UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

ASSESSMENT OF THE DETERMINANTS OF HOUSEHOLDS ENERGY USE IN RWANDA

A Thesis submitted to the African Centre of Excellence in Energy studies for sustainable development (ACE-ESD)

In partial fulfilment of the requirement for the degree of MASTERS OF SCIENCEINENERGY ECONOMICS

By: IRADUKUNDA Aime Robert

Advisor: Prof. NIYITANGA Fidèle

09November, 2021

Kigali-Rwanda

DECLARATION

I, the undersigned, declare that this thesis is my original work, and has not been presented for a degree in University of Rwanda or any other universities. All sources of materials that will be used for the thesis work will have been fully acknowledged.

Name: IRADUKUNDA Aime Robert

Signature

SUBMISSION

Date of Submission: 19/11/2021.

This thesis has been submitted for examination with my approval as a university advisor.

Prof: NIYITANGA Fidèle

Thesis Advisor Signature 

DEDICATION

My late father Ndolimana Paul;

My late mother Kayitesi Madeleine;

My late grandmother Kanyanja Edissa;

My brothers and sisters;

All UR/ACE-ESD Community;

My classmate in program of Energy Economics;

Anyone else who is not appearing in this list but whose role is recognized.

ACKNOWLEDGEMENTS

It has been an exciting and instructive study time at the African Center of excellence-energy for sustainable development (ACE-ESD) and I feel privileged by having this opportunity to carry out this study as a demonstrating fact of the knowledge obtained in the period of my studies at African center of excellence –energy for sustainable development (ACE-ESD).With these acknowledgements, it would be impossible not to take into account various people who in one way or another, directly or indirectly have contributed to the accomplishment of such project as they played the big role in the accomplishment of this Project from the starting of University up to now. Let me therefore thank them as they did great to me

Firstly, I indebted to the powerful God for blessing me and being around me throughout the study rom primary school up to the University. He guaranteed me life, kept my life safe in this hard time under which the whole world is suffering from pandemic of covid-19(coronavirus). I am deeply obliged on the Government of Rwanda and the World Bank group who created this chance and I got benefited through this good policy of setting the African Centre of Excellences and decide to host them in University of Rwanda. With this, I gained the scholarship which facilitated me to study and I got much knowledge about energy sector and its derivatives

I also send the warm appreciation to my supervisor Prof Fidèle NIYITANGA for his exemplary guidance and supports. His continuous availability, his assistance and instructive comments have all contributed to the smooth success of this dissertation. He has spent his time and energy to make sure that I remain in right track while I was writing this research project. Without his supports, this project would have not been a success to me.

May God bless you abundantly

Mr: Aime Robert Iradukunda

ABSTRACT

The National Institute of Statistics of Rwanda (NISR) fifth's Integrated Household Living Conditions Survey is used in this dissertation to examine the factors that influence how much energy is used in the home in Rwanda and to evaluate the aspects that are likely to impact household decisions when it comes to choosing an energy source for various activities like lighting and cooking. A multinomial logit selection model was employed for identification and analysis. The findings show that a family's choice of cooking or lighting is influenced by its location, income level, household size and education. It reveals that rural households are more likely than urban households to use traditional energy. In addition, high-income earners are more likely to use modern energy for cooking or lighting.

Key words: Household energy consumption, cooking energy, lightening energy.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

EAPP: East Africa Power Pool

EICV: Integrated Household Living Condition Survey

EIA: Energy Information Administration

IT: Information Technology

LPG: Liquified Petroleum Gas

MININFRA: Ministry of infrastructure

R&D: Research and development

RDB: Rwanda Development Board

RE: Renewable Energy

REG: Rwanda Energy Group

MW: Mega Watts

NISR: National Institute of Statistics of Rwanda

TWh: Tela Watts hour

USAID: United State Agency for International Development

WAPP: West Africa Power Pool

CHAPTER ONE: GENERAL INTRODUCTION

1.1.Background of study

Ability to do work or produce heat is a common definition of energy. Normally, heat is produced by burning a fuel, which is a substance with internal energy, energy obtained by capturing the sun's rays or from the rocks beneath the earth's surface, or by other techniques such as capturing the sun's rays (Bhattacharyya, 2011).

