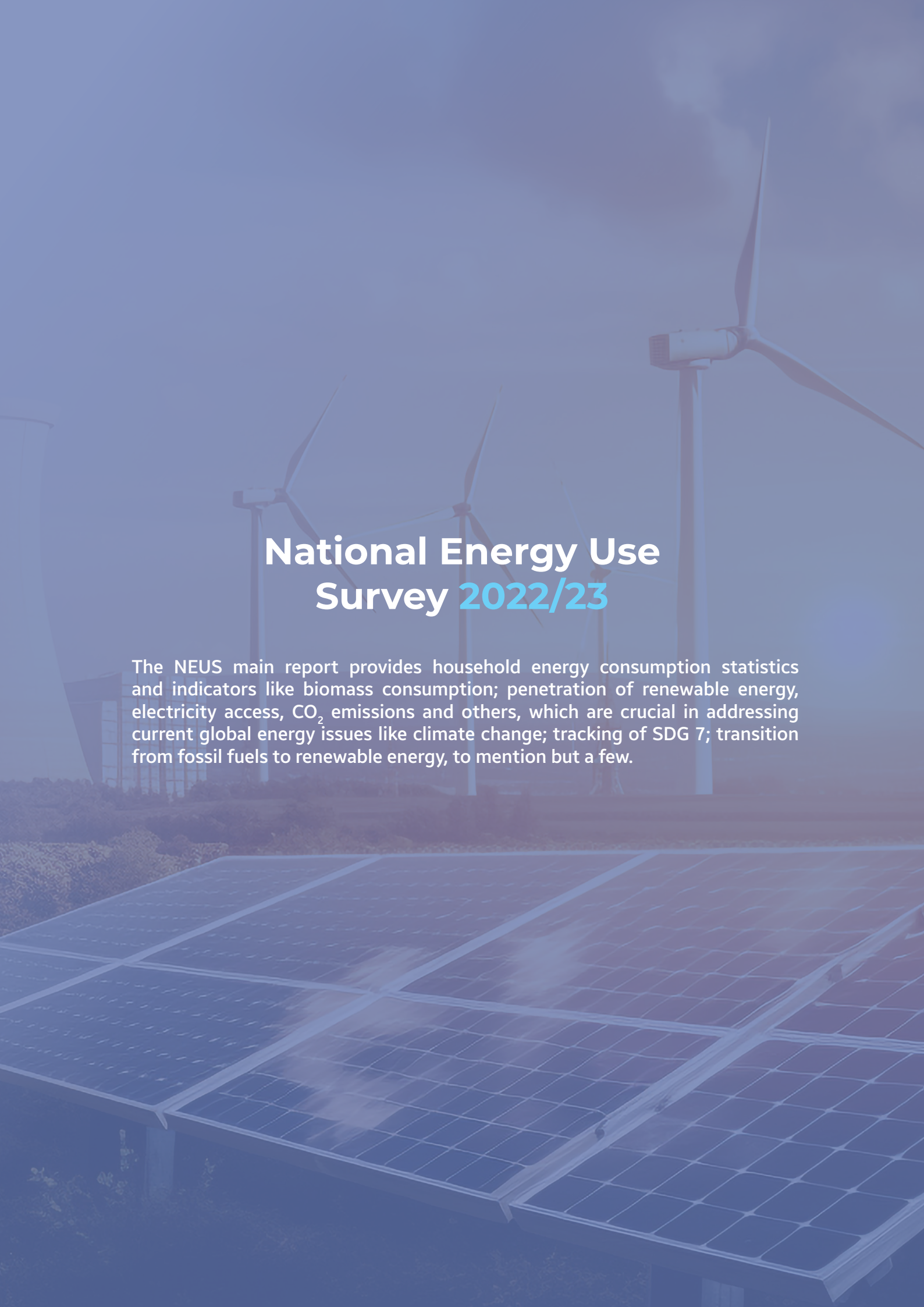
Fax: +267 3914201

Website: www.gov.bw

ISBN: 978-99968-909-1-8 (Paperback)

ISBN: 978-99968-909-1-8 (E-Book)

AUGUST 2024



National Energy Use Survey 2022/23

The NEUS main report provides household energy consumption statistics and indicators like biomass consumption; penetration of renewable energy, electricity access, CO_2 emissions and others, which are crucial in addressing current global energy issues like climate change; tracking of SDG 7; transition from fossil fuels to renewable energy, to mention but a few.

FOREWORD

The National Energy Use Survey (NEUS) publication is the first of its kind. I therefore wish to express my sincere gratitude that the Department of Energy in collaboration with Statistics Botswana (SB) and Botswana Institute for Technology, Research and Innovation (BITRI) have managed to successfully conduct a National Energy Use Survey.

Availability of accurate and timely data cannot be overemphasised as it is the foundation for analysis and policy meant to direct and shape the energy landscape going forward. Having employed international methodologies to conduct NEUS, I can confidently say that the NEUS main report provides household energy consumption statistics and indicators like biomass consumption; penetration of renewable energy, electricity access, CO_2 emissions and others, which are crucial in addressing current global energy issues like climate change; tracking of SDG 7; transition from fossil fuels to renewable energy, to mention but a few.

It is my sincere hope that the NEUS results and information will prove useful to policy makers, academia and researchers globally. Official statistics is a public good and a foundation for a knowledge based economy which Botswana aspires to move to from a resource based economy. I am pleased to announce that the NEUS Report is accessible to all and is available for free from the Ministry of Minerals and Energy offices and on SB and MME websites (www.statsbots.org.bw and www.gov.bw respectively).

The Ministry acknowledges the cooperation and support extended by all stakeholders, especially households in undertaking this exercise. I believe the support will continue to enable the Ministry provide such information for evidence based decision making.

Pelaelo Khowe
Permanent Secretary
Ministry of Minerals and Energy
August 2024

PREFACE

This report presents the findings of the 2022/23 National Energy Use Survey (NEUS), which concentrated on the household unit.

The report focuses primarily on the main indicators in the Energy Sector, such as total energy consumption, energy consumption per use, electricity access, carbon dioxide emissions and energy consumption for transportation and agricultural purposes, amongst others. It provides reliable and baseline statistics to help strengthen energy planning and policy formulation, as well as monitoring of relevant SDGs.

The 2022/23 National Energy Use Survey was conducted by the Department of Energy in collaboration with Statistics Botswana (SB) and Botswana Institute for Technology Research and Innovation (BITRI). Collaboration among the partners in producing this report has been fundamental and we look forward to the continued partnership.

Statistics Botswana joins other partners in recognising all stakeholders for their invaluable contribution in the production of this report. In particular, we thank the households for providing required data.

It is my hope that users will find this report informative and relevant.

Dr. Lucky Mokgatlhe
Statistician General (Ag.)
Statistics Botswana
August 2024

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DEFINITION OF TERMS

The following terms which are used in this document are defined below:

Affordable: A measure of the cost relative to the amount that the purchaser is able to pay and the consumer's capacity to afford the commodity.

Annual Energy Consumption: The amount of energy consumed by a household during a twelve months period.

Bio-energy: Final energy carrier produced from biomass or any other organic waste material or otherwise.

Biogas: It is a gaseous fuel produced by fermentation of organic matter. It contains various gases especially methane (CH4) and can be used as a fuel for heating/cooking.

Biomass: The solid organic material such as firewood, wood waste, crop waste, charcoal, animal wastes, etc. especially when used as a source of energy.

Clean Energy: Energy source that causes minimal or no pollution to the environment when consumed.

Consumption per Use: The use to which energy source are put to, e.g. cooking, lighting, space cooling, space heating, refrigeration, drying, ironing, etc.

Documents: All information/documentation used during the NEUS kept in hard or soft copy, e.g. questionnaires, maps, manuals, etc.

Energy: It is the capacity of a physical system to perform work. It is the quantitative property that must be transferred to an object in order to perform work on, or to heat this object. Energy is measured in kilowatt hours (kWh).

Energy Access: Access to electricity in the context of this document is determined by number of household connected/number of household in Botswana.

Energy Carrier: A substance (energy form) or sometimes a phenomenon (energy system) that contains energy that can be converted to other forms such as mechanical work or heat or to operate chemical or physical processes.

Energy Policy: A set of policy decisions and actions adopted by the Government and the legislators to lead the development of the energy sector in the country over the next decade. It can be amended depending on international, regional and local prevailing conditions.

Energy Security: A condition in which the economy has access to sufficient energy resources for the foreseeable future at an acceptable risk level.

Energy Source: Refer to any form of energy that can be used by living organisms or machines. Energy sources can be chemical, electrical, thermal, mechanical, nuclear, etc. and they range from: wind, hydrogen, wave, solar, biomass, etc. and contain energy in different forms that can be converted into useful work or heat.

Enumeration Area: (EA) It is the smallest geographic unit which represents an average workload for an enumerator over a specified period. The average size of an EA in Rural Areas ranges between 75-150 dwellings with a population size of between 330 and 660. EA's in Urban Areas and Major Villages range between 220-440 dwellings with a population size of between 440 and 880 people.

Expenditure on Energy: The amount of money spent on energy by a household which includes VAT and other taxes as well as delivery costs to the household.

Household: A household comprises of one or more persons, related or unrelated living together under the same roof in the same lolwapa, "eating from the same pot" or making common provision for food and other living arrangements.

Power: The rate of doing work or transferring heat, the amount of energy transferred or converted per unit time. It is measured in watts (W). One watt is defined as the energy consumption rate of one joule per second. Power is also measured in kW (kilowatt which is equal to 1000 W i.e. 1kW=1000W.

Self-Sufficiency: To be able to maintain oneself or itself without outside aid hence minimizing imports by increasing the use of indigenous energy resources.

Sustainable: Long-term maintenance of responsibility which has environmental economic and social dimensions and encompasses the responsible management of resource use.

Abbreviations & Acronyms

BERA	Botswana Energy Regulatory Authority
BITRI	Botswana Institute for Technology Research and Innovation
BPC	Botswana Power Corporation
BWP	Botswana Pula Currency
CAPI	Computer Assisted Personal Interview
CBM	Coal Bed Methane
CFL	Compact Fluorescent Lamp
CO_2	Carbon Dioxide
CTO	Central Transport Organisation
DEFF	Design Effect
DoE	Department of Energy
EA	Enumeration Area
EE & C	Energy Efficiency and Conservation
Gg	Giga grams
GHG	Greenhouse gas
GJ	Giga joule
GWh	Gigawatt hour
Hh	Household
IOC	International Oil Companies
IRP	Integrated Resource Plan
KJ/m2	Kilo joules per square meter
kWh	Kilowatt hour
LED	Light Emitting Diodes
LPG	Liquefied Petroleum Gas
MJ	Mega joule
MJ/m2	Mega joules per square meter
MME	Ministry of Minerals and Energy
MOS	Measures of Size
MSW	Municipal Solid Waste
MW	Megawatt
NCV	Net Calorific Value
NEP	National Energy Policy
NESC	National Electrification Standard Cost
NEUS	National Energy Use Survey
PPS	Probability Proportions to Measures of Size
PSUs	Primary Sampling Units
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Sources
SB	Statistics Botswana
SDGs	Sustainable Development Goals
SSUs	Secondary Sampling Units
TJ	Tera joules
UNEP	United Nations Environment Programme
VAT	Value Added Tax

Executive Summary

The Ministry of Minerals and Energy through its Department of Energy in partnership with Statistics Botswana (SB) and Botswana Institute for Technology Research and Innovation (BITRI) conducted the National Energy Use Survey (NEUS) over a two (2) months period between November 2022 and February 2023. Although initially the Survey covered both Households and Enterprises (Business) sectors, the Enterprises Survey data could not be analysed due to low response rate of 44%, hence all discussions are centred on the Household Survey. The Household Survey covered a sample size of 4 260 households located in 355 Enumeration Areas (EAs) and was completed successfully with a response rate of 99.4%.

The main objective of the Survey is to strengthen the energy sector by improving energy statistics and providing robust data for energy planning, policy formulation and review. From the analysis, the following are key findings:

Total Final Energy Consumption:

- Total Final Energy Consumption stands at 43 001.66TJ dominated by Biomass at 28 360.8TJ, constituting a share of 66.0%. It is followed by Petrol at 6 280.1 TJ constituting a share of 15% whilst Electricity follows at 4 576.5 TJ at a share of 11%. Consumption of the rest of the fuels is comparatively insignificant with shares of 5% and below.

- Total Final Energy Consumption at District level is led by Kweneng East at 5 585.41TJ, followed by Serowe Palapye at 3 693.76TJ whilst the least is Sowa at 81.29TJ.

- The average energy consumption per household is high in Rural Villages at 0.08TJ (42%) whilst that of Cities and Towns is the least at 0.04TJ (22%). The high average energy consumption per household in Rural Villages could be due to high usage of biomass since it is comparatively accessible and cheaper to acquire in Rural Areas than other Locality Types.

- On average, a household within an income bracket of "BWP12001 and Above" consumes more energy than a household in other income brackets at 103.27GJ per annum. The least energy consuming household falls within the BWP1001-3000 income bracket at 55.66GJ per annum showing a positive relationship between energy expenditure/consumption and household income level.

Biomass Consumption:

- Biomass consumption is constituted of: charcoal, firewood, shrubs, wood waste, crop waste, animal waste and wood pellets. Firewood consumption is the highest at 2 7217.2 TJ (96%) followed by Shrubs at 690.9TJ (2.4%). The least is Crop Waste at 16.2 TJ (0.06%).

- Kweneng East leads in Biomass consumption at 3 217.4 TJ (11.3%) followed by Serowe/Palapye at 2 917.1TJ (10.3%) whilst the least consuming district is Orapa at 2.3 TJ (0.01%), probably because it is a mining town with total access to electricity and LPG.

- Most firewood is sourced from communal forests with about 50% of households spending 1-2 hours collecting firewood.

Consumption of Other Renewables & Solar Energy

- Measured in terms of penetration, Photovoltaic Systems showed a higher penetration rate of 77.5% in Rural Areas and Solar Water Heaters penetrated Urban Villages mostly, at a rate of 47.7%. Biogas Digesters have penetrated Rural Villages only.

- Generation & Consumption of solar energy from SWH and PV Systems showed that Central Mahalapye district generates more electricity at 66.61TJ than all other districts. This could be due to the wide spread use of solar for water pumping in Central Mahalapye district.

Energy Consumption per Use:

- Energy Consumption per Use considered here include: Space Heating, Space Cooling, Water Heating, Cooking and Lighting.

- Space Heating: The main sources of energy used for space heating are electricity at 88.2%, followed by firewood at a share of 7.1%. The commonly used appliances are Air Conditioners & Electric Heaters dominating at a share of 88.4%.

- Space Cooling: Gaborone District dominates space cooling with a share of 24.8% out of 83 545 households whilst all other districts recorded 14% and below. Total electricity consumption for space cooling amounted to 48 872 672. 67 kWh (48.9 GWh) per annum, the main consuming technologies being Air Conditioners at 42 698 244.55 kWh (42.7 GWh).

- Water Heating: Electricity is the main source of energy used for water heating with a share of 54.5% followed by firewood at 39.7%. Data shows that of all water heating appliances, electric geysers have the highest electricity consumption.

- Cooking: The main sources of energy used for cooking are: Liquefied Petroleum Gas (LPG) at 42.7% followed by Firewood at 32.8% and Electricity at 24.4% respectively. LPG and electricity dominate as cooking fuels in Cities & Towns and Urban Towns whilst Firewood dominates in Rural Villages.

- Lighting: The share of Grid electricity dominates for lighting with Cities & Towns at 90.6% followed by Urban Villages at 87.6%. Compact Fluorescent (CFL) is the most commonly used type of bulb across all three Locality Types at 77.9%. The most energy consuming type of bulb is Incandescent bulb, whilst the most efficient is the LED bulb.

Access to Electricity:

- At national level, out of 634 076 households, 468 344 (73.9%) households were connected to electricity and 165 732 (26.1%) households were not connected.

- Orapa and Sowa districts enjoy 100% connection rate whilst Ngwaketse West stood at the lowest connection rate of 14.3%.

- Of the 466 147 households connected to grid electricity, a total of 282 879 (61%) connections were subsidised through the National Electrification Standard Cost (NESC).

- The main constraints for not connecting are: limited funds for wiring and connection as well as distance from the grid.

Energy Consumption for Transport, Agriculture & by Generators

- Total fuel consumption (diesel and petrol) by households amounts to 8 434.66TJ. The total has been sub-divided between consumption of: vehicles/cars (Transport) at 8 434.66TJ; tractors (Agriculture) at 153.78TJ and Generators at 235.55TJ.

- At national level, consumption of petrol amounts to 6 280 TJ while that of diesel amounts to 2 154 TJ.

- At district level, Gaborone and Kweneng East registered the highest consumption of fuels at 1 256.94 TJ and 1 286.76 TJ respectively, whilst Sowa registered the lowest consumption at 25TJ.

Building Characteristics:

- Detached type of houses dominates other types of houses in Botswana at a share of 54.7%.
- Modern bricks (84% of houses) are the preferred wall material across all Locality Types; Corrugated iron/zinc/tin is the preferred roof material at 77% (houses) while Cement is the dominant floor material (62% houses) across all districts. Lastly, Iron Frame Single Glass is the predominantly used type of window (78% houses) across all localities.
- The use of Aluminium Double Glazing type of window registered only 1.2% despite it being the most efficient. The low use could be because it is pricy or due to lack of awareness of it being efficient.

Energy Efficiency & Renewable Energy Plans & Barriers:

- At national level, only 26% of households showed interest in adopting EE & RE solutions.
- The following energy efficiency measures were planned: replacing light bulbs with CFL and LED; installing SWH and PV systems; insulating roofs and walls, etc.
- Households which had no plans to adopt energy efficiency measures cited the following reasons: response rates on high purchasing costs sat at 47% followed by 'do not own the house' at 45%.

CO_2 Emissions by Source:

- Total CO_2 emissions generated by the household sector at national level is 3 872.2 $GgCO_2$.
- The highest share of CO_2 emissions comes from biomass (3 176.4 $GgCO_2$) at 82.0% followed by petrol (435.2 GgCO2) at 11.2%.
- Districts with the highest consumption of biomass emits more CO_2 than those with the least biomass consumption, e.g. Kweneng East, which consumes more biomass than any other district, generated CO_2 emissions amounting to 466.11 Gg CO_2.

Despite challenges encountered especially due to the complex nature of the energy sector, this work being the first of its kind and the need to cover extensive ground, sound recommendations have been drawn from this study which, if implemented, will guide and shape the now and future of the energy sector.

1. BACKGROUND OF THE ENERGY SECTOR

Botswana's energy sector developments are directed by the National Energy Policy (NEP 2021), which outlines the government's aims for effectively coordinating the development and management of the energy sector. NEP is established on three guiding principles being economic development, equity and environmental protection with a view to contribute towards achievement of National Prosperity, Sustainable Economic Development and Sustainable Environment in line with the country's goals outlined in the Botswana Vision 2036 and the eleventh National Development Plan (NDP 11). These two documents are the country's high level planning frameworks for the period 2017-2036 and 2017-2023 respectively.

The NEP is expected to create a conducive environment that will facilitate investment in the energy sector and also add value to export revenues, facilitate production in other sectors of the economy and create employment within the energy sector.

The energy sector has in recent years faced challenges impacting the country's economic prospects. For example, between 2008 and 2014 there was a significant mismatch between power supply and demand, threatening the country's energy security. In response, in 2020 the Government of Botswana launched the Integrated Resource Plan (IRP) for electricity. The Plan proposes various electricity generation methods, including renewable energy sources to meet projected demand until 2040. Additionally, several renewable energy projects such as Rooftop Solar, Off-Grid Solar, and Biogas Program are being implemented to address other energy needs. Furthermore, the Ministry has formulated the Renewable Energy and Energy Efficiency and Conservation strategies to promote adoption of renewable energy technologies and encourage energy-saving practices.

Pertaining to the power sector, electricity generation primarily relies on two coal power stations: Morupule A and Morupule B with installed capacities of 132 MW and 600 MW respectively. Furthermore, there are two diesel peaking plants, Orapa and Matshelagabedi with installed capacities of 90MW and 70MW respectively. To address electricity demand shortfall, Botswana imports electricity through bilateral agreements with neighbouring countries, namely: South Africa, Namibia, Zimbabwe, and Zambia. To facilitate nationwide electricity access and regional trading, various transmission infrastructure projects are either in place, underway or at planning phase.