Globally By 2030, global energy consumption will be two-thirds of what it is today, developing countries will overtake developed countries as the largest group of energy users, and non-renewable will continue to be the major source of energy, accounting for 80 percent of total energy consumption (James P. Dorian,Herman T. Franssen, Dale R. Simbeck, 2005).

The world’s energy demand is rising, particularly in undeveloped countries. In the last 50 years, global energy consumption has tripled, and it is anticipated to triple again in the next 30. While China and India's fast-growing economies will drive much of this increase, many established countries, particularly those in Europe, are striving to meet their energy needs by increasing the use of renewable energy sources (LumenCandela, 2021).

Lack of energy is restricting China's and India's rapid economic expansion. In 2003, The United States has replaced Japan as the world's second-largest oil consumer. More than a third of it, though, comes from outside the country. Coal dominates China's commercial energy resources, accounting for two-thirds of the country's energy consumption. Unlike most Western countries. In 2009, China overtook the US as the world's leading CO2 emitter (LumenCandela, 2021)

India's primary energy sources are biomass (wood and dung) and coal. Import half of the country's oil. Coal is utilized to generate about 70% of India's electricity, which is very polluting. Nonetheless, in the field of renewable energy, considerable progress has been made. India has the largest solar cooking program in the world and a rapidly growing wind energy base (LumenCandela, 2021)

Despite its enormous and quickly expanding population, Africa's energy consumption is expected to continue to be small of global totals through 2050, according to the US Energy Information Administration (EIA). Africa's power generation mix could shift away from coal and natural gas, which are currently used in the central grid, and toward a greater contribution from renewable resources to meet demand, due to the limited reach of central grid power in rural areas and the unpredictability of central grid power in urban areas (Administration, 2021).

The entire electricity demand on the continent was 613 TWh in 2015. According to the estimates, they are predicted to expand by approximately three times (2030 TWh) by 2040 and nine times (5331 TWh) by 2065. The Western African power pool, with an average annual growth rate of 6.9%, has the highest increase in energy demand, followed by the Central and Eastern African power pools. Nigeria is the driving force behind WAPP demand. In EAPP, demand will be driven by sustained expansion in Egypt, Ethiopia, and Kenya, while in CAPP, demand will be driven by the Democratic Republic of Congo, Nonetheless, from a low starting point. In each scenario, these countries account for more than half of their respective power pool demands. Increases in energy consumption are induced by population expansion, rising electrification rates, and rising economic growth (I. Pappis, M. Howells, V. Sridharan, W. Usher, A. Shivakumar, F. Gardumi, and E. Ramos, 2019)

Rwanda's economy and development ambitions are heavily reliant on energy. Housing and urbanization, manufacturing, agro-processing, mining, tourism, and IT services are all supported by it. 85 percent of all energy consumed comes from biomass. Bioproducts are included in this subsector. Bio-products are fuels made from biological resources. They are divided into two types: wood-based fuels like wood and charcoal, and waste-based fuels like biogas. Petroleum focuses on the purchase and storage of petroleum and related products, such as diesel, kerosene, LPG, and natural gas. Biomass is mostly used for cooking, with wood utilized by rural homes and charcoal by urban people. Petroleum accounts for 13% of the country's overall energy consumption. Petroleum is utilized in transportation, power generation, and cooking (as LPG). As urban households move away from utilizing firewood, the usage of LPG in cooking is likely to grow dramatically (MININFRA, 2018)

According to RDB report of 2017, the Rwanda energy consumption was at 210.9 MW installed capacity and this quantity generated was the triple argument than how it was in 2010.In this procedure, the generation mix is presented as follow: Hydro power plants accounted for 48%, thermal power plants are at 32%, solar PV 5.7 percent, and methane to power 14.3 percent. However, according to the REG Report of 2017, Rwanda has 40.5 percent access to energy, with 29.5 percent on-grid and 11 percent off-grid (RDB, 2017).

Governments and development agencies around the world are dealing with problems such as energy scarcity, global warming, and climate change. As a result, government policies are shifting to promote energy efficiency and develop low-carbon economies. As a result, renewable energy (RE) development is becoming a more essential source of alternative energy, however, expensive R&D costs, long-term planning processes, massive investment risks, and unpredictable returns limit the development of RE technology. Due to these constraints, emerging countries must rely on traditional energy carriers to provide for their populations (Inayatullah Jan1, Humayun Khan, Shakeel Hayat, 2011)

Energy generation from wood fuels dominates in Rwanda, amounting for around 95% of total energy supply. Between 1990 and 2005, the country's forest and woodland environment was lost by 50.2 percent (Bensch & Peters, 2010).

Providing poor households in developing nations with reliable access to clean and inexpensive electricity is a critical component of the fight against poverty (Riahi, 2010).The use of traditional form of energy carries adverse effects, like emissions of particular matter to deforestation and environmental degradation are all hazardous to people's health. They are so my factors that influence someone to use one fuel to another, because wood is readily available in rural regions, people prefer to utilize it because it is the cheapest option compared to other options. The use of dirty energy for cooking or lighting is a hardship for children and women in particular, affecting their education as well as poverty among women.

Rwanda main cooking fuel is biomass, Charcoal, LPGs and others. This differentiates from one household to another because of many factors like location, Income, availability of fuel. Rwanda

has been improved its energy sector for providing electricity in all corners of the country, even though there are still people that are still use traditional means of lighting but electricity is improving(Researcher, 2021). This study will be focused on the factors that make a household member to use one type of fuel in cooking to another, one type for lighting for another.

1.2. Problem Statement

Nearly 40% of global yearly energy consumption is consumed by buildings. Lighting, heating, cooling, and air conditioning make up a large part of this energy (Ome, 2009). For any country in order to develop there is a need to improve its energy sector. Energy is a basic human requirement and the driving factor behind the development of all sectors(George Kilama, Peter et Al, 2019).

Global energy consumption has increased by about a third since 2000, and it is anticipated that it will continue to rise in the foreseeable future. Global energy demand increased by 2.9 percent in 2018, and if trends continue, global energy consumption will reach 740 million terajoules by 2040, representing a 30 percent increase. This will result in a 77 percent increase in global energy consumption between 2000 and 2040. Global energy consumption could quadruple from roughly 300 to 900 million terajoules between 1980 and 2050 (worldcounts, 2021)

About 2.5 billion people depend on woody products across the world. waste, agricultural waste, twigs, and other non-woody substances) biomass fuel and coal for cooking and space heating and also for lighting purposes 1.6 billion people are now in a similar situation.

Today there is also no electricity. This is a great danger. to achieving the Kyoto Protocol's emission reduction goals. In emerging countries, there is a focus on poverty alleviation and long-term development (Inayatullah Jan1, Humayun Khan, Shakeel Hayat, 2011)

The energy situation in Rwanda is affected by the country's geographical and socioeconomic circumstances, which limit access to modern fuels (Mazimpaka, 2014). Like other developing countries, Rwanda main energy consumption source are traditional ones to which are harmful both to environment and health. With the rise of environmental challenges and global warming

problems, the policies are focused on shift from that so-called dirty energy to clean energy, through Paris agreement where the countries agreed to decrease the amount of carbon dioxide so that global warming should be reduced.

Rwanda currently has a total installed capacity of 235.6 MW generated by various power facilities, the majority of which are hydroelectric. Only 11% of the available capacity is imported, with the balance coming from native sources. Hydrological resources account for 50.6 percent of the generation technology mix, followed by thermal sources (43.4 percent) and solar sources 5% (REG, 2021).