With regard to the petroleum sector, Botswana heavily relies on imports of refined petroleum products because it has no proven crude oil reserves and refineries. The majority of imported fuels come from South Africa. Currently, the country's annual consumption of petrol, diesel and illuminating paraffin amounts to 1.2 billion liters and that of aviation fuels amounts to 20 million liters. The petroleum industry is dominated by International Oil Companies (IOC) and prices for petrol, diesel and Illuminating Paraffin are regulated by the Botswana Energy Regulatory Authority (BERA). Currently, the country has a strategic storage capacity for liquid fuels equivalent to approximately 18 days of national consumption. The ongoing Tshele Hill project aims to increase this capacity to 60 days in its first phase and ultimately reach 90 days upon completion, aligning with the international standard.

Botswana is endowed with coal resources estimated at about 212 billion tonnes, and significant Coal Bed Methane (CBM) reserves of 196 trillion cubic feet which is primarily used for power generation, with a smaller portion allocated for local industry and export. Commercial viability of CBM exploration is ongoing to determine its potential.

The country enjoys over 3 200 hours of sunshine annually, with high solar irradiation throughout. Solar energy is considered a promising renewable energy source for Botswana. The nation also has favourable wind conditions, primarily in the South-West, Central, and Eastern regions, with untapped wind energy potential. Wind is primarily utilized in the agricultural sector for water pumping.

Biomass energy has a substantial potential of 32 million GJ per year, mainly from livestock residues, offering practical opportunities for energy production. Availability of significant Municipal Solid Waste (MSW) offers opportunity to generate energy at city level. Crop and agro-industrial residues have limited energy potential.

Successful execution of the NEP is expected to set a foundation that will steer the utilization of locally available energy resources optimally and efficiently to ensure that Botswana attains a sustainable and low carbon economic development.

The NEUS report is arranged as follows: Chapter 2 gives the Overview of the Survey whilst Chapter 3 describes the Methodology employed in carrying out the NEUS. Chapter 4 presents Analysis and Results whereas Chapter 5 gives the Conclusions and Recommendations. Finally, Chapter 6 dwells on the limitations of NEUS.

2. OVERVIEW OF THE SURVEY

The Department of Energy (DoE) in collaboration with Statistics Botswana (SB) and Botswana Institute for Technology Research and Innovation (BITRI) conducted the National Energy Use Survey (NEUS) from November 2022 to February 2023. The partnership was necessitated by the fact that SB is the national statistics authority institution and BITRI is a research institution in the energy space.

The survey was the first of its kind and will be conducted every five (5) years. NEUS field work was conducted over a two (2) months period from the 14th of November 2022 to the 17th of February 2023. The fieldwork was divided into two rounds: the first round commenced from 14th November 2022 until 16th December 2022 and the second round from the 9th January 2023 until 17th February 2023 with a break from mid-December until mid-January 2023 to cater for the festive season.

NEUS covered all the sampled households in Botswana and provided a detailed picture of the breakdown of consumption of each energy product. It also provided important and critical information that is currently not available such as consumption of biomass and penetration of renewable energy technologies. The survey covered 355 Enumeration Areas (EAs) which translated into 4260 households.

The survey results which are presented in the following sections include among others:

- Total annual energy consumption per energy source,
- Quantities and types of energy consumed by households;
- Quantities and types of energy consumed for cooking, space heating, water heating and lighting;
- Annual energy consumption by income level and geographic area,
- Electrification level (grid and off-grid)
- Penetration of renewable energy technologies;
- Perception of Renewable Energy (RE) and Energy Efficiency (EE) technologies and barriers towards their introduction.
- CO2 Emissions by energy source

2.1 Objectives

The main objective of the survey was to strengthen the energy sector by improving energy statistics and providing robust data for energy planning, policy formulation and review.
Reliable statistics in the form of a detailed energy balance and energy indicators are necessary in order to monitor the energy sector and the implementation of related programmes and strategies. The specific objectives of the National Energy Use Survey in respect to households are:

- To estimate the level of energy use in the residential sector;
- To analyse the structure of energy consumption per use;
- To provide data for energy planning purposes.

3. SURVEY METHODOLOGY

This Chapter discusses the methodology employed for carrying out the NEUS.

3.1 Target Population

The target population covered all members of the household and visitors who spent the night with the household, only one member was interviewed.

3.2 Scope and Coverage

Only private dwellings were within the scope of the survey. Institutional dwellings (prisons, hospitals, army barracks, hotels, etc.), and Enumeration Areas (EAs) within completely industrial areas were not within the scope of the survey. The coverage was nation-wide using administrative districts and sub-districts that are usually used by Statistics Botswana in surveys and censuses.

The Sampling Frame (SF) and sample selection was based on the 2022 Population and Housing Census. The Population & Housing Census results give information on population, number of households at locality, Enumeration Area (EA), village and district/town levels. Also given for each EA is information on ecological zones in rural areas. The Sampling Frame was defined and constituted by all Enumeration Areas (EAs) found in three (3) geographical regions, otherwise known as domains and these are (i) Cities & Towns (ii) Urban Villages, and (iii) Rural Villages as defined by the 2022 Population and Housing Census.

3.3 Stratification

Since national level estimates are required in this survey, stratification has been implemented. It is an ideal procedure that is able to reduce sampling errors. As stated above, the country has been categorised into geographic stratification, being Urban, Rural Villages and Cities & Towns. These domains have a direct bearing on a sample design especially in determining the required sample size for the survey. It is worth noting that heterogeneity is expected across the strata more so that the stratification is done distinctly depending upon the aforementioned domains. However, the procedure reduces sampling error to the extent that the strata which are set up are internally homogeneous with respect to the variables of interest. Stratification further ensures that the sample is well spread out among its significant strata.

When Stratification is appropriately employed and used together with systematic Probability Proportion to Measures of Size (PPS), sampling automatically distributes the sample proportionately into each of the census districts as well as the domains. The fundamental reason for creation of strata is to:

i. Provide estimates for each stratum of interest
ii. Increase precision.

Apart from national and rural estimates, the Government of Botswana which is the main user of Statistics Botswana's data, requires accurate estimates for all regions for planning and monitoring of development projects. Stratification was therefore undertaken such that, Cities and Towns, Urban Villages and Rural Villages form their own strata. With regard to increasing precision, consideration was also given to grouping EAs according to the twenty-seven (27) districts.

3.4 Sample Design

This is a complex sampling design that combined stratification alluded to in the form of geographical areas and sampling of clusters at hierarchical stages. A two-stage cluster sampling design (1st and 2nd) in the selection of enumeration areas at first stage, followed by random selection of dwelling units at second stage.

The 1st stage involved selection of EAs as Primary Sampling Units (PSUs) selected with Probability Proportional to Measures of Size (PPS), where Measures of Size (MOS) were the number of dwellings/ households in the EA as defined by the 2022 Population and Housing Census. In all, 355 EAs were selected with probability proportional to size.

The following is the procedure for selecting an EA in each stratum:

i. Calculating the sampling interval for the stratum:

$$I = \square Mi / n$$

Where;

$\square$ Mi is the size of the stratum (total number of households in the stratum according to 2022 Census) and 'n' is the number of EAs to be selected in the stratum.

i. Calculating the cumulated size of each EA.

ii. Calculating the sampling numbers R, R+I, R+2I....., R+(n-1) I, where R is the random number between 1 and I.

iii. Comparing each sampling number with the cumulated size.

The selected EA was the first whose cumulated size was greater or equal to the sampling number.

Concerning the 2nd stage of sampling, households were systematically selected from a fresh list of occupied households prepared at the beginning of the survey's fieldwork (i.e. listing of households for selected EAs). In total, a sample of four thousand, two hundred and sixty (4,260) households were drawn systematically.

Upon completion of households listing, the lists were carefully checked for correctness Household numbers were assigned to each occupied household in the EA whilst vacant, non-residential structures and structures under construction were not numbered. The total number of households in the EA was the last household number assigned in the EA. The listing operation was used mainly to update the Measures of Size at the EA level for second stage sampling.

The criterion for the number of households allocated in the EA was fixed because of administrative convenience and spread of sample over strata. The procedure for systematic selection of households involves:

i. Calculating the sampling interval for the stratum:

$$I = M / m$$

Where;

M is the total number of occupied households listed in the stratum and 'm' is the number of households to be selected in the stratum.

ii. Calculating the sampling numbers R, R+I, R+2I...., R+(m-1)I, where R is the random number between 1 and I.

3.5 Sample Size and Allocation of Sample (Households) to Strata

Determining of the sample size forms the most important part of the sample design because it affects the precision, the cost and duration of the survey more than any other factor. Other equally important statistical determinants entail specifying the margin of error, design effect, household size, which the survey require.

The general rule of thumb that governs the choice on numbers of Primary Sampling Units (EAs) and Secondary Sampling Units (households) was observed. It states that: it is better to have more PSUs and smaller cluster sizes so as to yield more reliable estimates because the sample is more spread out, hence the decision to use twelve (12) households per EA. The Design Effect (DEFF) which is the ratio of sample variances from the survey to that of a Simple Random Sample (SRS) of the same size has been carefully considered. It has an effect in determining the sample size and the acceptable range is normally between 1.5 and 2.5 and the decision to use DEFF of 2 was finally reached. Numerous consultations with relevant parties were carried out, and it was concluded that the survey should encompass 4 260 households located in 355 EAs as the sample for the National Energy Use Household Survey, 2022.

4. RESULTS AND ANALYSIS

Chapter 4 gives a summary of energy demand and use by households. Energy demand drives the whole energy system, influencing total amount of energy used; types of fuels used in the energy supply system and the characteristics of the end use technologies that consume energy.

4.1 Total Final Energy Consumption (TFEC)

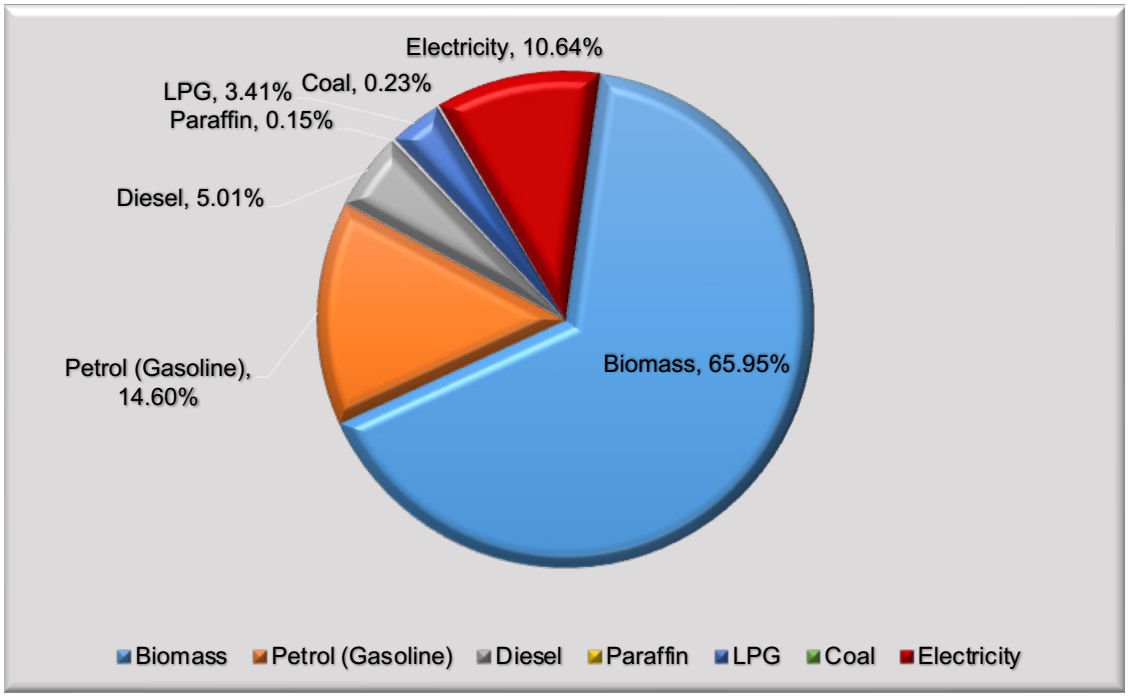
This section presents a summary of household's Total Final Energy Consumption by different fuels e.g. Electricity, Biomass, Diesel, Petrol, Paraffin, Coal and LPG. TEFC is further analysed by: fuel shares (%); Locality shares (Cities & Towns, Urban Villages and Rural Villages) and Income Level.

Table 1 below shows Total Final Energy Consumption by fuel at district and national levels whilst the accompanying Figure 1 shows fuel shares in Total Final Energy Consumption.

Table 1: Total Final Energy Consumption by District (TJ)

District	Biomass	Petrol (Gasoline)	Diesel	Paraffin	LPG	Coal	Electricity	Total
Gaborone	502.8	1,237.7	330.3	3.6	236.0	30.0	1,115.4	**3,455.7**
Francistown	358.3	280.4	100.3	1.5	65.0	8.4	241.4	**1,055.3**
Lobatse	171.5	81.2	34.1	3.3	41.7	5.4	77.4	**414.6**
Selibe Phikwe	177.1	101.9	10.6	0.3	26.9	0	78.4	**395.1**
Orapa	2.3	61.9	26.8	0	14.6	4.4	11.8	**121.8**
Jwaneng	160.5	41.5	0	0.7	18.3	0	50.6	**271.7**
Sowa	40.7	19.8	6.0	0	3.8	0	11.0	**81.3**
Ngwaketse South	2,621.1	299.8	58.3	5.6	101.6	1.3	138.1	**3,226.0**
Borolong	486.0	147.5	20.3	3.4	39.7	0	96.0	**792.9**
Ngwaketse West	536.3	48.3	146.7	0.9	3.1	0	3.1	**738.5**
South_East	1,122.8	397.1	147.0	1.7	115.4	12.3	287.7	**2,083.9**
Kweneng East	3,217.4	958.5	328.3	8.1	223.6	12.5	837.0	**5,585.4**
Kweneng West	1,475.6	62.7	92.9	2.1	18.1	4.8	42.2	**1,698.4**
Kgatleng	2,015.8	392.2	114.3	4.6	72.3	1.1	248.8	**2,849.1**
Serowe Palapye	2,917.1	337.5	82.0	5.4	72.6	8.9	270.2	**3,693.8**
Central Mahalapye	2,587.5	238.0	176.5	7.5	57.0	0	149.8	**3,216.2**
Central Bobonong	1,353.9	104.8	31.6	0.6	18.7	0	66.3	**1,575.9**
Central Boteti	1,251.6	227.1	39.9	0.6	56.4	0	136.8	**1,712.4**
Central Tutume	2,469.3	230.1	88.9	2.9	54.7	0	142.7	**2,988.6**
North East	1,035.8	212.3	39.2	1.8	49.5	1.0	132.7	**1,472.3**
Ngami East	1,523.4	356.4	71.9	5.7	113.4	0	227.1	**2,297.8**
Ngamiland West	399.1	33.6	5.0	0.1	7.9	4.1	34.8	**484.6**
Chobe	350.7	62.6	14.0	0.5	14.0	0	67.2	**509.0**
Ghanzi	592.7	215.0	140.0	0.8	19.5	0	57.0	**1,025.1**
Kgalagadi South	410.7	76.2	24.0	1.6	15.5	5.9	29.7	**563.7**
Kgalagadi North	580.7	56.1	25.7	0.5	6.3	0	23.5	**692.7**
National Level	**28,360.8**	**6,280.1**	**2,154.5**	**63.9**	**1,465.6**	**100.3**	**4,576.4**	**43,001.7**

Figure 1: Fuel Shares of Total Final Energy Consumption.



The following discussions are based on Table 1 and Figure 1 above. Table 1 depicts that Total Final Energy Consumption at national level is 43 002TJ. Total Final Energy Consumption is dominated by biomass at 28 360.8TJ, constituting a share of 66.0%. Next is petrol at 6 280.1 TJ constituting a share of 15%, followed by electricity at 4 576.5 TJ with a share of 11%. Consumption of the rest of the fuels is comparatively insignificant with shares of 5% and below. Consumption of paraffin could be very low because of increased access to electricity and availability of solar lanterns, especially for lighting.

At District level, Total Final Energy Consumption is led by Kweneng East at 5585.41TJ (13%) followed by Serowe-Palapye and Gaborone at 3 693.76TJ (9%) and 3 455.73 TJ (8%) respectively. Contribution of Sowa district to Total Final Energy Consumption is the least at 81.29TJ representing (0.2%). It is interesting to note that, whilst Total Final Energy Consumption for twenty-four (24) districts is dominated by biomass, that of Gaborone and Orapa is dominated by petrol.

More than 30% of the energy consumed in Africa comes from biomass whilst for sub-Saharan African countries it accounts for more than 80%. UNEP (2017). Botswana is no exception, since biomass consumption accounts for 66% of the Total Final Energy consumption. Given that biomass has been and continues to be the main source of energy for households, a separate survey/research on Biomass should be carried out to determine supply and consumption levels as well as the socio-economic and environmental impact of biomass use.

The next discussions, focused on Figure 2 & 3 show Locality shares of Total Final Energy Consumption as well as average energy consumption per household by Locality Type respectively.

Figure 2: Locality Shares of Total Final Energy Consumption

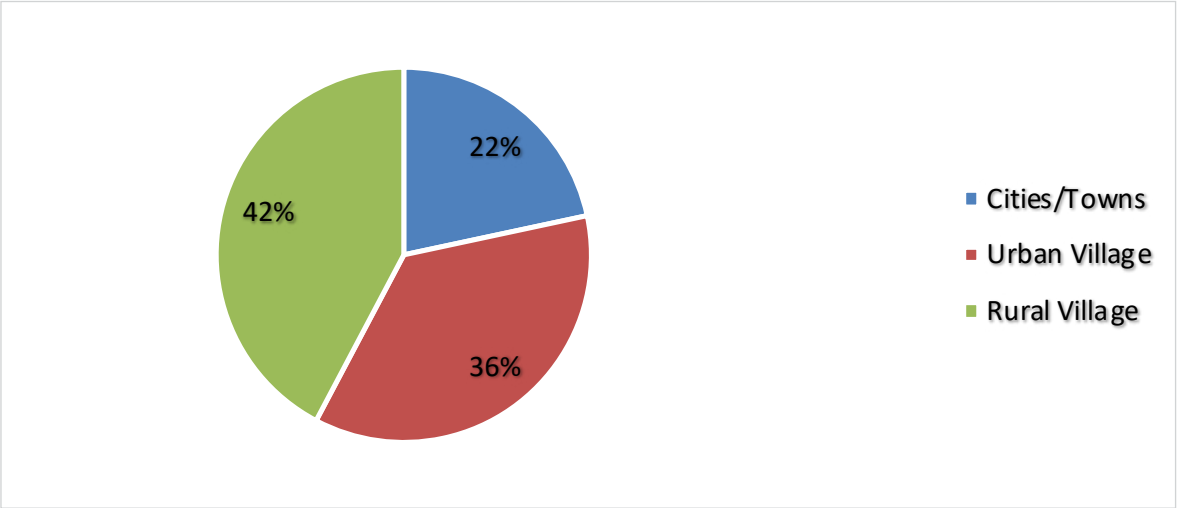
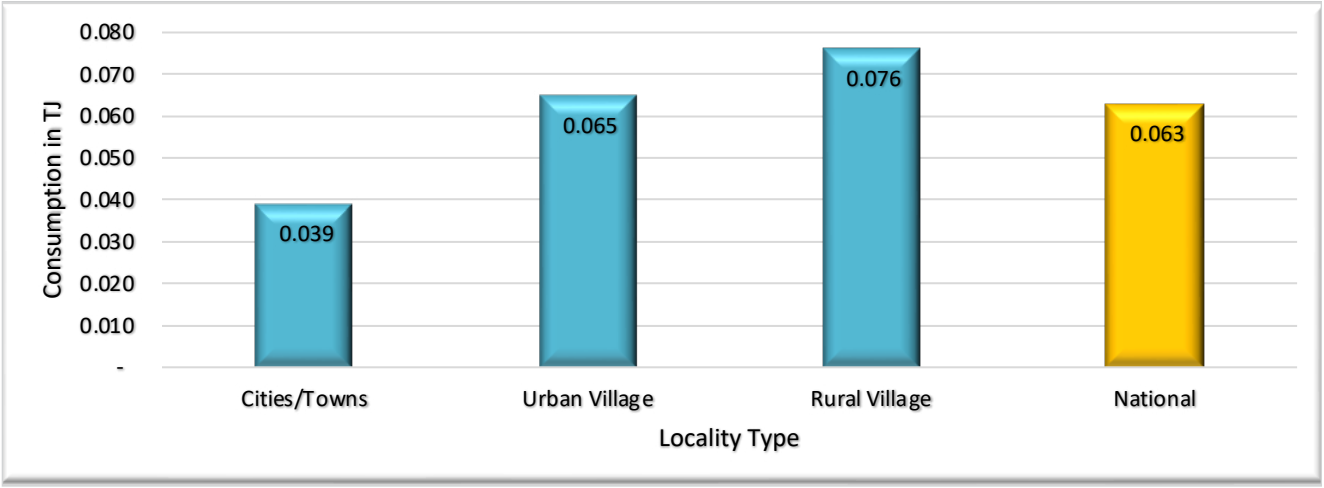


Figure 3: Average Energy Consumption per Household by Locality Type



Rural Villages have the highest share in Total Final Energy Consumption at 42% compared to the other two Locality Types. This might be due to high usage of biomass which is comparatively accessible and cheaper to acquire in Rural Villages and the high number of people living in each household in Rural Villages (Statistics Botswana, 2020). As per Figure 3, of the three Locality Types, the average energy consumption per household in Cities and Towns is the least at 0.04TJ (22%). The national average energy consumption per household in Botswana is 0.06TJ, which is lower than that of Rural Villages.