Rwanda utilized 15,834,435,000 BTU (0.02 quadrillion BTU) of energy in 2017. This amounts to 0.001% of world's energy consumption. Rwanda produced 3,012,651,000 BTU (0.00 quadrillion BTU) of energy, enough to cover 19 percent of the country's annual energy needs. Rwanda's non-renewable energy accounts for 81 percent of the country's total energy consumption 12,771,000,000 BTU. Renewable energy accounts for 19 percent of the country BTU: 3,012,651,000 (worldometers, 2021)

In Rwanda's example, she is attempting to use liquefied petroleum gas (LPG) as a source of energy for cooking in Kigali and other cities, but the government has made more efforts by giving incentives such as subsidies, wood fuel remains the primary source of cooking in Rwanda. Changes in the climate and the degradation of quality of the environment have brought a rise in global interest in environmental governance, energy restructuring, and the effects of pollutant emissions on public health. Rapid economic growth not only leads to increased consumption of fossil fuels, but also to increased emissions of numerous pollutants. Pollutant emissions induced by the usage of fossil fuels have been found to be harmful to the public's physical and mental health. Public health is a worldwide concern, but new research on the linkages between fossil energy consumption, pollutant emissions, and public health has been published recently (Xinpeng Xing, Jianhua Wang et al, 2019).

The theory of consumer behaviour could better explain household energy usage. According to the basic consumer behaviour theory, a rational buyer would often choose the most desirable

package from a set of viable options. The majority of households make fuel-choice selections depending on economic or non-economic, cultural, personal, and psychological considerations. The goal of this study is to determine the elements that influence how much energy a home use.

1.3. Objectives of the study

1.3.1. Major Objectives

The primary goal of this study is to assess the determinants of household's energy use in Rwanda.

1.3.2. Specific objective

As particular objective, this research aims at assessing the socio-economic factors underlying the household's energy consumption decisions.

1.4. Scope of the study

The study's emphasis is on how Rwandan households utilize energy, as well as the underlying factors that influence which energy they use for cooking and lighting. is study will be focused on how people at household level consume energy, by looking on which kind of energy they use for cooking and lightning, what the effects that kind of energy brought to them. The analysis is based on EICV 5 data (Integrated Household Living Condition Survey (EICV 5).

1.5. Expected outcomes and significance of the study

1.5.1. Expected outcomes of the study

1. The education, income and household size are the main socio-economic factors underlying the household's energy use decisions

2. The households energy use decisions are influenced by the location of the households, located in rural or urban area.

1.5.2. Significance of the study

1. The household energy consumption is reflected by the available abilities of households with considering their socio-economic status.

2. The current research is significant in that it shows the factors underlying the household's energy decisions. This finding could contribute to guidance of investments in energy production and distribution in Rwanda.

CHAPTER TWO: LITERATURE REVIEW

2.1. Definition of key concepts

Household

Household is a social unit made up of people who live in the same house (Merriam-websiter, 2021). The term household is the art of economic agent which is responsible to purchase the products offered by manufacturing firms so as to satisfy their basic needs (Karl Max,1954).

Energy

Energy is the capacity of a physical system to do work (Contributor, 2021). Energy first of all the ability to do work or generate heat is how most people perceive energy, usually, burning a fuel, that is to say, a material with internal components energy that generates heat in other ways, such as by capturing the rayon’s

Energy Consumption/use

All energy used to accomplish an action, make something, or simply live in a building is referred to as energy consumption (Teba, 2021). The energy consumption is the practice of making products using the available energy source. In another words, energy consumption refers to the utilization of available energy so as to satisfy personal needs (Researcher,2021).