The next discussions consider Total Final Energy Consumption per Household by income level (Table 2).

Table 2 Total Final Energy Consumption per Household by Income Level

Income / Month (BWP)	Average Energy Consumption per Household (TJ)	Average Energy Consumption per Household (GJ)
No income	0.059	59.11
Less than 1000	0.057	56.96
1001-3000	0.056	55.66
3001-5000	0.067	67.43
5001-7000	0.072	72.12
7001-9000	0.075	75.07
9001-12000	0.085	84.71
12001 and above	0.103	103.27
National Level	**0.068**	**67.54**

Table 2 shows that on average a household within an income bracket of BWP12001 and Above consumes more energy than a household in other income brackets at 103.27GJ per annum. The least energy consuming household falls within the BWP1001-3000 income bracket at 55.66GJ per annum. This shows that there is a positive relationship between energy expenditure and household income level.

According to an abstract by nature.com, there is a positive relationship between energy consumption expenditure at the household level and household income across countries. This means, all things equal, as household income increases, expenditure on energy also increases.

4.2 Biomass Consumption

This section presents findings on different types of biomass consumed by households per annum. Biomass consists of: Charcoal, Firewood, Shrubs, Wood Waste, Wood Pellets/Briquettes, Crop Waste and Animal Waste/Dung. Consumption is analysed per: biomass type, District; Shares (%) of Firewood Collection Areas by Locality Type as well as Time Spent on Firewood Collection by Locality Type. Table 3 below depicts consumption of biomass per category at district and national level.

Table 3: Biomass Consumption by District

District	Charcoal	Firewood	Shrubs	Wood waste	Wood pellets, briquettes, others	Crop waste	Animal waste/ dung	Total
Gaborone	19.0	458.8	11.0	9.9	0.7	3.1	0.2	502.8
Francistown	3.4	350.3	4.3	0.0	0.3	0.0	0.1	358.3
Lobatse	0.9	168.4	1.2	0.3	0.6	0.0	0.1	171.5
Selibe Phikwe	0.4	172.1	2.3	2.4	0.0	0.0	0.0	177.1
Orapa	1.8	0.4	0.0	0.0	0.0	0.0	0.0	2.3
Jwaneng	0.5	151.8	6.4	0.7	0.0	1.2	0.0	160.5
Sowa	0.0	40.7	0.0	0.0	0.0	0.0	0.0	40.7
Ngwaketse South	1.8	2,540.1	68.4	7.4	0.0	1.1	2.3	2,621.1
Borolong	1.1	432.8	44.7	0.7	0.0	1.6	5.2	486.0
Ngwaketse West	0.0	511.5	22.3	2.2	0.0	0.3	0.1	536.3
South_East	5.0	1,103.7	8.3	2.3	1.5	1.0	0.9	1,122.8
Kweneng East	17.0	3,100.4	44.3	4.1	45.7	4.9	1.0	3,217.4
Kweneng West	1.3	1,412.5	54.0	7.4	0.0	0.1	0.4	1,475.6
Kgatleng	2.9	1,960.4	42.6	8.5	0.4	0.3	0.7	2,015.8
Serowe Palapye	10.3	2,833.8	58.1	14.5	0.0	0.0	0.4	2,917.1
Central Mahalapye	0.4	2,523.9	34.0	26.3	1.2	0.3	1.3	2,587.5
Central Bobonong	1.5	1,261.6	75.3	11.5	2.3	1.6	0.1	1,353.9
Central Boteti	10.6	1,084.3	31.4	104.3	19.9	0.3	0.7	1,251.6
Central Tutume	0.9	2,392.6	70.5	5.2	0.0	0.0	0.2	2,469.3
North East	0.6	997.5	5.2	0.0	32.2	0.3	0.0	1,035.8
Ngami East	1.9	1,491.6	18.9	2.9	0.0	0.0	8.2	1,523.4
Ngamiland West	1.0	393.7	4.2	0.2	0.0	0.0	0.0	399.1
Chobe	11.6	328.8	9.1	1.2	0.0	0.0	0.0	350.7
Ghanzi	2.3	571.2	17.7	0.0	0.1	0.0	1.5	592.7
Kgalagadi South	3.1	404.8	2.1	0.6	0.1	0.0	0.0	410.7
Kgalagadi North	0.6	529.5	44.8	0.0	0.0	0.0	5.9	580.7
National Level	**99.9**	**27,217.2**	**680.9**	**212.4**	**105.0**	**16.2**	**29.3**	**28,360.8**

Table 3 shows that at National Level, total biomass consumption stands at 28361TJ. As illustrated in the table, the most common type of biomass at national level and across all districts is firewood recording 27217.2 TJ (96%), followed by Shrubs at 680.9 TJ (2.4%) and the least being Crop Waste at 16.2 TJ (0.06%). The shares of Crop Waste at 16.2 TJ (0.06%) and Animal Waste/Dung at 29.3 TJ (0.10 %) are still very insignificant comparatively. Although the implementation of the Biogas Program could increase their contribution, this will require intensive promotion, especially of animal waste/dung and continuous tracking of their contribution to the energy mix.

At district level, Kweneng East district is the biggest consumer of biomass at 3217.4 TJ (11%) followed by Serowe-Palapye at 2917.1TJ (10%). The least consumer of biomass is Orapa at 2.3 TJ (0.01%), presumably because it is a mining town with total access to modern fuels, electricity and LPG.

Figure 4 below indicates various areas where households source firewood by Locality Type.

Figure 4: Shares of Firewood Sourcing Areas by Locality Type

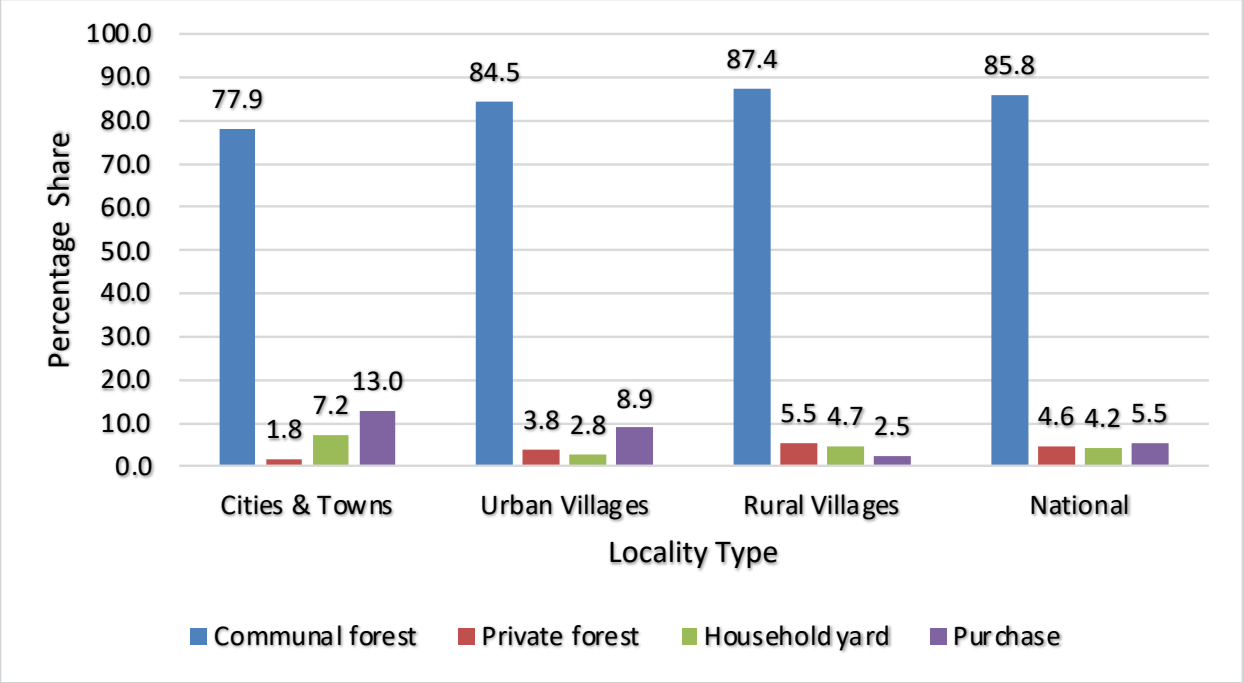


Figure 4 shows that most of the firewood used by households is sourced from Communal Forest which recorded above 70% for all Localities and scored an average share of 85.8% nationally. The share of 'Purchasing' takes second place for both Cities & Towns (13%) and Urban Villages (8.9%) registering 5.5% at national level.

Figure 5 below depicts time spent on firewood collection. Time factor plays a crucial role in firewood collection, once it involves many hours, it's thought to negatively impinge on other activities.

Figure 5: Time Spent on Firewood Collection by Locality Type

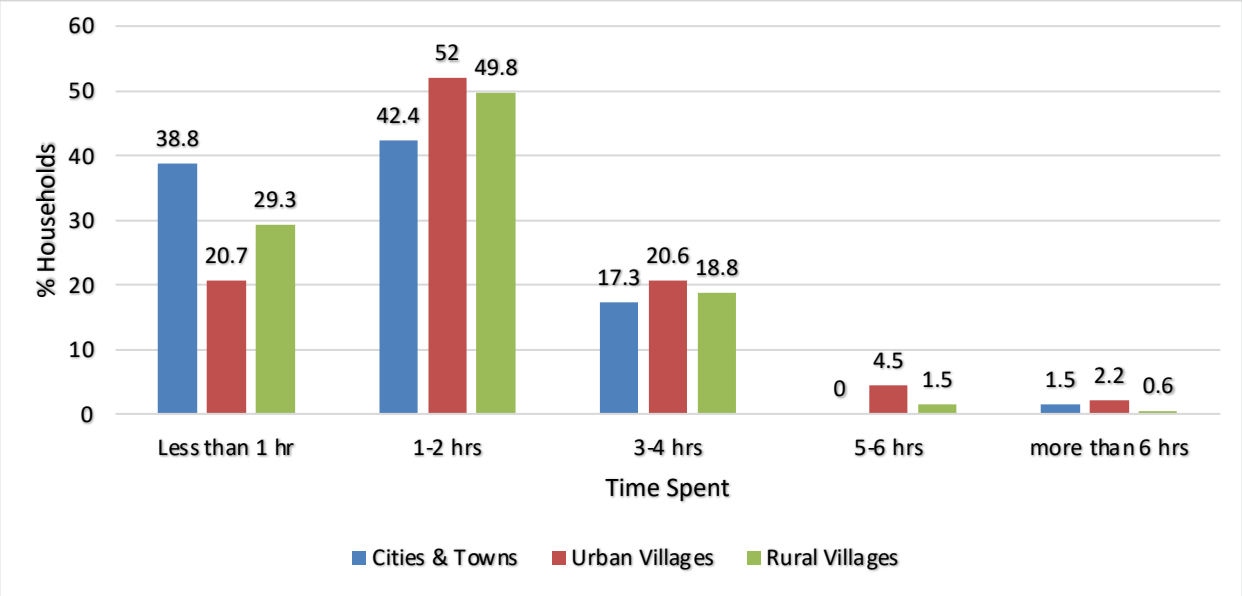


Figure 5 depicts that time spent by household members collecting firewood varies from less than one (1) hour to at least six (6) hours. Approximately 50% of households across all Locality Types spend on average 1 to 2 hours collecting firewood.

4.3 Consumption of Other Renewable Energy Sources

This section presents findings on consumption of Other Renewable Energy Sources other than Biomass and Electricity (Grid). Analysis focuses on penetration of PV Systems, Solar Water Heaters and Biogas Digesters by Monthly Income Level and Locality Type.

Table 4: Penetration of Other Renewable Energy Technologies by Monthly Income Level

	Households with PV Systems		Households with Solar Water Heating Systems		Households with Biogas Digesters	
Income Level(BWP)	Number	Share (%)	Number	Share (%)	Number	Share (%)
No income	4,424	15.1	288	2.4	0	0.0
Less than 1000	5,480	18.7	551	4.7	0	0.0
1001 - 3000	9,766	33.4	617	5.2	216	100.0
3001 - 5000	2,166	7.4	68	0.6	0	0.0
5001 - 7000	2,109	7.2	392	3.3	0	0.0
7001 - 9000	839	2.9	1,098	9.3	0	0.0
9001 - 12000	1,085	3.7	1,815	15.4	0	0.0
Above 12000	3,386	11.6	6,947	59.0	0	0.0
National Level	**29,255**	**100.0**	**11,776**	**100.0**	**216**	**100.0**

Table 4 shows penetration of Other Renewable Energy Technologies by Income Level. For Photovoltaic Systems, households within the BWP1001-3000 income bracket have the highest share of PV Systems at 33.4% followed by the BWP1-1000 income bracket households at 18.7% and the category "No Income" at 15.1% share. For Solar Water Heaters, households within the "BWP12001 and Above" income bracket accounts for a 59.0% share followed by those within BWP9001-12000 and BWP7001-9000 income brackets at 15.4% and 9.3% respectively. All Biogas Digesters were found to be used by households within the BWP1001-3000 income bracket.

The use of Other Renewable Energy Sources by Locality Type is discussed below as depicted in Table 5.

Table 5: Penetration of Other Renewable Energy Technologies by Monthly Income Level

Locality Type	Households with PV Systems		Households with solar waterheating systems		Households with biogas digesters	
	Number	Share (%)	Number	Share (%)	Number	Share (%)
Cities & Towns	1,595	5.5	4,100	34.8	0	0.0
Urban Villages	4,987	17.0	5,617	47.7	0	0.0
Rural Villages	22,674	77.5	2,058	17.5	216	100.0
National Level	**29,256**	**100.0**	**11,775**	**100.0**	**216**	**100.0**

Table 5 shows penetration of other renewable energy technologies by Locality Type. Photovoltaic Systems show a higher penetration rate in Rural Villages with 22674 (77.5%) households owning the systems. Biogas Digesters have penetrated Rural Villages only with 216 households owning them. Solar Water Heaters are common in Urban Villages owned by 5 617 (47.7%) households whilst in Rural Villages only 2 058 (17.5%) households own them.

From the analysis of ownership and use of Other Renewable Energy technologies by Locality Type and Income Level, it can be concluded that PV Systems are seemingly affordable given their high penetration in Rural Villages especially that they are mostly owned by households (33%) within the income bracket of BWP 1000 -3000. This warrants concerted efforts in promotion of PV Systems in Rural Villages with pricing issues, accessibility etc. continually assessed.

4.4 Solar Energy Consumption

This Section focuses on the use of solar energy captured from various solar equipment/technologies during a 12 months' period. The section shows both electricity generated and amounts of electricity used by district. This assumes that electricity generated is equal to electricity used (see Figure 6 below).

Figure 6: Total Energy Generated from Solar (TJ) per District

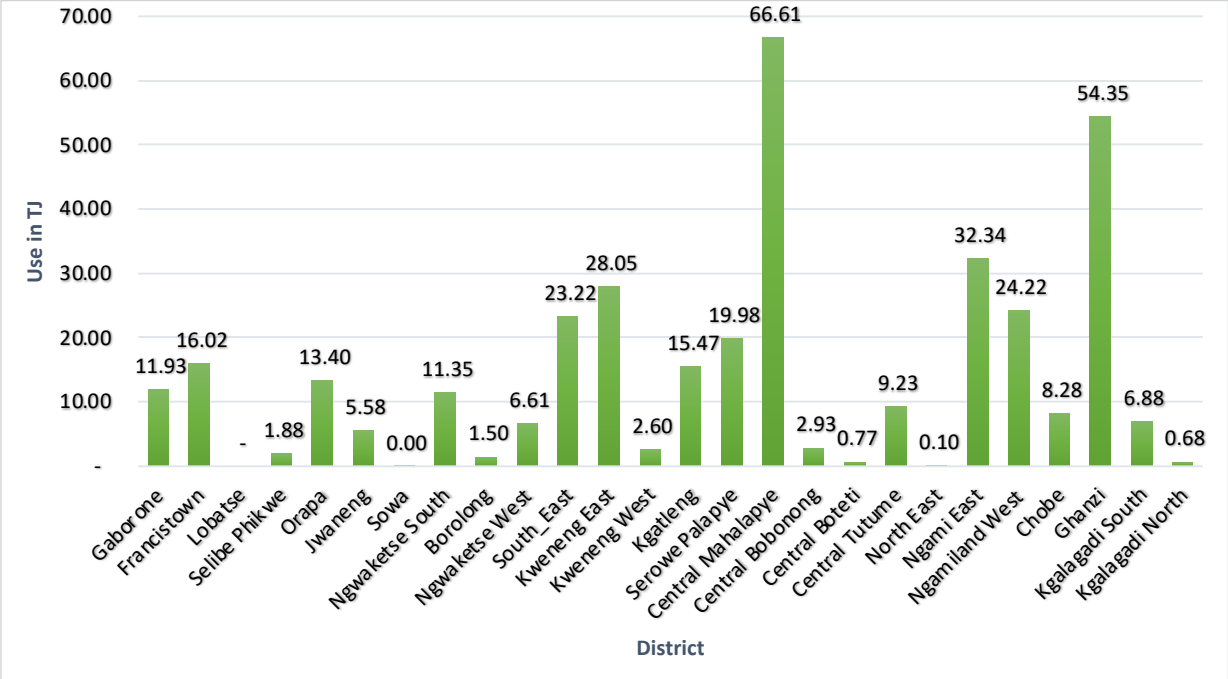


Figure 6 shows that Central Mahalapye district has the highest generation of energy from solar (from both Solar Water Heaters and Solar PV Systems) at 66.61TJ, followed by Ghanzi district at 54.35TJ. Majority of the districts generated below 10TJ.This could be due to the wide spread use of solar for water pumping in Central Mahalapye.

4.5 Energy Consumption per Use

This section discusses Energy Consumption per Use. Analysis is based on all sources of energy (electricity, LPG, firewood, coal, oil, solar etc.) and the use to which they are put to, e.g. Space Heating, Space Cooling, Water Heating, Cooking and Lighting by Locality Type, District and Income Level.

In most instances, technologies or appliances used for water heating, cooling, lighting etc., are also discussed with respect to the amount of energy consumed by the concerned appliances or their level of efficiency.

4.5.1 Energy Consumption for Space Heating

Figure 7: Shares of Technologies Used for Space Heating

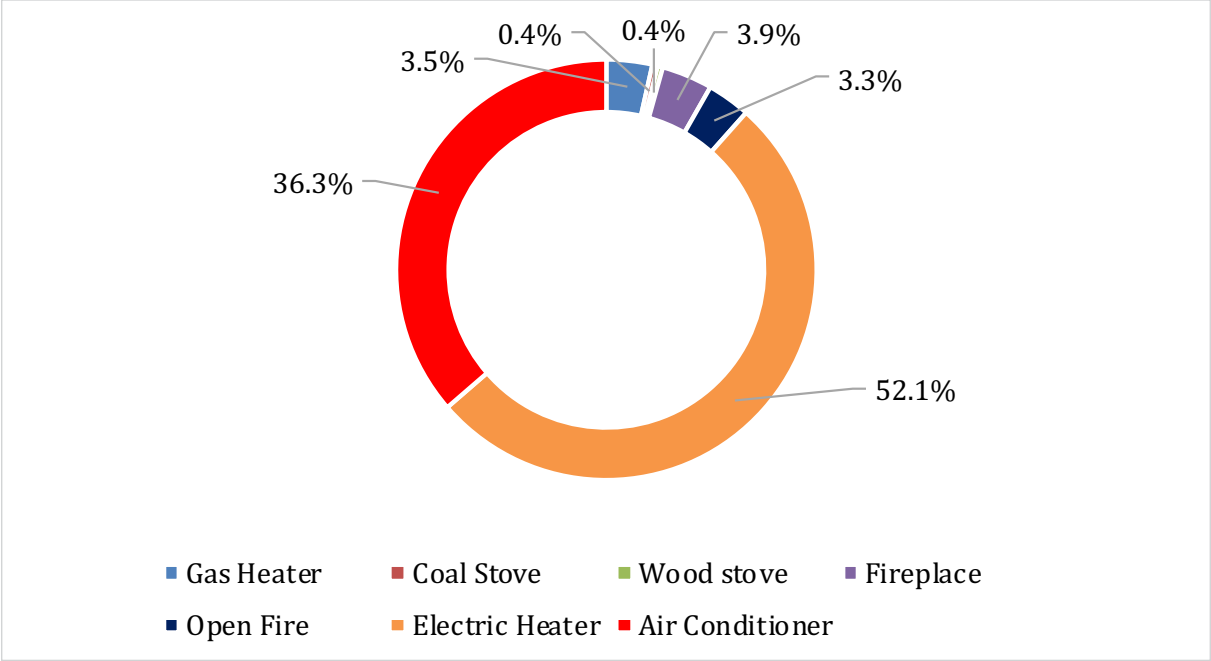


Figure 7 shows shares of technologies used for Space Heating. Electric Heater dominates space heating at 52% followed by Air Conditioner at 36.3%. The shares of other technologies are comparatively insignificant at around 3.9% and below.

Figure 8: Fuel Shares for Space Heating

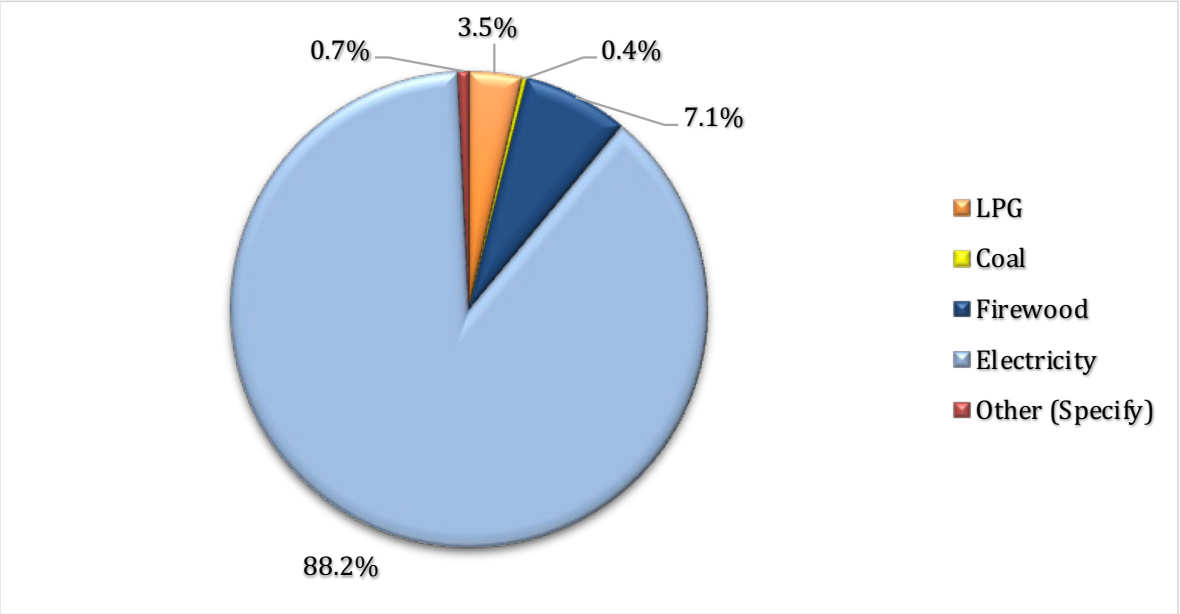


Figure 8 shows fuel share for space heating is electricity at 88.2%. This is expected because the two technologies, namely, Air Conditioners and Electric Heaters dominate space heating at a share of 88.4%, (See Figure 8 above). Firewood follows at a share of 7.1% while coal registered the lowest share at 0.4%.

Table 6: Electricity Consumption for Space Heating (TJ)

Heating Equipment	Number of Units	Calculated Electricity Consumption KWh/year	Consumption inTJ/year
Electric Heater	26,662.1	7,605,499.9	27.4
Air Conditioner	18,842.1	21,913,025.2	78.9
Total	**45,504.2**	**29,518,525.1**	**106.3**

Table 6 shows that electricity consumed by Air Conditioners amounts to 78.89 TJ and that consumed by Electric Heaters amounts to 27.38 TJ.

4.5.2 Energy Consumption for Space Cooling

Figure 9: Share of Households with Space Cooling by District

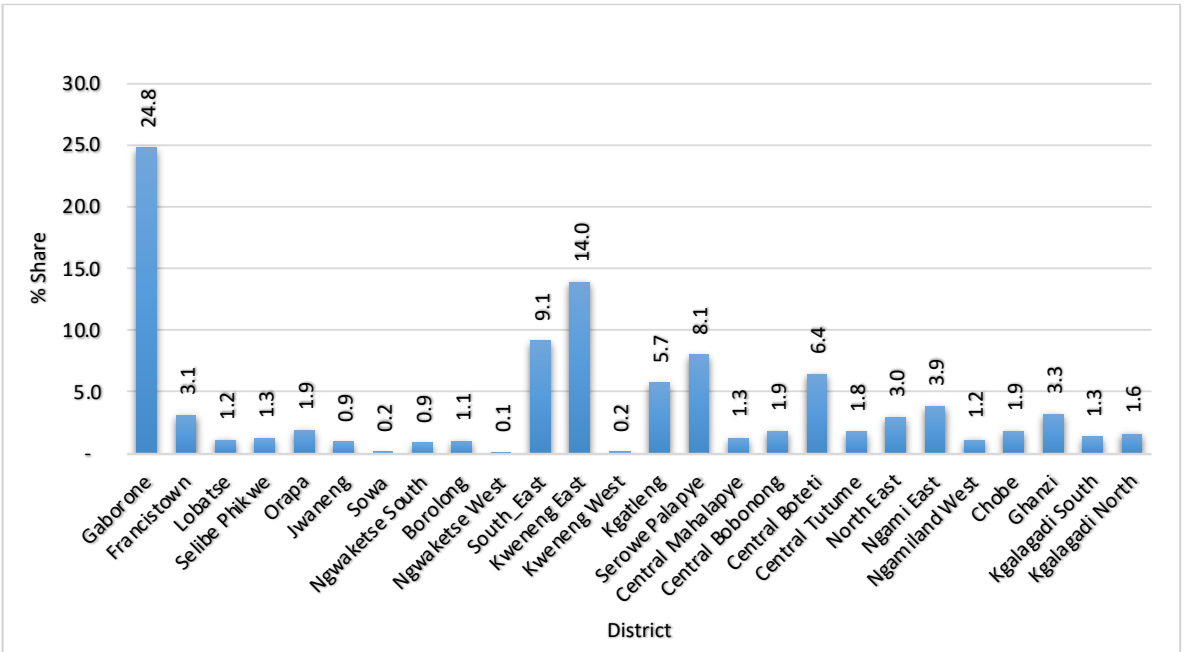


Figure 9 shows that out of households that cool their houses during the hot season, Gaborone district contributes 24.8% of 83 545 households. This might be attributed to the reason that most households in Gaborone own modern housing units installed with cooling systems. It is noted that all other districts recorded a percentage share of 14% and below.

Table 7: Electricity Consumption for Space Cooling by Cooling System(TJ/year)

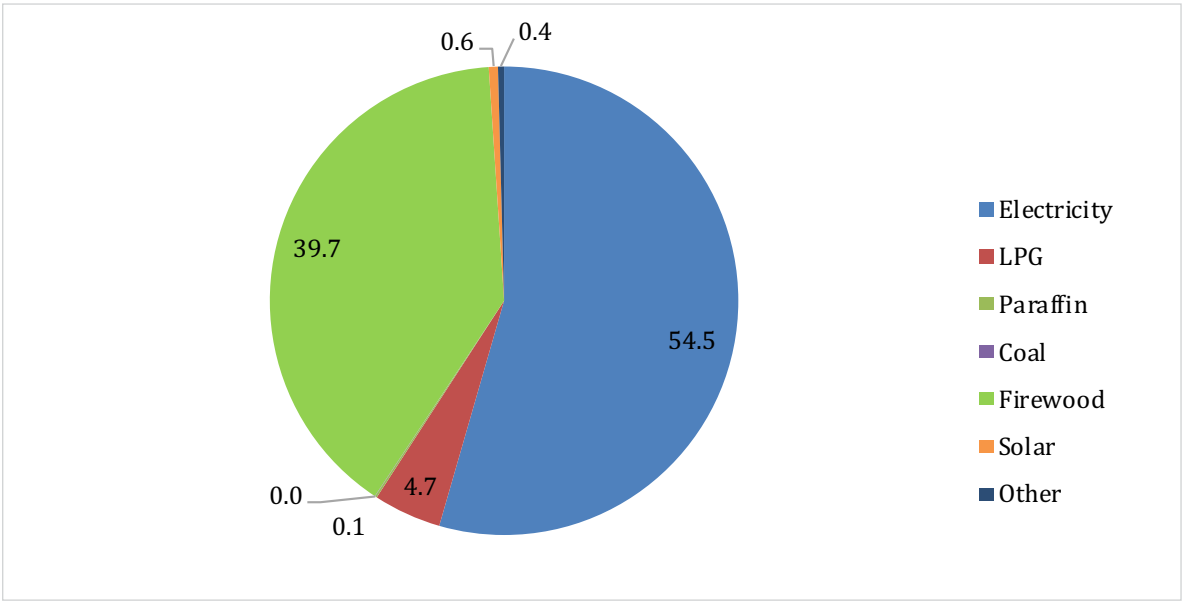
Cooling Systems	Calculated Electricity Consumption (kWh/per year)	Consumption inTJ/year
Air Conditioner	42,698,244.6	153.7
Air Cooler	426,781.6	1.5
Cooling Fans	5,747,646.5	20.7
Total electricity for cooling	**48,872,672.7**	**175.9**

Table 7 shows calculated electricity used for Space Cooling in Terajoules at national level in TJ. The total electricity consumption for cooling amounted to 48 872 672. 7 kWh (48.9 GWh) per annum. Air Conditioners recorded the highest consumption of 42698 244.6 kWh (42.7 GWh) per annum representing 87% followed by Cooling Fans consuming 5747646.5 kWh (5.7 GWh) per annum (12%) and the least, Air Cooler consuming 426781.6 kWh (0.4 GWh) per annum (1%).

4.5.3 Energy Consumption for Water Heating

Discussion on the above captioned is based on Figure 10 and Table 8 below both of which depict fuel shares for water heating.

Figure 10: Fuel Shares for Water Heating



Tabe 8:Fuel Shares for Water Heating by District

District	Electricity	LPG	Paraffin	Coal	Firewood	Solar	Other	Total
Gaborone	89.0	6.6	0.0	0.0	2.8	0.4	1.3	100
Francistown	73.3	7.5	0.7	0.0	15.9	2.6	0.0	100
Lobatse	76.6	3.1	0.0	0.0	18.9	0.0	1.4	100
Selibe Phikwe	77.1	5.1	0.0	0.0	17.8	0.0	0.0	100
Orapa	76.5	0.0	0.0	0.0	0.0	23.5	0.0	100
Jwaneng	76.0	11.6	0.0	0.0	12.3	0.0	0.0	100
Sowa	67.6	15.1	0.0	0.0	17.4	0.0	0.0	100
Ngwaketse South	39.6	3.1	0.0	0.0	57.3	0.0	0.0	100
Borolong	52.6	8.8	0.0	0.0	37.9	0.7	0.0	100
Ngwaketse West	4.1	2.2	0.0	0.0	93.7	0.0	0.0	100
South_East	70.7	3.5	0.0	0.0	24.5	0.3	1.0	100
Kweneng East	65.0	6.3	0.0	0.0	27.8	0.1	0.8	100
Kweneng West	20.5	2.9	2.0	0.0	74.7	0.0	0.0	100
Kgatleng	54.1	6.4	0.4	0.0	37.8	0.5	0.8	100
Serowe Palapye	43.8	3.8	0.0	0.0	52.2	0.2	0.0	100
Central Mahalapye	33.6	1.7	0.0	0.0	63.3	1.3	0.0	100
Central Bobonong	23.0	0.0	0.0	0.0	77.0	0.0	0.0	100
Central Boteti	52.1	10.0	0.0	0.0	37.9	0.0	0.0	100
Central Tutume	25.7	3.0	0.5	0.4	70.5	0.0	0.0	100
North East	46.9	0.9	0.0	0.0	52.3	0.0	0.0	100
Ngami East	53.0	4.1	0.0	0.0	41.7	1.2	0.0	100
Ngamiland West	25.3	0.0	0.0	0.0	71.8	2.9	0.0	100
Chobe	67.6	0.0	0.0	0.0	31.0	1.4	0.0	100
Ghanzi	56.7	2.8	0.0	0.0	33.6	3.9	3.0	100
Kgalagadi South	33.8	8.3	0.0	0.0	58.0	0.0	0.0	100
Kgalagadi North	42.8	2.3	0.0	0.0	54.9	0.0	0.0	100
National Level	**54.5**	**4.7**	**0.1**	**0.0**	**39.7**	**0.6**	**0.4**	**100**

Both Figure 10 and Table 8 show fuel shares for water heating per annum at both district and national levels. Electricity contributes the highest share of 54.5% hence the main source of energy used for water heating followed by firewood at a share of 39.7%. All Other energy sources recorded shares below 5%.

Table 9: Electricity Consumpion for Water heating by Appliance (TJ/year)

Appliance	Calculated Electricity consumption kWh/year	Consumption in TJ/year
Electrical geyser	226,110,056.5	814.0
Electric Kettle	210,019,075.0	756.1
Total	**436,129,131.5**	**1,570.1**

Table 9 shows that total electricity consumption for water heating by different appliances, namely, Electric Kettle and Electrical Geysers stood at 436 129 131.5 kWh (436.1 GWh) per year. Electrical Geysers recorded the highest electricity consumption at 226 110 056.5 kWh (226.1 GWh) per year or 52%, whilst Electric Kettles registered electricity consumption of 210 019 075.0 kWh (210 GWh) per year representing 48%.

Figure 11: Locality Shares of Electricity Consumption for Water Heating

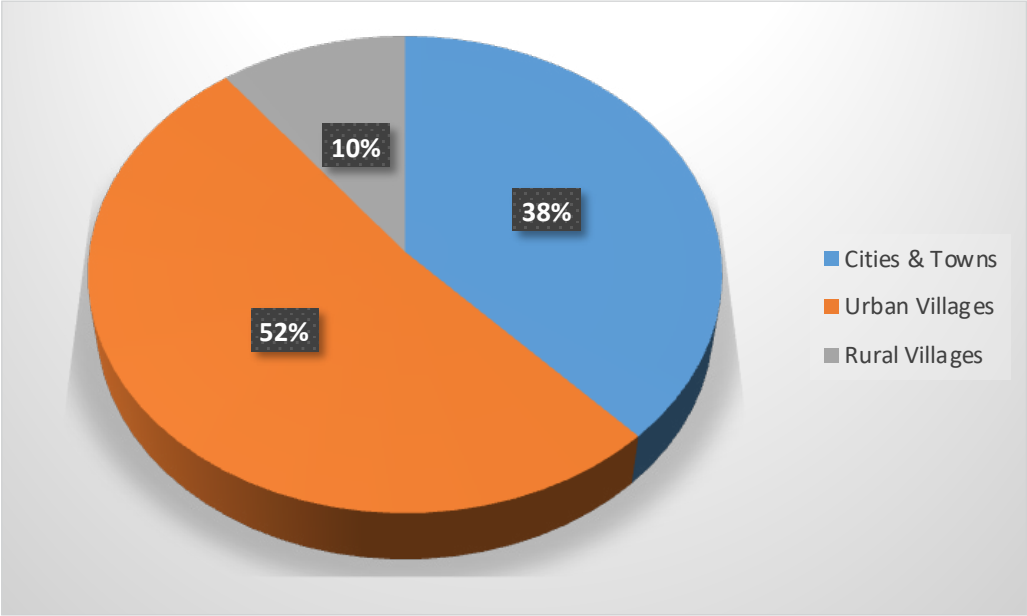


Figure 11 depicts locality shares of electricity consumption for Water Heating. Urban Villages have the highest share of electricity consumption at 52% annually followed by Cities and Towns at 38% and lastly, Rural Villages at 10% per year. This is because there is high density of households in Urban Villages compared to other two Locality Types

4.5.4 Energy Consumption for Cooking.

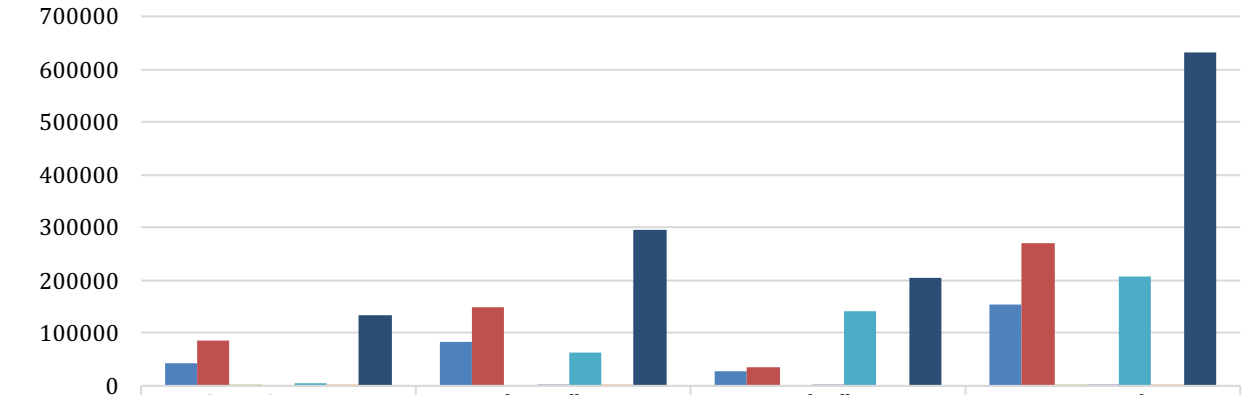
Table 10: Fuel Shares for Cooking by District

District	Electricity	LPG	Paraffin	Coal	Wood	Other	Total
Gaborone	34.9	65.1	0.0	0.0	0.0	0.0	100
Francistown	31.7	60.6	0.7	0.0	6.4	0.7	100
Lobatse	33.5	58.7	1.4	0.0	6.5	0.0	100
Selibe Phikwe	27.0	60.6	0.0	0.0	12.5	0.0	100
Orapa	20.0	80.0	0.0	0.0	0.0	0.0	100
Jwaneng	21.5	74.6	0.0	0.0	3.8	0.0	100
Sowa	59.5	38.2	0.0	0.0	2.3	0.0	100
Ngwaketse South	23.8	28.4	0.0	0.0	47.8	0.0	100
Borolong	31.1	40.1	0.0	0.0	28.8	0.0	100
Ngwaketse West	6.1	12.3	0.0	0.0	81.6	0.0	100
South_East	32.3	53.5	0.0	0.0	14.2	0.0	100
Kweneng East	22.0	56.9	0.0	0.0	20.9	0.2	100
Kweneng West	11.3	12.0	0.0	0.0	76.6	0.0	100
Kgatleng	23.5	47.8	0.0	0.3	28.3	0.0	100
Serowe Palapye	17.4	36.7	0.0	0.4	45.5	0.0	100
Central Mahalapye	19.4	25.6	0.0	0.0	55.0	0.0	100
Central Bobonong	12.2	16.2	0.0	0.0	71.5	0.0	100
Central Boteti	15.7	54.7	0.0	0.0	29.6	0.0	100
Central Tutume	16.6	18.3	0.0	0.0	65.1	0.0	100
North East	28.8	34.0	0.0	0.0	37.2	0.0	100
Ngami East	26.7	38.8	0.0	0.0	34.5	0.0	100
Ngamiland West	21.1	5.7	0.0	0.0	73.2	0.0	100
Chobe	36.4	37.3	0.0	0.0	26.3	0.0	100
Ghanzi	27.0	43.5	0.0	0.0	29.5	0.0	100
Kgalagadi South	28.7	21.4	0.0	0.0	49.9	0.0	100
Kgalagadi North	31.9	17.4	0.0	0.0	50.7	0.0	100
National Level	**24.4**	**42.7**	**0.1**	**0.1**	**32.8**	**0.1**	**100**

Table 10 shows fuel shares for cooking at both district and national levels. Results show that Liquefied Petroleum Gas (LPG) is the main source of energy used for cooking at 42.7% followed by Firewood at 32.8%. Electricity accounts for 24.4% and the rest, Paraffin, Coal and Others account for around 0.1% each. The high share of LPG might be attributed to preference over other fuels as well as its cost effectiveness compared to electricity.