2.2. Rwanda Energy Status

Rwanda is a small country in East Africa with a population of 12,089,721 (NISR, 2018) people living on a surface area of 26,338 km2, 94.7 percent of which is land and the remaining 5.3 percent is water. Its terrain is located between latitudes 1.050 and 2.840°S and longitudes 28.860 and 30.900°E (Atlas, 2017), with two rainy seasons per year, the country's diverse river systems are organically fed. Between them are Uganda, Burundi, Tanzania, and the Democratic Republic of Congo (Atlas, 2017). Rwanda's government has set lofty goals for the electricity sector,

including expanding installed power generation capacity from 216 MW to 512 MW by 2023/24 and reaching universal access (100%) by 2023/24.

The target is to have 52 percent on-grid and 48 percent off-grid connections by 2023/24. The many branch offices of the Rwanda Energy Group (REG) were used to review and determine the power sector's success in meeting its goals, aims, and aspirations. Because of its longer plant life, improved capacity factor, and availability, as well as Rwanda's upgrade and development initiatives, hydropower has a high generating percentage (46.8%). Additionally, the cost-effectiveness of generating electricity from local resources such as hydropower, peat, lake gas methane, and geothermal energy is expected to total roughly 1,613 MW (Samuel Bimenyimana et al, 2018).

Rwanda's efforts are focused on making the shift from a low-income to a middle-income economy a reality. To meet this goal, the government is aiming for 100% electricity availability by 2024. In Rwanda, natural energy sources such as hydro, sun, and methane gas predominate. It only has 218 MW of installed producing capacity at the moment. According to the International Energy Agency (IEA), Rwanda's national electrification rate is predicted to reach 30%. (USAID, 2020). In Biomass sources account for 85 percent of primary energy in Rwanda, with 94 percent of all households using biomass for cooking. Biomass sources include wood, charcoal, and agricultural waste. (Evaluation, August 2014)

The rapid growth of residential household energy consumption and its significant place in overall energy consumption have seen it increasingly discussed in the field of energy economics. Household energy use has received a lot of publicity in order to cut costs emissions of carbon dioxide (Xiaowei Ma et al, 2019).

2.3. Rwanda household energy consumption situation

According to present domestic energy balance estimates, biomass (mainly wood fuel) provides for around 83 percent of total energy consumption, followed by petroleum (9.7%), electricity (1.3%), and others (less than 0.5 percent). In rural regions, biomass is used more than 90% of the

time. The majority of Rwandans reside in rural regions, where wood fire is still the most often used form of cooking energy (REG, 2021).

Biomass

In 2009, there was an expected deficit of 870,000 tons of woody biomass, biomass use is putting strain on current resources. Furthermore, the use of biomass as a fuel has negative health and environmental consequences.

Biogas

In Rwanda, the potential biogas market is anticipated to be 150,000 families, primarily in rural areas. Since 2007, the government has implemented a comprehensive program to distribute bio digesters to houses, reduce consumption for wood and charcoal in schools and prisons to enhance people's health while also slowing for wood and charcoal.

LPG

Société Pétrolière-SP, Kobil, Sulfo Rwanda, Rwanda Oxygène, Merez Hashi energy, Abbarci Petroleum, Safe gas Lake Petroleum Rwanda, and RUCSA Investment are the top ten importers and marketers of LPG in Rwanda. Retail distribution is available through service stations, independent distributors, and supermarkets in cylinder sizes ranging from 3 kg to 50 kg, as well as tanks ranging from 500 kg to 5000 kg for major institutions.

2.4. Household energy use hypothesis

According to research on household energy demand and choice, households in transition (those between low and high income) use transition fuels such as charcoal and kerosene. While lower-income families use biomass fuels, higher-income households choose cleaner, more expensive energy sources such as liquefied petroleum gas and electricity (Heltberg, 2005).

According to Leach's (1992) research, the energy ladder hypothesis, which is one of the most common conceptualisations of energy usage patterns among families, contains a number of

ideas. Traditional stoves and cooking fuels such as animal dung, charcoal, and wood are assumed to be used by low-income households, whereas higher-income households are thought to use modern cooking technology and fuels. As household income rises, they switch from traditional fuels and cooking stoves to modern fuels and culinary equipment (Baldwi, 1986).