At district level, Orapa and Jwaneng commands the biggest share of LPG usage at 80% and 74.6% respectively. The high share of LPG in the two Debswana diamond mining towns arises because it is part of employee benefits (it is given free). Ngamiland West has the lowest share of LPG at 5.7% and was found to have a higher share of electricity than LPG at 21.1%.

Figure 12: Main Sources of Energy for Cooking by Locality Type



	Cities & Towns	Urban Villages	Rural Villages	National
Electricity	43295	82472	27900	153667
LPG	84491	149392	35351	269234
Paraffin	330	0	0	330
Coal	0	229	110	339
Firewood	4028	62307	140460	206795
Other	194	159	0	353
Total	132338	294559	203821	630718

From Figure 12 it can be deduced that the majority of households in both Urban Villages and Cities & Towns use LPG and Electricity respectively as the main sources of energy for cooking. Firewood dominates in Rural Villages as the main source of energy used for cooking by 140 460 (69%) households out of a total of 203 821 households. This could be because in Rural Villages Firewood is readily available and comparatively cheaper compared to LPG and Electricity while the opposite is true for Urban Villages. It is observed that at National Level, out of a total of 630,718 households, 269 234 (42.6%) use LPG; whilst 206 795 (32.8%) households use Firewood and lastly, 153 667 (24.4%) households use Electricity.

The dominance of LPG use for cooking to some extent corresponds with the Botswana Demographic Survey 2017 Report results which showed that out of 649, 806 households, 259 922 (40.6%) used LPG for cooking. The results from the same report showed fuelwood following at 33.9% with electricity closely behind at 24.8%, which is the same sequence as the current study. (Statistics Botswana 2018.)

The next section discusses electricity consumption for cooking by Income Level as depicted in Figure 13.

Figure 13: Electricity Consumption for Cooking by Income Level

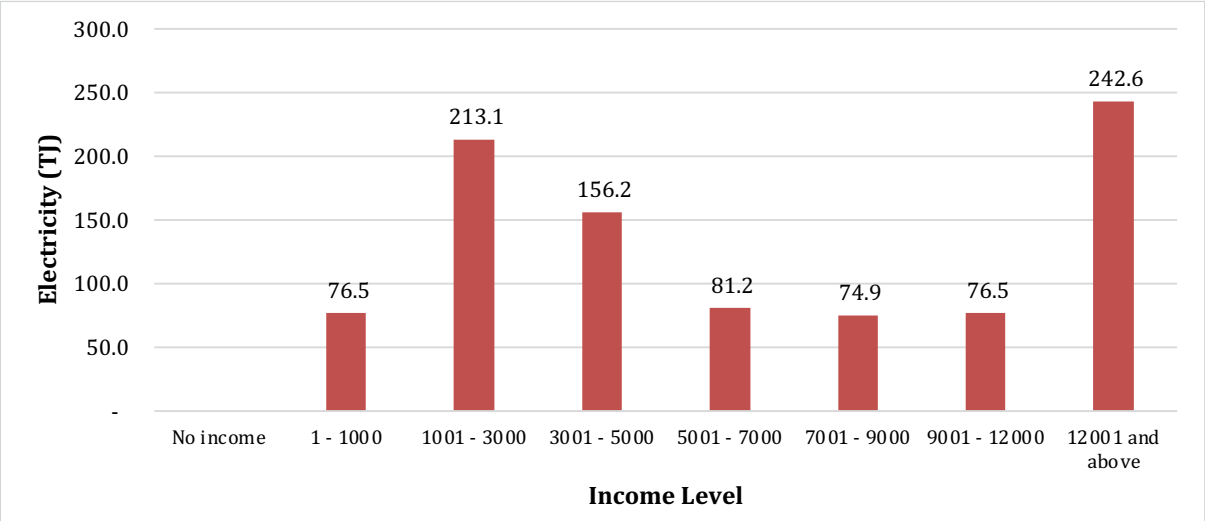


Figure 13 shows that Households earning BWP12001 and Above use electricity as the main source of energy for cooking followed by the BWP1001-3000 income bracket households. The use of electricity as the main source of energy for cooking within the latter income bracket could be influenced by the high number of households within the income bracket.

The following section seeks to determine the energy content of each source of energy used for cooking (Table 11 below.)

Table 11: Calculation of energy for cooking per household (kJ/household) By District

District	Firewood	LPG	Coal	Paraffin	Electricity
Gaborone	0.0	9.7	0.0	0.0	159.6
Francistown	5.9	1.3	0.0	0.0	56.4
Lobatse	0.1	1.9	0.0	0.1	17.2
Selibe Phikwe	8.1	1.6	0.0	0.0	15.6
Orapa	0.0	0.4	0.0	0.0	3.4
Jwaneng	1.2	0.5	0.0	0.0	15.9
Sowa	0.4	0.1	0.0	0.0	3.2
Ngwaketse South	90.8	3.6	0.0	0.0	43.7
Borolong	24.4	1.7	0.0	0.0	33.5
Ngwaketse West	30.8	0.1	0.0	0.0	2.3
South_East	19.4	5.7	0.0	0.0	75.4
Kweneng East	106.2	4.8	0.0	0.0	129.5
Kweneng West	71.0	0.2	0.0	0.0	15.9
Kgatleng	29.1	2.8	0.9	0.0	53.8
Serowe Palapye	132.3	3.2	0.1	0.0	77.7
Central Mahalapye	92.7	1.5	0.0	0.0	50.3
Central Bobonong	79.0	0.5	0.0	0.0	12.2
Central Boteti	50.8	1.5	0.0	0.0	34.4
Central Tutume	114.9	1.0	0.0	0.0	31.5
North East	51.2	0.7	0.0	0.0	40.7
Ngami East	91.6	1.4	0.0	0.0	45.5
Ngamiland West	22.1	2.0	0.0	0.0	18.2
Chobe	10.1	0.3	0.0	0.0	20.0
Ghanzi	19.9	3.4	0.0	0.0	18.6
Kgalagadi South	25.1	0.2	0.0	0.0	14.3
Kgalagadi North	31.4	0.4	0.0	0.0	16.2
National Total	1108.5	50.5	0.0	0.0	1005.1
National(Average)	**42.6**	**1.9**	**0.0**	**0.0**	**38.7**

Table 11 shows that at National Level, a household requires on average 42.6 TJ of firewood to cook followed by electricity and LPG at 38.7TJ and 1.9 TJ respectively. If affordability was not an issue, households could be encouraged to gradually move to LPG for cooking.

4.5.5 Energy Consumption for Lighting by Locality Type

The following discussions look into percentage shares of sources of energy used in households for lighting by Locality Type.

Figure 14: Fuel Shares for Lighting by Locality Type

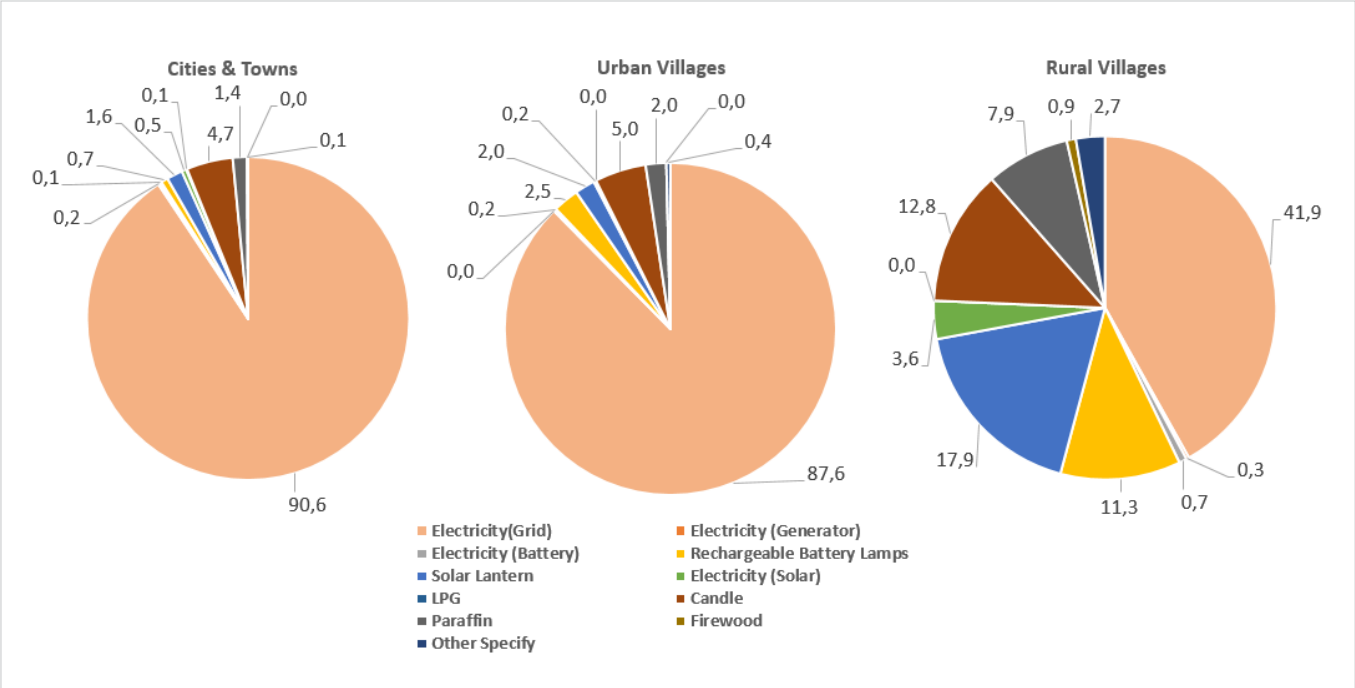


Figure 14 shows that for the three Locality Types, the share of electricity (grid) for lighting dominates, the highest share goes to Cities & Towns at 90.6% followed by Urban Villages at 87.6% and lowest in Rural Villages at 41.9%. Compared to the other two Locality Types, other sources of energy like Solar Lantern, Candles and Rechargeable Battery Lamps are still widely used in Rural Villages, with shares between 10% and 20%. In Cities & Towns as well as Urban Villages, the shares of all other energy sources are below 10%.

It is observed that though insignificant by comparison, other forms of energy sources/technologies such as Solar Lanterns, Rechargeable Battery Lamps etc. are finding in roads in Rural Villages complementing electricity where it is not accessible or affordable.

Figure 15: Shares of Types of Bulbs by Locality Type

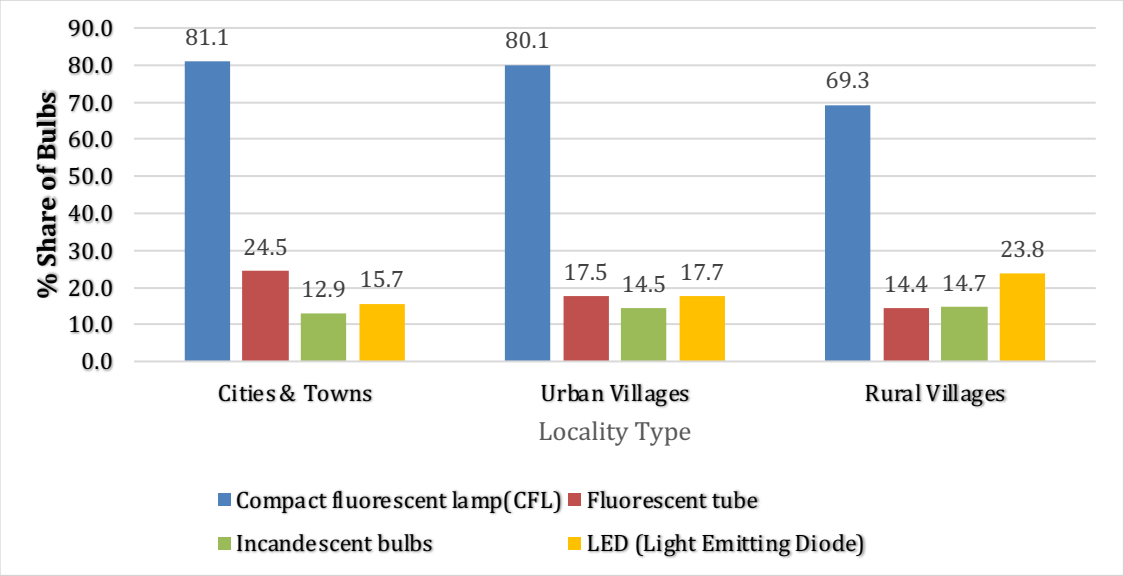


Figure 15 shows that Compact Fluorescent (CFL) is the most common type of bulb used for lighting across all three Locality Types at 77.9%. The share of the rest of the technologies (bulbs) fall below 25%. The high share of CFLs may be because of the roll out campaign which was conducted in the residential sector by Botswana Power Corporation (BPC) in 2010. The other reason is that currently, CFL bulbs are more affordable than other energy saving bulbs. Fluorescent tubes and LED have almost equal shares (57% and 58% respectively), and this may be due to the fact that Fluorescent Tubes are mostly used in kitchens and LEDs are still penetrating the market. It is also noted that Incandescent bulbs have the lowest share, this might be due to the fact that it is an old technology which is gradually fading away.

Table 12: Electricity Consumption by Type of Bulb

Type Of Bulb	Number of bulbs	Cosumption in KWh	Consumption inTJ
Compact Flourescent Lamp	1,943,186.6	71,126,096.5	256.1
Flourescent tube	125,881.7	6,535,744.8	23.5
Incandescent bulbs	220,969.6	27,761,724.0	99.9
Light Emitting Diode (LED)	434,474.8	12,717,693.8	45.8
Total	**2,724,512.7**	**118,141,259.1**	**425.3**

Table 12 shows consumption of electricity by type of bulb. The most energy consuming type of bulb is Incandescent Bulb at 125.6 kWh per year. The second most energy consuming type of bulb is Fluorescent tube at 51.9 kWh per year. This shows that LED bulbs are the most efficient at 29.3 kWh per year. Therefore, for purposes of saving electricity for lighting purposes, it is advisable to use LEDs than any other type of bulb.

Table 13: Total Energy Consumption (TJ) for Lighting by Locality Type

Locality Type	LPG	Paraffin	Firewood	Electricity	Total
Cities & Towns	0.0	8.7	0.0	99.9	108.5
Urban Villages	0.0	17.5	0.0	248.9	266.4
Rural Villages	0.0	48.6	9,646.5	76.5	9,771.6
National Level	**0.0**	**74.7**	**9,646.5**	**425.3**	**10,146.5**

Note: Candles were excluded because of lack of Net Calorific Value (NCV)

Table 13 depicts that at national level the main source energy for lighting is Firewood at 9646.5TJ followed by Electricity at 425.3 TJ. The high consumption of Electricity is evident in Urban Villages followed by Cities and Towns, whilst Firewood is highly consumed in Rural Villages which is the only Locality Type using Firewood for lighting. This is not surprising because in Botswana, culturally fire (from firewood), whether enclosed or in the open, serves many purposes like cooking, heating and lighting.

4.6 Access to Electricity

This subsection examines household connection rate to the electrical grid as a measure of electricity access. Household connection figures include households connected to grid power at both district and national levels. The number of households in a district and the proportion of those connected and not connected to grid power are reflected in Table 14 Below. Furthermore, analysis of electricity connection by income level is depicted in Table 15 with the aim to identify the relationship between affordability and the level or rate of connection.

Table 14:Proportion of Households Electrified/Not Electrified by District

District	Households connected to grid electricity			Households not connected to grid electricity	Number of Households in District
	Number	Proportion in District(%)	Proportion to National Level(%)		
Gaborone	69,357	94.3	10.9	4,172	73,540
Francistown	25,217	86.2	4.0	4,022	29,243
Lobatse	8,239	81.9	1.3	1,818	10,058
Selibe Phikwe	8,794	88.5	1.4	1,138	9,933
Orapa	2,365	100.0	0.4	0	2,365
Jwaneng	6,293	91.2	1.0	607	6,901
Sowa	1,014	100.0	0.2	0	1,014
Ngwaketse South	20,561	62.9	3.2	12,110	32,674
Borolong	14,698	86.5	2.3	2,282	16,982
Ngwaketse West	626	14.3	0.1	3,739	4,365
South_East	28,931	85.2	4.6	5,004	33,940
Kweneng East	70,406	82.8	11.1	14,653	85,070
Kweneng West	6,451	38.2	1.0	10,456	16,908
Kgatleng	24,591	77.0	3.9	7,337	31,932
Serowe Palapye	37,500	66.4	5.9	18,981	56,487
Central Mahalapye	21,671	59.9	3.4	14,480	36,154
Central Bobonong	9,985	54.7	1.6	8,260	18,247
Central Boteti	19,627	77.5	3.1	5,703	25,333
Central Tutume	21,066	54.9	3.3	17,288	38,357
North East	18,126	88.6	2.9	2,340	20,469
Ngami East	22,931	75.6	3.6	7,396	30,331
Ngamiland West	5,728	36.6	0.9	9,904	15,633
Chobe	9,009	84.6	1.4	1,641	10,651
Ghanzi	6,792	67.2	1.1	3,317	10,110
Kgalagadi South	4,475	47.8	0.7	4,882	9,358
Kgalagadi North	3,891	48.1	0.6	4,202	8,094
National Level	**468,344**	**73.9**	**73.9**	**165,732**	**634,150**

Table 14 shows proportion of households connected and not connected to electricity by district. At national level, 468 344 (73.9%) out of 634 076 households are connected to electricity and 165 732 (26.1%) households are not connected to electricity.

At district level, Orapa and Sowa districts have the highest connectivity at 100% each, while Gaborone and Jwaneng districts constitute above 90%. Ngwaketse West has the lowest connection rate at only 14.3%.