The energy ladder hypothesis is based on consumer behaviour economic theory. Structured codified formalized formal the theoretical premise underlying the energy ladder theory is that low living standards increase reliance on firewood and other biomass fuels due to a combination of income and substitution impacts (Baland, 2007). Furthermore, the energy ladder hypothesis assumes that cleaner fuels are standard commercial commodities, whereas old fuels are inferior (Fournier, 2011).

2.5. Conceptual framework

A theoretical framework is made up of a single formal theory. The theory is the essential tool for comprehending and exploring the research problem when a study is developed around a theoretical framework. Theoretical frameworks are typically used in quantitative studies, but they can also be used in qualitative research. The theoretical framework is A conceptual framework is made up of one or more formal theories (in part or whole), as well as other concepts and actual evidence from the literature. It's used to illustrate how these concepts are connected to one another and to the research study.

2.6. Empirical review on determinants of household energy consumption

Empirical evidence based on energy demand research has confirmed both the energy ladder and the fuel stacking hypotheses. Weerahewa (2007), for example, looked into the patterns of household energy usage in Sri Lanka's urban, rural, and estate sectors. The data show that Sri Lanka's energy ladder hypothesis is valid, and the country is moving toward modern fuels like liquefied petroleum gas (LPG) and electricity as a whole. The urban sector progresses significantly more quickly than the rural sector (Weerahewa, 2007).In Ouagadougou, Ouedraogo (2006) utilized a multinomial logit model to investigate the characteristics that influence urban

household energy preferences for cooking. Low income, limited access to electricity for main and secondary energy needs, low housing standards, and household size all contribute to the inertia of household cooking energy preferences, according to the findings. From low-income to higher-income households, the consumption of firewood diminishes. The marginal impacts of household income on firewood and charcoal are negligible. When this variable goes from higher education to primary education, the probability of utilizing firewood as a primary cooking energy increases by 0.61 percent. Wood energy choices are influenced by the size of the home, cooking habits, and formal education level of the household leaders.

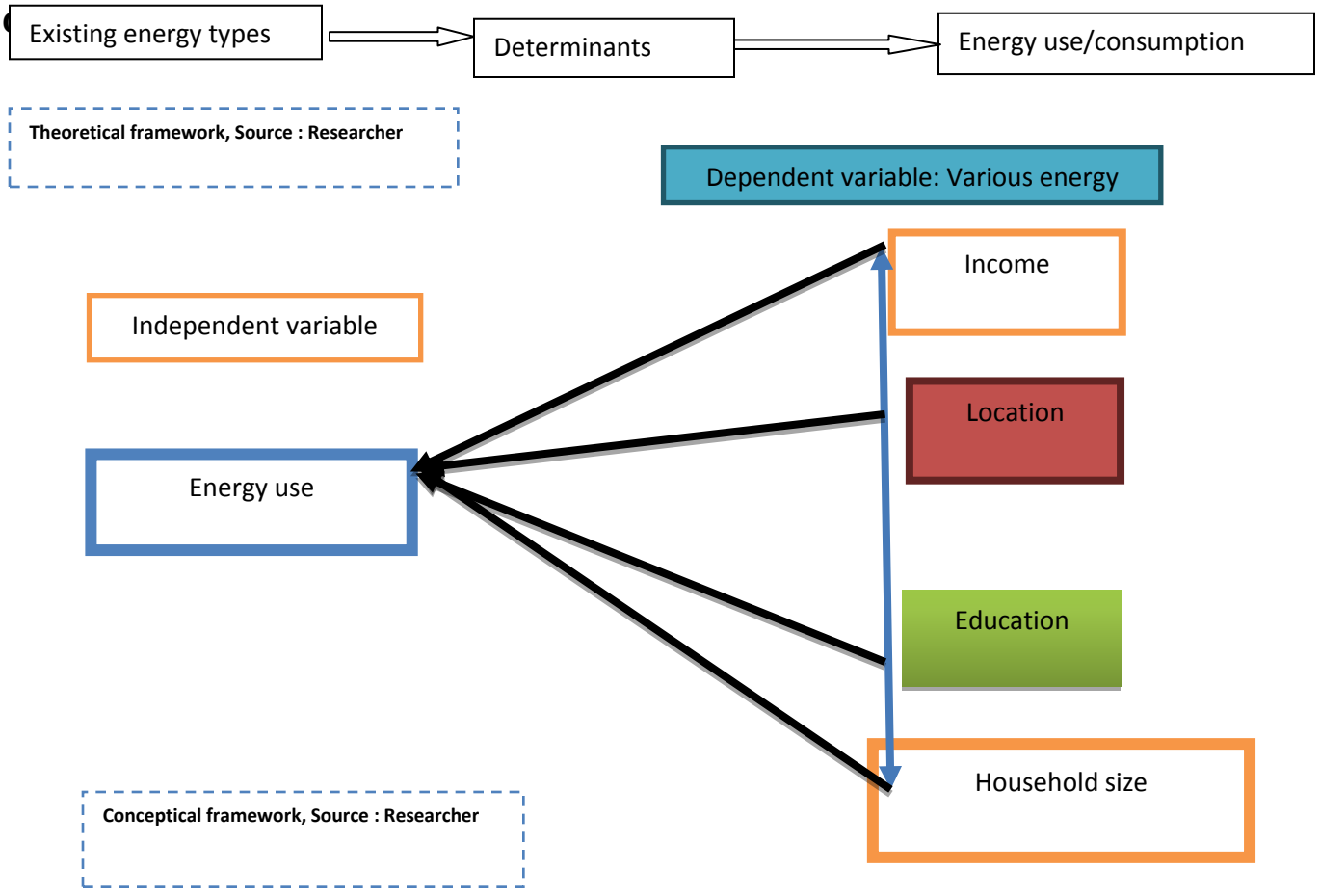
Barnes (2010) observed that combining traditional (biomass energy used in traditional stoves) and contemporary (electricity and kerosene) energy sources boosts household consumption and income; the return on modern sources is 20 to 25 times higher than the return on traditional sources. Furthermore, they discovered that 58 percent of rural households in Bangladesh were energy poor, compared to 45 percent who were money poor, after comparing multiple metrics of the energy poverty line. Increased electrification and the use of efficient cooking stoves for biomass use can alleviate energy poverty while also lowering carbon dioxide emissions, according to the research. According to the findings, alleviating energy poverty is a good idea that reducing energy poverty helps in reducing income poverty as well (Barnes, 2010).

Demurger and Fournier (2011) used descriptive data from a household survey conducted in ten villages in Labagoumen Township in northern China to assess the general dependency of families on forest resources as well as energy consumption patterns in the analyzed villages. The marginal impacts of several socioeconomic variables on coal use were determined using the probity model in this study. It was revealed that income has a considerable impact on energy use and fuel substitution. It was also revealed that household firewood usage is a substantial and negative indicator of wealth. Further research implies that there may be a floor effect in decreasing firewood consumption at the top of the wealth distribution, and that, even with higher living standards, transitioning away from traditional cooking methods may be difficult in a given location.

Theoretical and Conceptual framework

Theories are created in order to explain, forecast, and grasp facts, as well as to examine and extend current skills in a variety of situations, all while maintaining within the confines of crucial constraining assumptions. The theoretical framework is the structure that holds or supports a research investigation's theory. The theoretical framework describes and introduces the theory that explains why the research problem was chosen in the first place.

Theories are developed to explain, forecast, and grasp facts, as well as to examine and extend current knowledge in a variety of situations, all while maintaining within the confines of crucial constraining assumptions. The theoretical framework holds or supports a research investigation's theory. The theoretical framework defines and introduces the theory that explains why the research problem under consideration exists.