Table 15: Proportion of Households Electrified/Not Electrified by Monthly Income Level

Income Level (BWP))	Households connected to grid electricity		Households with off-grid electricity		Households not connected to electricity		Connected to electricity	off-grid Contribution to electricity	Total
	Number	Share (%)	Number	Share (%)	Number	Share (%)			
No income	47,065	10.1	0	0.0	36,444	22.0	56.4	0.0	83,509
1-1000	48,647	10.5	0	0.0	42,427	25.6	53.4	0.0	91,074
1001-3000	124,919	26.9	1362	60.7	65,334	39.5	65.9	1.1	191,615
3001-5000	73,960	15.9	166	7.4	12,314	7.4	85.8	0.2	86,440
5001-7000	35,494	7.6	113	5.0	3,055	1.8	92.1	0.3	38,662
7001-9000	24,521	5.3	0	0.0	2,359	1.4	91.2	0.0	26,880
9001-12000	28,688	6.2	0	0.0	1,019	0.6	96.6	0.0	29,707
12001 and above	81,707	17.6	602	26.8	2,503	1.5	97.0	0.7	84,812
National Level	**465,001**	**100.0**	**2243**	**100.0**	**165,455**	**100.0**	**73.8**	**0.5**	**632,699**

1 The inconsistency in the total number of households for Tables 15 and 16 is due to the fact that some respondents did not disclose their incomes.

Table 15 depicts proportion of households electrified (grid and off-grid) and not electrified by monthly income level. Households within income bracket of BWP1001-3000 show the highest share of connection to the grid at 26.9%. The reason could be that there are more households in this income bracket than any other income bracket. The BWP12001 and Above income bracket follows at a share of 17.6%. Similarly, with off-grid electricity, the share of households within the income bracket of BWP1001-3000 accounts for 60.7% and BWP12001 and Above accounts for only 26.8%.

The following discussions examine ways of electrification for the grid connected households by Locality Type. Ways of electrification include: subsidised through NESC, individual expenditure (full cost), government, private entities and "Other." (See Figure 16 below).

Figure 16: Ways of Household Electrification by Locality Type

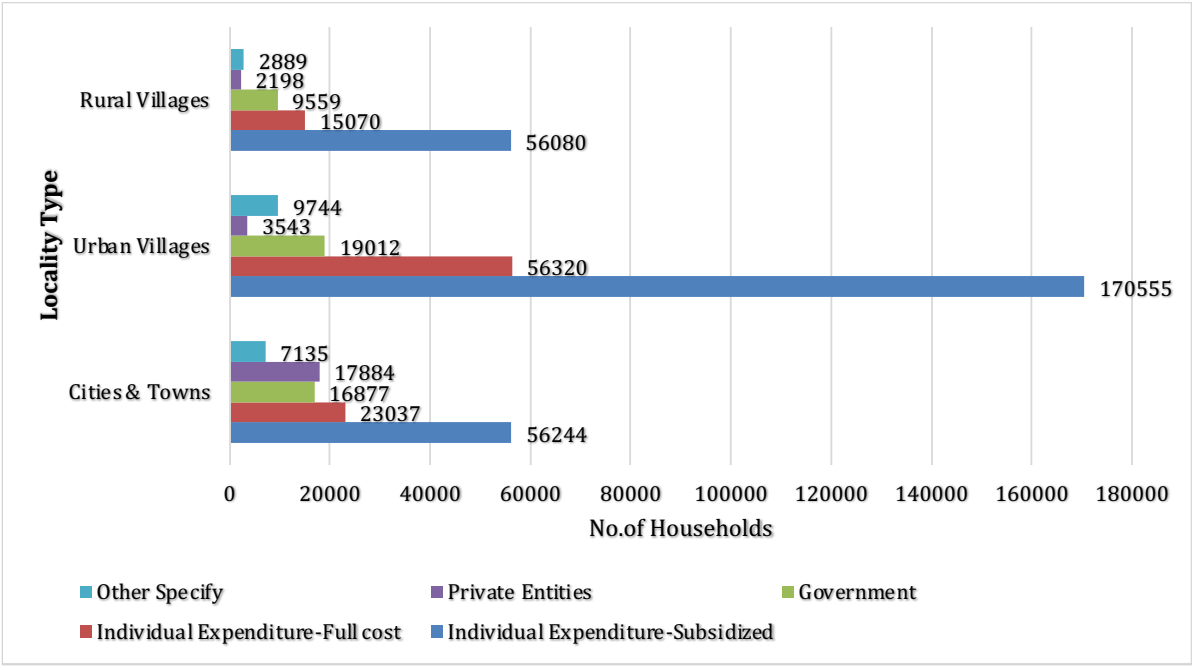


Figure 16 shows that out of 466,147 households connected to grid electricity, 282 879 (61.0%) were subsidised through the National Electrification Standard Cost (NESC) which was implemented in 2010. The next category, 94 427 (20.0%) households fully funded their connection to the grid, and lastly, the lowest connection to the grid by 19 768 (4%) households, was done through 'Other'. It is observed that whilst all five categories (ways of electrification) in Rural Villages have the lowest shares compared to those in Urban Village and Cities & Towns, four (4) categories in Urban Villages have the highest shares except one (1) category, within Cities & Towns which has the highest share of 76% household connections through Private Entities.

Table 16: Main Reasons for not Connecting to Grid Electricity by Locality Type

Locality Type	Lack of funds for wiring	Lack of funds for connecting	Far from electricity lines	Using renewable off-grid	Choice for off-grid	Other specify	Total
Cities & Towns	1,283	4,015	0	0	0	6,458	11,756
Urban Villages	10,607	16,752	166	0	25	8,166	35,716
Rural Villages	19,538	35,234	51,311	900	994	10,282	118,259
National Level	**31,428**	**56,001**	**51,477**	**900**	**1,019**	**24,906**	**165,731**

Table 16 shows primary reasons why households are not connected to grid electricity categorized by Locality Type. Both Rural and Urban Villages cited 'financial constraints' and 'distance from electricity lines' as some of the main reasons for not connecting. Lack of funds, especially for wiring was cited by 19 538 (62%) households in Rural Villages followed by 10 607 (34%) households in Urban Villages. However, the majority of unconnected households, 51 311 (99.7%) in Rural Areas cited distance from electricity lines out of a total of 51 477 households whilst only 166 (0.3%) households in Urban Villages cited the same reason.

4.7 Total Energy Consumption for Transport, Agriculture & Generators

Household consumption (diesel and petrol) by motor vehicles/cars and tractors is generally categorised under transport and agriculture respectively to avoid over reporting on households or under reporting on transport and agriculture sectors. Consumption of both fuels by generators is also treated separately from that of transportation and agriculture. Table 17 below depicts total fuel consumption for the said categories. For all categories consumption of both diesel and petrol are lumped together but are separated in the following sections where categories are discussed individually.

Table 17:Total Final Energy Consumption for Transportation,Agriculture and Generators(TJ)

District	Transportation	Agriculture	Generators	Total
Gaborone	1,553.25	14.47	0.23	**1,567.94**
Francistown	380.64	0.00	0.02	**380.66**
Lobatse	115.15	0.00	0.17	**115.33**
Selibe Phikwe	112.48	0.00	0.00	**112.48**
Orapa	88.69	0.00	0.01	**88.70**
Jwaneng	41.50	0.00	0.00	**41.50**
Sowa	25.74	0.00	0.00	**25.74**
Ngwaketse South	350.87	1.42	5.84	**358.14**
Borolong	151.53	13.21	3.03	**167.77**
Ngwaketse West	145.78	41.22	8.06	**195.07**
South_East	536.40	4.14	3.59	**544.13**
Kweneng East	1,262.24	10.87	13.65	**1,286.76**
Kweneng West	147.52	7.13	1.00	**155.64**
Kgatleng	491.88	13.75	0.88	**506.51**
Serowe Palapye	405.15	3.32	11.04	**419.51**
Central Mahalapye	329.59	35.70	49.17	**414.45**
Central Bobonong	128.76	3.26	4.40	**136.42**
Central Boteti	255.05	1.96	10.04	**267.05**
Central Tutume	297.43	2.19	19.34	**318.97**
North East	251.14	0.18	0.17	**251.49**
Ngami East	412.32	0.00	15.90	**428.22**
Ngamiland West	38.13	0.00	0.48	**38.61**
Chobe	76.53	0.00	0.02	**76.54**
Ghanzi	267.14	0.08	87.84	**355.07**
Kgalagadi South	99.12	0.87	0.23	**100.22**
Kgalagadi North	81.30	0.00	0.41	**81.72**
National Level	**8,045.33**	**153.78**	**235.55**	**8,434.66**

At national level, household total fuel consumption (diesel and petrol) amounts to 8 434.7TJ. Consumption for transport purposes (motor vehicles & cars) stands at 8 045.4TJ whilst consumption for agriculture purposes (tractors) stands at 153.8 TJ. It was observed that for agriculture, only diesel was consumed. Consumption by generators, which includes both diesel and petrol, stands at 235.4 TJ.
At district level, across the three uses: transport, agriculture and generators, Gaborone and Kweneng East registered the highest combined consumption of petrol and diesel at 1 567.9TJ and 1 286.8TJ respectively. Sowa registered the lowest consumption at 25TJ.

4.7.1 Total Energy Consumption for Transport Purposes

This section discusses the use of diesel and petrol for transport (motor vehicles and cars) purposes by households at district and national levels.

Table 18: Final Energy Consumption for Transport(TJ) by Districts

District	Petrol (Gasoline)	Diesel	Total
Gaborone	1,237.54	315.71	1,553.25
Francistown	280.35	100.29	380.64
Lobatse	81.19	33.96	115.15
Selibe Phikwe	101.93	10.55	112.48
Orapa	61.87	26.82	88.69
Jwaneng	41.50	0.00	41.50
Sowa	19.79	5.95	25.74
Ngwaketse South	299.16	51.72	350.87
Borolong	144.49	7.04	151.53
Ngwaketse West	46.78	99.00	145.78
South_East	396.24	140.16	536.40
Kweneng East	946.33	315.91	1,262.24
Kweneng West	61.75	85.77	147.52
Kgatleng	391.32	100.55	491.88
Serowe Palapye	337.13	68.02	405.15
Central Mahalapye	231.62	97.97	329.59
Central Bobonong	100.44	28.32	128.76
Central Boteti	217.10	37.96	255.05
Central Tutume	226.11	71.32	297.43
North East	212.26	38.88	251.14
Ngami East	349.19	63.12	412.32
Ngamiland West	33.10	5.03	38.13
Chobe	62.54	13.99	76.53
Ghanzi	215.03	52.11	267.14
Kgalagadi South	75.98	23.13	99.12
Kgalagadi North	55.64	25.66	81.30
National Level	**6,226.38**	**1,818.95**	**8,045.33**

Note: Jwaneng has zero consumption of diesel because of a large margin of error due to the small sample size.

Table 18 above shows total annual fuel consumption of diesel and petrol for household transportation. Household total fuel consumption for transport purposes is 8 045.3 TJ approximately 20% of the national annual consumption of petroleum products, which is 1.2billion litres (Government of Botswana, 2022).

The commonly used type of fuel for transport by households is petrol at 6 226.4 TJ (77.4%), whilst diesel accounts for 1 818.95 TJ (22.6%) on an annual basis. For both petrol and diesel, Gaborone has the highest consumption at 1 553.2 TJ per annum followed by Kweneng East District at 1 262.2 TJ and South East rounds up the top three at 536.4 TJ. The lowest consuming district is Sowa at 25.7 TJ.

4.7.2 Energy Consumption by Generators

The section focuses on consumption of fuel (diesel and petrol) by households for generators at district and national levels. The average fuel consumption of a generator by a household varies depending on several factors, e.g. size of generator, type of fuel used, the load it supports and the generator's efficiency, to mention a few. Figure 18 below shows generators fuel consumption by districts.

Figure 17: Total Energy Consumption by Generators (TJ) per District

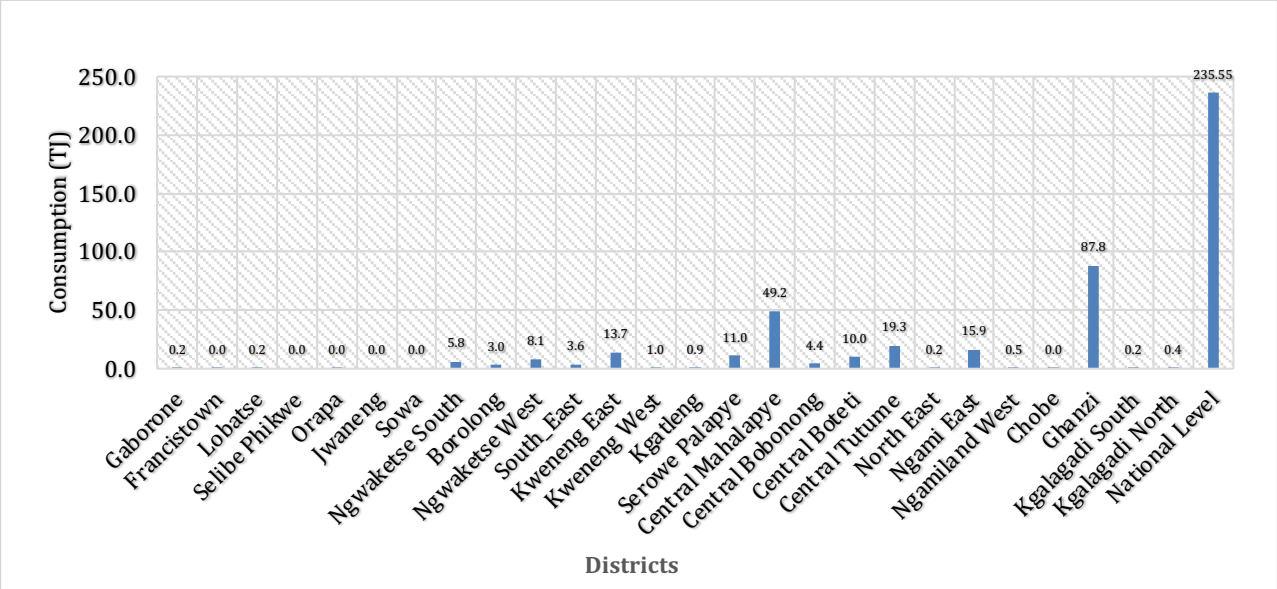
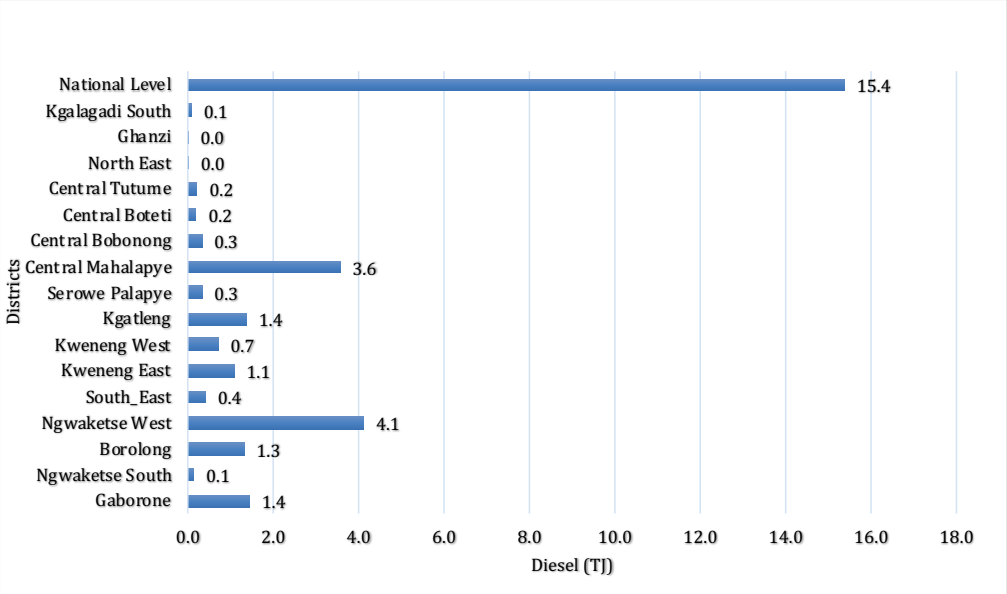


Figure 17 above shows annual fuel consumption by generators at District and National levels. Consumption includes both diesel and petrol but because of low amounts, the two products have been lumped together. At national level, consumption stands at 235.4TJ led by Ghanzi and Central Mahalapye districts at 87.8TJ and 49.2TJ respectively. Other districts registered consumption as low as 19.3TJ and below.

4.7.3 Energy Consumption for Agriculture Purposes

The discussions below centres on fuel consumption for agriculture. Since fuel consumption was directed to tractors, it was observed that only diesel was consumed. Consumption figures are depicted in Figure 19 below.

Figure 18: Total Energy Consumption for Agriculture (TJ) per District



Note: Includes only districts with generator data

Figure 18 above shows that at national level, households' fuel (diesel) consumption for Agriculture purposes stands at 154 TJ on an annual basis. At district level, Ngamiland West and Central Mahalapye registered the highest consumption of diesel at 41TJ and 36TJ respectively. Most of the districts registered extremely low levels of consumption as shown in the diagram.

It must be pointed out that nil or low diesel consumption within some districts does not mean farming (agriculture) is non-existent. The fact of the matter is that households were asked about ownership of tractors and amounts of diesel consumed by tractors for farming purposes, it must be noted that though many people plough their fields, they hire people with tractors to plough for them and those hired normally purchase diesel.

4.8 Building Characteristics

Analysis on Building Characteristics focuses on the distribution of houses by type of main wall material, main roof material, main floor material, type of windows and insulation used. The type of walls, roof, floor, windows and insulation determine the thermal behaviour of the building and therefore the energy needs for space heating and space cooling. Analysis is also by District, Locality Type and Income Level.

Table 19: Distribution of Types of Houses(%) by Locality Type

Locality Type	% House Type									Total
	Traditional structure (Lolwapa)	Detatched house	Semi-Detached	Town house/ Terraced	Flats, apartments	Part of commercial building	Movable	Shack	Rooms	
Cities & Towns	0.0	54.1	13.1	2.9	6.4	0.1	0.0	0.3	23.0	100.0
Urban Villages	3.7	58.4	8.5	3.3	1.1	0.1	0.0	0.5	24.5	100.0
Rural Towns	18.9	50.0	3.1	0.8	0.2	0.0	0.7	7.1	19.0	100.0
National Level	**8.5**	**54.7**	**7.4**	**2.3**	**1.7**	**0.1**	**0.3**	**2.8**	**22.3**	**100.0**

Table 19 shows proportion of types of houses by Locality Type. According to the table, there are no traditional structures in Cities and Towns, which is in line with Town and Country Planning Act of 2013; Building Control Regulations and Development Control Codes. Traditional structures are mainly found in Rural Villages because of their low construction costs, availability of local building materials and cultural set-up. The Table also shows that Detached type of houses dominate in Botswana at a share of 54.7%. Detached houses are dominant in Urban Villages at 58.4% followed by Cities and Towns at 54.1%. The least owned type of house found in Botswana is the Part Commercial Building at a share of 0.1%.

Table 20: Distribution of Houses by Type of Main Wall Material & Locality Type

Locality Type	Number of Households using the type of wall materials									Total
	Modern bricks/blocks	Mud bricks/ blocks	Mud and poles/ cowdung/ thatch/ reeds	Poles and reeds/straw	Corrugated iron/zinc/ tin	Asbestos	Stone	Pallet	Other (specify)	
Cities & Towns	138,989	953	0	0	634	424	0	0	0	141,000
Urban Villages	369,782	17,083	6,113	525	1,144	0	325	221	332	395,525
Rural Towns	192,488	51,077	23,980	3,343	21,622	189	178	1037	2,543	296,457
National Level	**701,259**	**69,113**	**30,093**	**3,868**	**23,400**	**613**	**503**	**1258**	**2,875**	**832,982**

Table 20 shows that across all Locality Types, the most preferred wall material is modern bricks at 701 259 houses, of which 369 782(53%) are situated in Urban Villages. Modern bricks (masonry) came as a result of development of commercial building materials and to some extent became a symbol of status and prestige hence their dominant use. Mud bricks is the second common wall material at a total of 69 113 houses, most of which, 51 077 (74%), are found in Rural Villages. Stone is the least used wall material found in Urban Villages' houses.

Table 21: Distribution of Houses by Type of Main Roof Material & District

District	Slate	Thatch/ straw	Roof tiles	Corrugated iron/zinc/tin	Asbestos	Concrete	Other, (specify)	Total
Gaborone	307	0	23,305	50,463	3,094	0	259	77,428
Francistown	0	0	5,230	27,275	0	0	0	32,505
Lobatse	0	0	1,343	9,385	0	0	0	10,728
Selibe Phikwe	0	0	2,984	6,690	386	0	0	10,060
Orapa	0	74	1,023	1,268	0	0	0	2,365
Jwaneng	0	0	405	6,357	138	0	0	6,900
Sowa	0	0	1,014	0	0	0	0	1,014
Ngwaketse South	0	4,021	4,957	29,883	0	131	0	38,992
Borolong	0	87	2,225	17,205	0	350	0	19,867
Ngwaketse West	0	403	268	5,618	0	0	0	6,289
South_East	0	248	9,883	28,177	0	0	142	38,450
Kweneng East	290	5,202	13,613	79,633	329	0	0	99,067
Kweneng West	137	7,285	1,044	18,582	0	0	234	27,282
Kgatleng	0	380	6,079	34,652	0	1,023	213	42,347
Serowe Palapye	0	8,592	6,894	67,338	0	0	202	83,026
Central Mahalapye	0	5,384	6,959	37,457	203	0	189	50,192
Central Bobonong	0	1,400	1,911	27,463	0	0	0	30,774
Central Boteti	0	2,386	2,266	30,941	540	0	84	36,217
Central Tutume	0	16,857	4,193	45,540	0	0	0	66,590
North East	147	2,264	6,081	24,567	0	0	0	33,059
Ngami East	0	2,517	2,755	43,035	0	0	337	48,644
Ngamiland West	0	13,315	437	13,725	0	0	103	27,580
Chobe	0	39	1,456	10,187	0	0	0	11,682
Ghanzi	0	564	1,025	9,596	0	0	434	11,619
Kgalagadi South	0	346	714	10,591	0	0	231	11,882
Kgalagadi North	0	151	506	7,617	0	0	151	8,425
National Level	**881**	**71,515**	**108,570**	**643,245**	**4,690**	**1,504**	**2,579**	**832,984**

Table 21 illustrates the distribution of types of houses by type of main roof material by district. The most common type of roof material is corrugated iron/zinc/tin, found in 643 245 (77.22%) houses out of a total of 832 984 houses nationally. Roof Tiles follow at 108 570 (13.03%) houses most of which are situated at Gaborone (23 305 or 21%). Slate is the least common type of roof material with only 881(0.11%) out of 832 984 houses and distributed across only four (4) out of twenty-six (26) districts. According to the table, only 71 515 (8.59 %) out of 832 984 houses are thatched, and are distributed across most districts except for Gaborone, Francistown, Lobatse, Selibe Phikwe, Jwaneng and Sowa all of which fall under Cities and Towns.

Table 22: Distribution of Houses/Structures by Type of Main Floor Material and District

District	Cement	Mud/mud and dung	Poles/Pallets	Brick/stones	Tile	Other (specify).....	Total
Gaborone	35,804	0	0	0	40,400	1,225	77,429
Francistown	20,181	0	0	0	12,324	0	32,505
Lobatse	8,250	0	0	0	2,478	0	10,728
Selibe Phikwe	5,893	0	0	0	4,031	134	10,058
Orapa	0	0	0	0	2,365	0	2,365
Jwaneng	4,347	0	0	0	2,422	130	6,899
Sowa	805	0	0	0	209	0	1,014
Ngwaketse South	25,167	3,519	0	207	10,100	0	38,993
Borolong	12,264	212	0	0	7,391	0	19,867
Ngwaketse West	3,222	1,669	0	0	532	867	6,290
South_East	20,436	389	0	132	17,102	179	38,238
Kweneng East	62,196	3,033	0	0	33,836	0	99,065
Kweneng West	18,026	5,604	234	447	2,735	234	27,280
Kgatleng	26,947	962	0	380	13,431	628	42,348
Serowe Palapye	55,906	8,797	0	0	15,329	2,992	83,024
Central Mahalapye	37,193	4,337	109	0	8,318	236	50,193
Central Bobonong	22,477	4,723	0	0	3,438	135	30,773
Central Boteti	23,664	5,749	0	0	6,450	355	36,218
Central Tutume	41,095	16,966	0	209	7,913	408	66,591
North East	22,629	932	0	0	9,498	0	33,059
Ngami East	31,724	5,405	84	0	10,858	572	48,643
Ngamiland West	13,398	11,186	0	0	1,556	1,440	27,580
Chobe	8,274	192	0	0	3,216	0	11,682
Ghanzi	5,367	400	100	0	4,509	1,243	11,619
Kgalagadi South	7,166	1,388	0	0	2,595	732	11,881
Kgalagadi North	5,183	621	0	0	1,461	1,159	8,424
National Level	**517,614**	**76,084**	**527**	**1,375**	**224,497**	**12,669**	**832,766**

Table 22 illustrates the distribution of houses (housing structures) by type of main floor material and district. The results show that the main floor material for majority of houses (517 614) in Botswana is cement, which is 62% of all houses across the country. Out of a total of 832 766 housing structures, about 224 497 (27%) have tiles as their main floor material, which is the second most used in the country. The third most used floor material is mud and dung which is used in 76 084 (9%) houses/housing structures. District differentials show that Central Tutume has the highest number of houses/housing structures (16 966 or 22%) which have mud and dung as their main floor material.

Table 23: Distribution of Houses/Structures by Type of Window and Locality Type

Locality Type	Wooden Frame Single Glass	Iron Frame Single Glass	Aluminum Frame Single Glass	Aluminum Frame Double Glazing	No Windows	Total
Cities & Towns	3,550	120,065	11,794	5,460	130	140,999
Urban Villages	13,849	335,807	27,968	3,741	13,948	395,313
Rural Towns	12,192	196,935	10,901	897	75,531	296,456
National Level	**29,591**	**652,807**	**50,663**	**10,098**	**89,609**	**832,768**

Table 23 shows that at National Level, Iron Frame Single Glass is the most commonly used type of window in 652 897 (78.4%) housing structures. It is followed by Aluminium Frame Single Glass and Wooden Frame Single Glass which are fitted in 50 663 (6.1%) and 29 591 (4.0%) houses respectively. The data further indicates that majority of houses which have Iron Frame Single Glass are found in Urban Villages. The "no windows" category refers to a situation where a house does not have glass panes, it has the second highest number of houses nationally (89 609) which is 11% of all housing structures. The table further shows that Rural Villages have the highest number of houses with no windows.

Figure 19: Locality Shares of Houses with Insulation

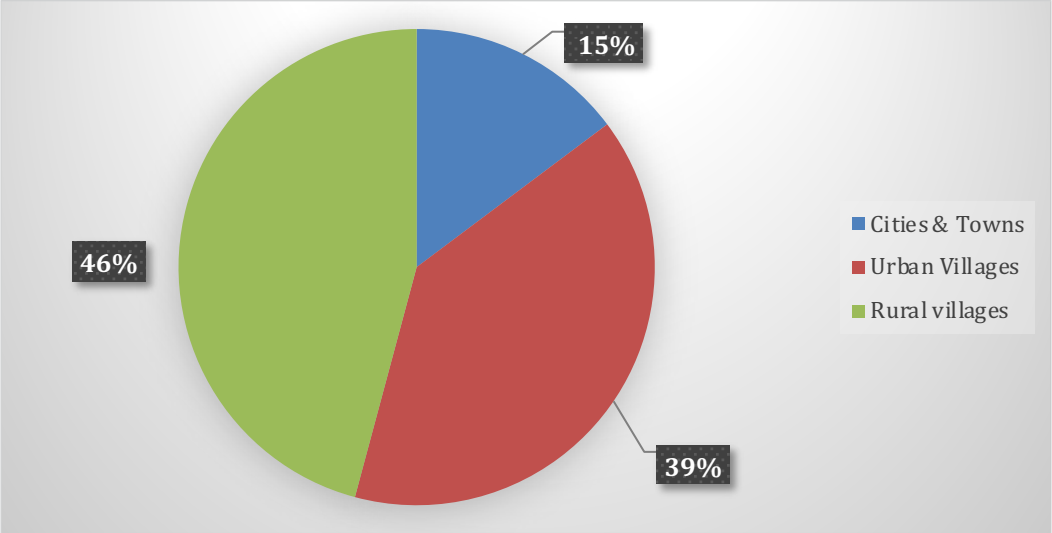


Figure 19 shows that Rural Villages recorded the highest share of insulated houses at 46% followed by Urban Villages at 39% and Cities and Towns at 15%. The reason for the high number of insulated houses in Rural and Urban Villages is because most houses are thatched, and thatch in the context of this report is considered a type of insulation.

Table 24: Distribution of Houses by Type of Insulation Material & Locality Type

Locality Type	Not Insulated	Thatch	Foam	Laminated Board	Fiberglass	Reflective Paints	Do not know	Other Specify	Total
Cities & Towns	116,240	0	715	1,858	6,009	3,250	10,795	2,133	141,000
Urban Villages	348,175	15,298	716	6,844	11,436	2,037	9,681	948	395,135
Rural Towns	247,772	38,500	474	1,823	2,022	434	5,341	91	296,457
National Level	**712,187**	**53,798**	**1,905**	**10,525**	**19,467**	**5,721**	**25,817**	**3,172**	**832,592**

Table 24 illustrates the distribution of houses with different types of insulation by Locality Type. At national level, 712 187 (86%) out of 832 592 houses are not insulated. Thatch is the main insulation type of material and is found mostly in Rural Villages with 38 500 (72%) houses followed by Urban Villages with 15 298 (28%) houses. Eleven Thousand, Four Hundred and Six (11 436 or 59%) houses situated in Urban Villages are insulated with Fibreglass which is the main insulation type of material in this Locality.

It can be concluded that people are seemingly not aware of the relevance and benefits of insulation and other types of building materials like: roofing, window, floor tile etc. in as far as energy efficiency is concerned. This calls for heightened public awareness.

4.9 Energy Efficiency & Conservation and Renewable Energy

This section discusses households' plans to implement Energy Efficiency (EE) and Renewable Energy (RE) measures as well as barriers towards implementation of EE and RE measures. The Section further considers types of electrical appliances owned by households with their corresponding energy efficiency classes (labelling). Lastly, the two appliances (air conditioner and electric heater) used for space heating with their associated energy efficiency labelling are discussed.

The issue of energy efficiency classes (labelling) is very crucial because it indicates efficiency of appliances owned and used by households. The results can then direct where wastages are and where energy efficiency measures can be applied.

4.9.1 EE & Conservation and RE Plans & Barriers

This section discusses share of Households with plans to apply EE & C and RE measures. Plans include replacement of inefficient light bulbs with CFL or LED, installation of Solar Water Heaters, installation of PV system & motion sensors, insulation of walls and roofs and other measures. The section further discusses barriers towards implementing EE and RE measures in cases where households indicated they had no such plans. See Figure 21 on proportion of Households with plans.

Figure 20: Share of Households with Plans to Apply EE&C & RE Measures by District

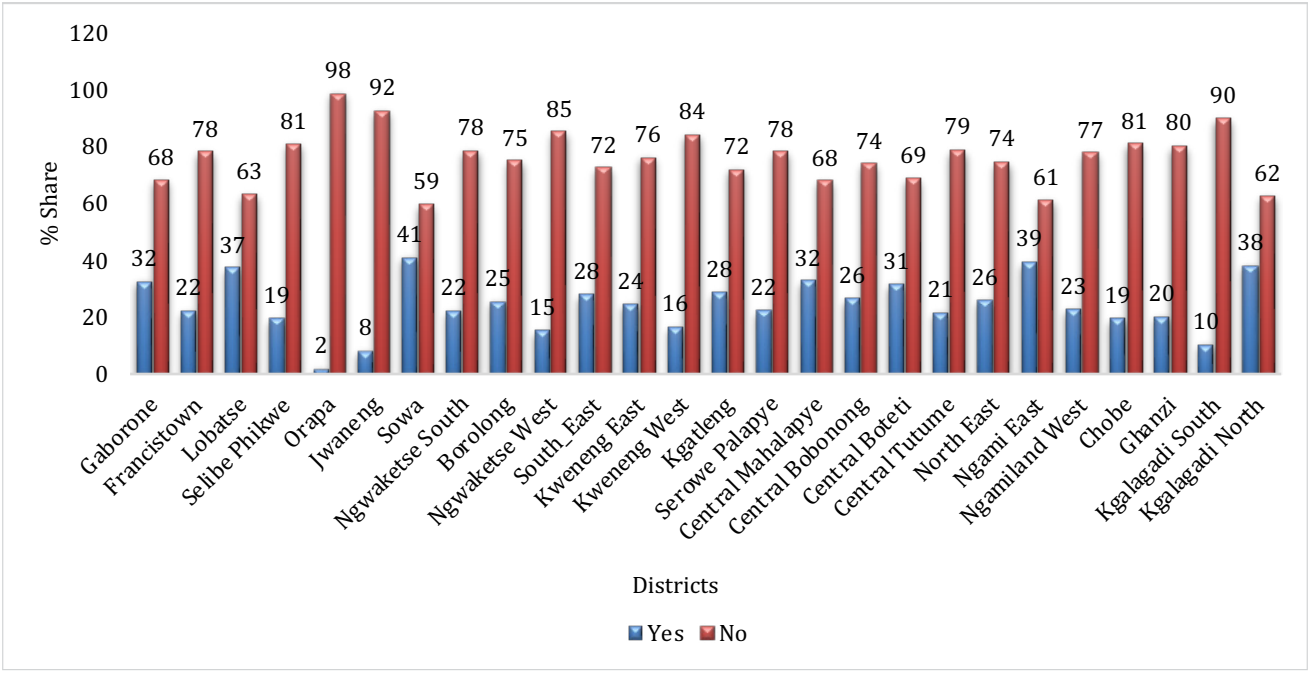


Figure 20 shows proportions of households with intentions to apply Energy Efficiency (EE) and Renewable Energy (RE) measures in future. Sowa district exhibit the highest proportion of households expressing an intention to apply EE and RE at 41% followed by Ngamiland East at 39% and Kgalagadi North at 38%. Conversely, Orapa and Jwaneng display the lowest intentions to apply EE and RE measures, with percentages of 2% and 8%, respectively. At National level, 26% of households showed interest in applying EE and RE measures.

Figure 21: Locality Shares on Plans to Apply EE & RE Measures

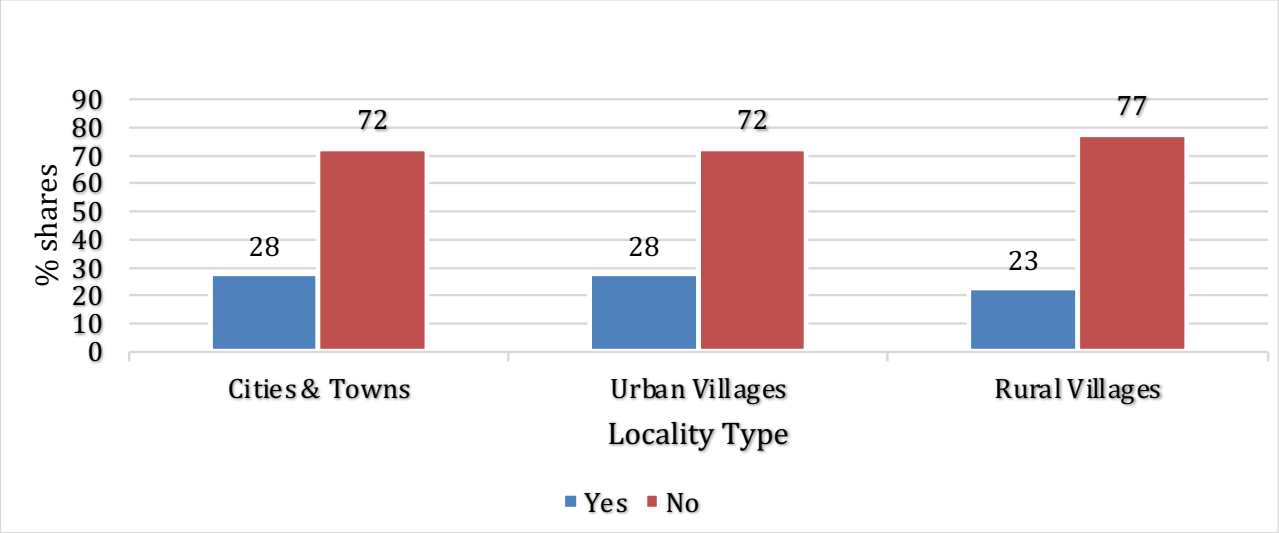


Figure 21 shows that over 70% households across all three Locality Types have no plans to apply EE & RE measures. Around 30% of households indicated that they have plans to apply energy efficiency and renewable energy measures. Reasons cited for lack of plans on EE and RE measures are covered in the frequency table that follows (Table 26).

Table 25: Actions Planned by Households to Apply EEC and RE Measures

No	Actions/Measures	Frequency	Percent
1	Replace light bulbs with CFL	52,560	32.1
2	Replace light bulbs with LED	53,700	32.8
3	Install a Solar Water heater	79,565	48.6
4	Install a PV System	84,333	51.5
5	Insulate the roof	42,987	26.2
6	Install motion sensors	39,715	24.2
7	Insulate walls	18,311	11.2
8	Replace windows	30,394	18.5
9	Other (specify)	11,032	6.7
Total		**163,870**	

Table 25 shows 163 870 response rates of households who plan to implement Energy Efficiency and Conservation measures. The highest response rate of 51.5% was by Households planning to install PV Systems, followed by those that planned to install Solar Water Heaters at 48.6%. Responses to replace light bulbs with CFL and LED recorded around 32%.

Households without plans cited the following barriers listed in Table 26 below.

Table 26: Reasons for No Plans for EEC and RE Measures

No	Reason	Frequency	Percent
1	I do not own the house	223,588	45
2	Low quality of products	23,546	5
3	High purchasing costs	236,347	47
4	Other (specify)	14,684	3
Total		**498,164**	**100**

Table 26 indicates reasons why households do not have plans to incorporate energy efficiency in their energy use. Forty-Seven percent (47%) of responses by households cited high purchasing costs while 45% responses were by households who do not own the houses they dwell in. Only 5% of responses were on low quality of products in the market as a hindrance to implementing energy efficiency measures.

Energy Efficiency & EE measures are considered pricy at 47%, despite this, there is need for intensive awareness campaigns given the importance of energy efficiency which might not be that obvious to people.

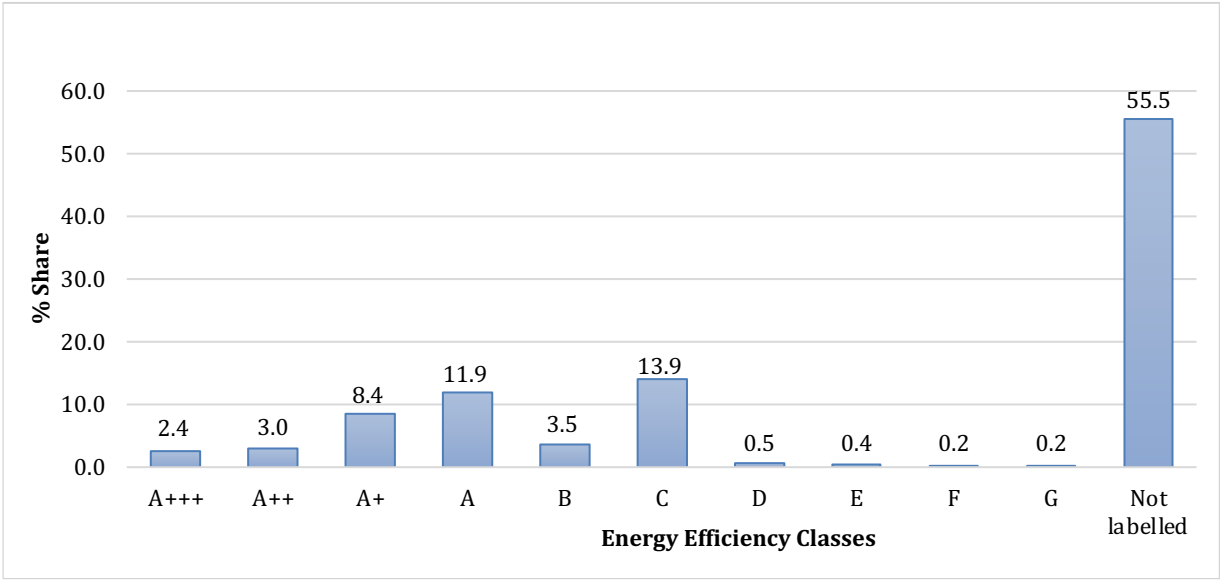
4.9.2 Number of Electrical Appliances by Energy Efficiency Class

Table 27 below shows the number of electrical appliances and their corresponding energy efficiency class at both district and national levels whilst the associated Figure 23 shows shares of energy efficiency classes.

Table 27: Number of Electrical Appliances by Energy Efficiency Class

Appliance	A+++	A++	A+	A	B	C	D	E	F	G	Not labelled	Total
Refrigerator	13,313	22,081	91,330	89,389	21,960	30,422	747	1,642	202	310	130,169	401,565
Gyser	2,351	2,486	2,969	8,828	10,597	14,559	1,410	121	0	117	47,359	90,797
Chest/deep freezer	1,313	3,830	4,561	14,830	4,659	4,483	74	148	0	144	20,973	55,015
Stove	2,959	4,372	11,172	18,500	6,898	31,285	887	824	0	237	136,056	213,190
Electric heater	812	361	949	1,691	622	2,997	408	148	0	0	18,704	26,692
Washing machine	4,362	2,536	3,597	6,232	3,255	6,405	202	0	0	121	28,149	54,859
Dishwasher	0	183	234	733	0	75	202	137	0	0	387	1,951
Tumble dryer	0	0	307	0	0	0	0	0	0	0	599	906
Hoover	553	0	42	922	148	947	0	0	0	0	6,022	8,634
Hair dryer	779	826	1,838	6,362	1,957	6,001	99	841	131	0	38,397	57,231
Plasma	4,125	6,997	10,819	16,526	5,947	19,753	652	488	1,406	900	99,319	166,932
CR TV	2,469	3,013	7,582	10,522	5,142	17,054	663	225	569	792	76,539	124,570
LED TV	562	1,113	3,113	4,093	622	8,180	330	0	0	446	15,240	33,699
LCD TV	135	944	729	1,978	821	5,896	580	0	0	0	22,240	33,323
Desk Top Computer	0	598	899	1931	0	1,065	106	0	0	0	11,115	15,714
Laptop	2,033	3,393	6,853	10,368	1,403	17,617	847	316	237	408	70,571	114,046
Elec iron	7,878	5,515	20,745	35,726	5,543	62,661	2,153	1,725	516	590	232,554	375,606
Kettle	7,760	6,036	19,096	34,438	7,145	63,398	1,976	1,820	377	590	223,557	366,193
Bread maker	0	0	0	0	0	571	0	0	0	137	1,188	1,896
Toaster	818	1,937	2,734	5,157	2,419	8,236	183	227	0	0	30,559	52,270
Microwave	4,737	4,792	12,961	16,173	5,423	29,434	684	750	237	486	100,606	176,283
Elec Pot	1,015	479	318	1,037	328	1,758	150	42	0	0	10,436	15,563
Blender	1,316	1,881	3,446	6,344	1,136	8,158	172	539	267	0	35,288	58,547
Sewing Machine	150	196	227	715	121	424	0	279	0	0	3,345	5,457
National Level	**59,440**	**73,569**	**206,521**	**292,495**	**86,146**	**341,379**	**12,525**	**10,272**	**3,942**	**5,278**	**1,359,372**	**2,450,939**

Figure 22: Shares of Energy Efficiency Classes



The results show that the majority of appliances owned by households are not labelled amounting to 1 359 372 (55%). This may be due to reasons like: labelling stickers fallen off, labelling no longer visible and old appliances without energy efficiency labels. The highest number of labelled Appliances fall under Class C at 341 379 (13.9%) followed by Class A appliances at 292 495 (11.9%). The rest of the classes fall below 8.4%. Classes E, F and G are generally inefficient, whilst class A+++ to C are the most efficient and recommended. The high numbers (shares) of unlabelled appliances is a concern. Therefore, there is need to enforce energy efficiency labelling schemes to regulate the market.

4.9.3 Heating Appliances by Energy Efficiency Class

Table 28 below shows number of space heating appliances, namely: Electric Heaters and Air Conditioners with corresponding energy efficiency labelling classes.

Table 28: numbers and Shares of Appliances for Space Heating by Energy Efficiency Class

Heating Appliance		Energy Label Class										Total
		A+++	A++	A+	A	B	C	E	F	G	Not labelled	
Electric Heater	Number	491	558	1,741	1,832	237	4,668	237	237	158	16,505	26,664
	%	1.8	2.1	6.5	6.9	0.9	17.5	0.9	0.9	0.6	61.9	100.0
Air Conditioner	Number	634	324	1,060	966	2,235	3,271	0	583	0	9,770	18,843
	%	3.4	1.7	5.6	5.1	11.9	17.4	0.0	3.1	0.0	51.8	100.0
National Level		**1,125**	**882**	**2,801**	**2,798**	**2,472**	**7,939**	**237**	**820**	**158**	**26,275**	**45,507**

At national level, Electric Heaters and Air Conditioners which are not labelled dominate. It is noted that most Electric Heaters (62%) are not labelled whist about 52% of Air Conditioners are not labelled, thus making it difficult to determine their efficiency. Of the labelled appliances, Class C is dominating at 7 939.

It is important to make people aware of owning labelled appliances as this could help in saving energy and managing energy expenditure.

4.10 CO_2 Emissions by Fuel

This section presents CO_2 emissions by fuel at both district and national levels. The amounts generated per fuel are also displayed in percentage form. Table 29 below shows CO_2 emissions by fuel as well as fuel shares in total CO_2 emissions.

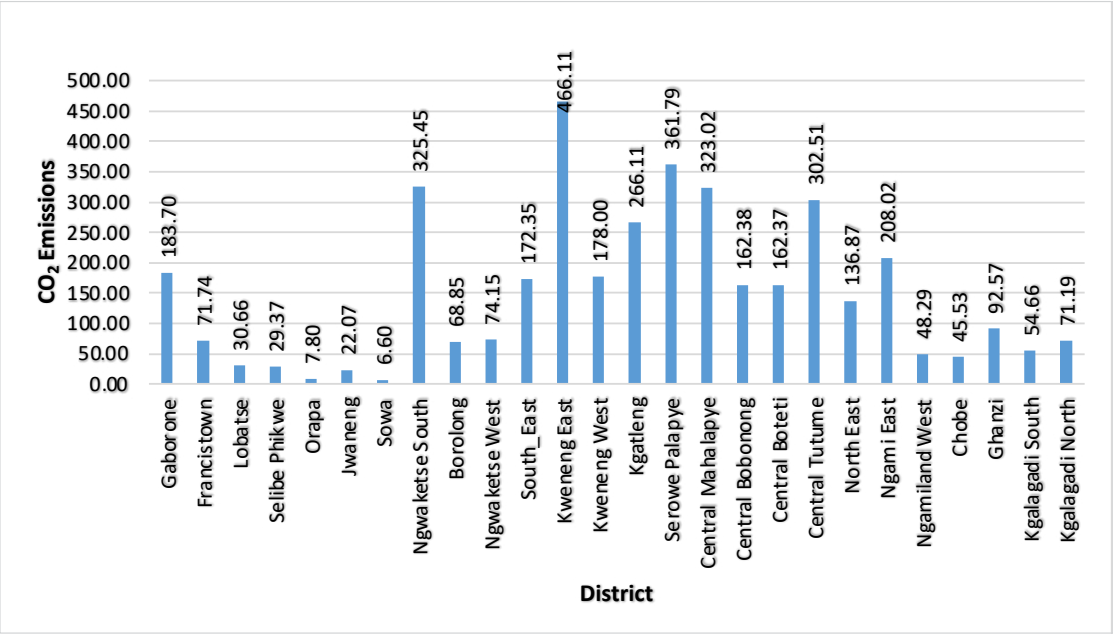
Table 29: CO2 Emissions by Energy Sources at National Level(Gg CO2)

Fuel Type	Biomass (wood)	Petrol (Gasoline)	Diesel	LPG	Parrafin (Other Kerosene)	Coal (Sub-Bituminous)	Total
% Share	82.0%	11.3%	4.0%	2.4%	0.1%	0.2%	100%
National Level	**3,176.4**	**436.2**	**153.8**	**92.5**	**4.5**	**9.5**	**3,872.2**

Note: Emissions from electricity use were also calculated but the figure came out very insignificant (close to zero) hence excluded from the analysis.

Table 29 indicates that total CO_2 emissions stood at 3 872.2 Gg of CO_2 at national level. Contribution of CO_2 emissions by fuel shows that large proportion of CO_2 emissions within the household sector are from biomass use at 3 176.4 Gg CO_2 (82.0%) followed by petrol at 435.2 Gg CO_2 (11.2%) and diesel at 153.8 Gg CO_2 (4.0%). Paraffin contributes the least share of 0.1% (4.59 Gg CO_2) to the total household CO_2 emissions. Figure 24 below shows CO_2 emission levels by District.

Figure 23: CO_2 Emissions by District (Gg CO2)



The levels of CO_2 emissions per district reveal that Kweneng East emits the highest CO_2 emissions with 466.11 Gg CO_2 followed by Serowe/Palapye with 361.79 Gg CO_2 and Ngwaketse South with 325.45 Gg CO_2. Within Cities and Towns, Gaborone emits the highest CO_2 emissions with 183.70 Gg CO_2 followed by Francistown with 71.74 Gg CO_2. Generally, it can be concluded that districts with the highest consumption of biomass experience high levels of CO_2 emissions than those with low biomass consumption.

The higher the consumption of biomass (firewood), the higher the level of CO_2 emissions generated. Therefore, educational and awareness campaigns on the impacts of CO_2 emissions are recommended, especially because firewood is generally used across various activities, namely: space heating, water heating and cooking.

5. CONCLUSION and RECOMMENDATIONS

The National Energy Use Survey (NEUS) was completed successfully despite the challenges encountered.

In the process of conducting NEUS, a thorough assessment of all aspects which make up energy consumption by households, directly and or indirectly, was undertaken. From the assessment, conclusions and recommendations were drawn from most or all of the components of the household energy use. Both the conclusions and recommendations are expected to go a long way in shaping and directing the course of the energy sector.

Concerning Total Final Energy Consumption, Botswana, just like most African countries, continues to experience the high share of biomass (66%) in Total Final Energy Consumption. Biomass is dominated by firewood taking a share of 96% followed by Shrubs at 2.40%.

Given that Biomass has been and continues to be the main source of energy for households, a separate survey/research on Biomass should be carried out to determine supply and consumption levels as well as the socio-economic and environmental impact of biomass use.

With respect to Consumption of Other Renewable Energies, Botswana aims to increase the share of renewable energy to the energy mix to 30% by 2030 in line with SDG 7.3.1. PV Systems and SWH have penetrated the market and are used to generate energy across all districts with Serowe Mahalapye and Ghanzi leading other districts. Bio-digesters on the other hand have so far penetrated Rural Villages only.

Promotion of PV Systems (which has penetrated Rural Villages more than other technologies) is recommended with consideration of affordability, availability, standards etc.

Biogas Program is expected not only to increase the contribution of animal waste (which at the moment stands at 0.10%), but should promote other "waste" and be extended to other localities, i.e. Urban Villages and Cities & Towns.

On Energy Consumption per Use, there are three main sources of energy used for space cooling, cooking, water heating and space heating, namely: Electricity, Firewood and LPG. (Note: Recommendations on Electricity and Firewood are found elsewhere). LPG is the dominant energy source for cooking, however, there are about 10 districts where firewood is more dominant.

Issues surrounding LPG like pricing, availability, standards and safety should be attended to with the aim to promoting its dominance over firewood in districts, where firewood dominates. This could be a strategy to help reduce the use of firewood and ultimately CO2 emissions.

Since LPG is seemingly the most energy efficient source of energy for cooking, more households should be encouraged to use it.

On Access to Electricity, both grid and off-grid, Botswana has made huge strides as evidence by the 73.9% access rate. It is evident that most households (61%) connected to the grid are subsidised through NESC and there are still those not connected due to financial constraints and distance from the grid.

Continuous assessment of electricity connection rate and associated barriers to connecting are encouraged with the aim to introduce other schemes that promote electricity connection.

Analysis of Total Energy Consumption for Transport, Agriculture and by Generators revealed that households consume a significant amount of petrol and diesel amounting to approximately 20% of national total annual consumption of 1.2 billion litres with a huge chunk (95%) going to fuelling vehicles and cars (transport).

On the aspect of Building Characteristics, it can be concluded that people are seemingly not aware of the role that insulation and the type of building materials (roofing, window, floor tile etc.) play in as far as energy efficiency is concerned.

It is recommended that there be educational campaigns/awareness raising on the role and relevance of types of building materials (insulation, window type etc.)

Regarding the issue of Energy Efficiency & RE Plans and Barriers, from the analysis it became apparent that the majority of households have no plans to apply EE & C and RE Measures/Solutions because of high purchasing cost as the main cause. Furthermore, the majority of appliances owned by households have no labelling classes which could be a sign of lack of knowledge on energy efficiency classes and energy efficiency in general. Given the above:

There is need for intensified awareness campaigns to address barriers towards adopting EE & RE measures as well as on the relevance of energy efficiency in reducing energy wastage and energy expenditure.

The high numbers of unlabelled appliances call for the need to enforce energy efficiency labelling schemes to regulate the market.

On the issue of CO_2 emissions, it was observed that the higher the level of firewood consumption, the higher the level of CO_2 emissions.

Educational and awareness campaigns are recommended to inform communities about the impacts of CO_2 emissions, this is so because firewood is an all-rounder, it is used across various consumption activities like water heating, cooking as well as space heating.

6. LIMITATIONS

The National Energy Use Survey (NEUS) was the first of its kind ever conducted by the Department of Energy. That compounded with the need for extensive baseline information necessitated the need to cover more ground resulting in lengthy questionnaires for both households and businesses. Furthermore, the energy sector is in itself highly complex and diverse in nature, for example, there are multiple sources/ resources, e.g. biomass; solar; petroleum products, coal etc. with associated technologies, different units of measurements, to mention but a few. Given the above, the NEUS experienced various limitations, however, the ones listed below are considered core:

i. Scope of the Survey limited the time to observe and measure firewood consumption (which could call for a separate/dedicated Biomass Survey);

ii. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories – IGES does not have Net Calorific Values (NCV) for Candles, thus this study could not convert candle consumption to energy equivalence.

iii. No attempt to segregate firewood use per: lighting, cooking, space heating and water heating which could result in either overestimation or underestimation of firewood consumption.

iv. Limited energy efficiency classes/labelling made it difficult to assess: whether there are wastages or where energy savings can be realised.

v. Townships such as Jwaneng have displayed large margins of error and wider confidence intervals because of their relatively small sample size.

Despite all the above, the household survey was completed successfully. Hence the above challenges and those considered administrative but not listed here are lessons which can guide the Department in future studies.

7. APPENDICES

7.1 Unit of Conversion for Energy

Unit	Joule	Indices
Kilojoule (Kj)	1,000	10^3
Megajoule (Mj)	1,000,000	10^6
Gigajoule (Gj)	1,000,000,000	10^9
Terajoule (Tj)	1,000,000,000,000	10^{12}

Natural Unit		Energy Units	
		Megajoule (MJ)	Terajoule (TJ)
1kg of sub-bituminous Coal	1Kg ≈ 0.001 TCE	1kg ≈ 30000000MJ	1Kg ≈ 30 TJ
1kg of firewood		1kg ≈ 14.9 MJ	1Kg ≈ 0,0000149 TJ
1kg of LPG	1Tonne = 1000kg	1ton ≈ 46150 MJ	1 ton ≈ 0.04615 TJ
1l of Petrol	1 Mtoe = 1000000 toe 1 m^3 petrol = 0,86 toe 1l petrol = 0.001m^3	1ton ≈ 44750 MJ	1 ton ≈ 0.0448 TJ 1 ton ≈ 0.0000342 TJ
1l of Diesel	1 m^3 diesel = 0,98 toe 1l diesel = 0.001m^3	1ton ≈ 43380 MJ	1 ton ≈ 0.0434 TJ
1l of Kerosene(Paraffin)	1l ≈ 0.000817 tons.	1ton ≈ 43920 MJ	1ton ≈ 0,04392 TJ 1 GWh ≈ 3.6 TJ
1Gwh	1GWh ≈ 1000 MWh	1GWh 1ton ≈ 3600000 MJ	

7.2 NCVs of Different Types of Biomass (Converting from Natural Units to Energy Units)

Biomass Type	Net Calorific Values (kJ/kg)	Source:
Charcoal	30800	IEA
Firewood (dry)	17000	South Africa DoE
Shrubs	16300	(1)[1]
Wood Waste	17000	Same as dry firewood
Wood Pellets/Briquettes	18400	(2)[2]
Crop Waste	14000	(3)[3]
Animal Waste/Dung	4200	(4)[4]

7.3 Proposed Net Calorific Values of Other Energy Sources (Converting Natural Units to Energy Units)

Carrier	Calorific Value	Calorific Value Unit	Density
LPG	26.7	MJ/l	0.54
Paraffin Power	37.5	MJ/l	0.81
Gas SASOL	18.0	MJ/m^3	
Diesel	38.1	MJ/l	0.84
Electricity	3.6	MJ/kWh	
Gas	41.0	MJ/m^3	
Heavy Fuel Oil	41.6	MJ/l	0.98
Petrol	34.2	MJ/l	0.72
Paraffin Illuminating CSS (StatsSA) Data	37.0	MJ/l	0.79
Aviation Gas	33.9	MJ/l	0.73
Jet Fuel	34.3	MJ/l	0.79
Coal Eskom Average	20.1	MJ/kg	
Coal (General purpose)	24.3	MJ/kg	
Coal (Coking)	30.1	MJ/kg	
Coke	27.9	MJ/kg	
Coke oven gas	17.3	MJ/m^3	
Blast furnace gas	3.1	MJ/m^3	
Bagasse (wet)	7.0	MJ/kg	
Bagasse fibre (dry)	14.0	MJ/kg	
Biomass (wood dry typical)	17.0	MJ/kg	

7.4 CO_2 Emission Factors (IPCC Default) Tier I

Fuel Type	CO2 Emission Factor (kg CO_2/TJ)
Liquid fuels	
Petrol (Gasoline)	69,300
Other Kerosene (paraffin)	71,900
Gas / Diesel Oil	71,400
LPG	63,100
Solid fuels	
Sub-bituminous coal	96,100
Biomass	
Wood / Wood Waste	112,000
Source: Emission Factors: 2006 IPCC Guidelines, Vol. 2. Energy, Table 2.2. Pages 2.16-2.17	

References:

Government of Botswana 2022. Pre-Feasibility of a cross-border petroleum multi-product supply pipeline. Final Report. Botswana Government Publishing.

Piao, X., Managi, S. 2023. Household energy-saving behaviour, its consumption, and life satisfaction in 37 countries. Sci Rep 13, 1382 (2023). Online at: https://doi.org/10.1038/s41598-023-28368-8 (accessed 15 April 2024)

Statistics Botswana 2020. Botswana Environment Statistics: Human Settlements Report 2017. Gaborone. Available from: https://www.statsbots.org.bw/sites/default/files/publications/Botswana%20Environment%20Statistics-%20Human%20Settlements%20Report%202018.pdf 12 April 2024.

UNEP 2017. Atlas of Africa Energy Resources. United Nations Environment Programme, Nairobi, Kenya.

Republic of Botswana
MINISTRY OF MINERALS & ENERGY

Ministry Of Minerals & Energy
Department Of Energy
Tel: 3640200
Fairground Office Park

BITRI
BOTSWANA INSTITUTE FOR TECHNOLOGY RESEARCH AND INNOVATION

STATISTICS BOTSWANA

@minerals_energy mmebotswana