CHAPTER THREE: METHODOLOGY

3.1. Data description

The data for this study came from the National Institute of Statistics of Rwanda's (NISR) Fifth Integrated Household Living Conditions Survey, which was conducted in all of Rwanda's districts. The research used cross section data, which examines data from a certain group of people at a specific point in time. Participants are chosen for this type of study depending on certain variables of interest. (Dotdash, 2021), the data was collected by the Rwandan National Institute of Statistics every three years, which means the data I am using in my thesis covers the years 2017 to 2020.The information in this study comes from the fifth Integrated Living Conditions Survey (EICV5), which questioned 14,580 families across the country between late October 2016 and early October 2017, totaling 64,314 people. The information gathered included a wide range of economic and socio-demographic factors.

3.2. Model specification

In this research, the econometric model will be built using the energy types that are used by the household members for lightening and cooking, energy consumption of various energy types like firewood, liquefied petroleum gas (LPG), or electricity, Charcoal. All the useful data in this research will be extracted from EICV5. The data to be considered here are the firewood, total number of people using LPG, Total number of people using Charcoal, Total number of people using Electricity. And in this research, I will use descriptive statistics and logit model,

In this study, descriptive statistics will be used to provide fundamental information about variables in a dataset and to highlight potential relationships between variables. The association between binary or ordinal response probability and explanatory variables has also been investigated using logistic regression analysis.

Moreover, metric of household energy consumption and various energy types can be shown below:

HHEC=f (M, T, U)

Where :

HHEC=Household Energy Consumption

M: number of people using modern energy

T: Total number of people using Traditional energy

U: Total number of people using Unspecific

Empirical model and estimation

$$hhec = \beta_0 + \beta_1 Loc + \beta_2 IL + \beta_3 ed + \beta_4 hhsize + \varepsilon$$

HHEC: household energy consumption

Loc: location

Ed: Education level

Hhsize: Household size

ε: Error term

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Descriptive statistics of the sample

Table 1: The descriptive statistics of the sample are presented below:

	mean	sd	min	max	count
Main source of Household Lightening	1.69	.47	1	3	89373
Main source of cooking fuel	1.99	.10	1	3	89373
Location	.14	.35	0	1	89373
Education Level	1.18	.39	1	2	81394
Income Level	2.43	.75	1	3	89373
Household Size	5.28	2.13	1	22	89373

Source: Secondary data from NISR(EICV5)

Above provide basic information about data set and highlighting potential correlation between variables

Table 2. Descriptive statistics of sample household lightening and Education level

Main source of Household Lightening	Education Level		
	Yes	No	Total
modern Energies	22695	2924	25619
Traditional energies	42951	12315	55266
Unspecified	400	109	509
Total	66046	15348	81394

Source: Secondary data from NISR (EICV5)

This is to illustrate that the educated household using modern energy for lightening that is (electricity, Panel, biogas) are 22,695, 42,951 use traditional(firewood), 400 use unspecified (torch, agriculture wastes), and household without education 2,924 use modern,12,315 use traditional and 109 use unspecific.

Table 3. Household location and Lightening

Location	Modern Energy (electricity and LPG)	Traditional energy (biomass and charcoal)	Unspecified energy (panel, torch)	Total
Rural	18,550	57,287	527	76,364
Urban	9,426	3,550	33	13,009
Total	27,976	60,837	560	89,373

Source: Secondary data from NISR (EICV5)

This table shows for the household live in rural area use traditional energy at high rate compare to rural areas where 57,287 household in rural areas use traditional energy for lightening compare to 3,550 in urban, also 9,426 households use modern in urban and 18,550 household use modern energy are located in rural, then 537 use unspecific in rural and 33 in urban.

Table 4. Household lightening and Income level

Income Level	modern energy	Traditional energy	Unspecified energy	Total
Severely poor	1,278	13,393	127	14,798
Moderately poor	3,286	17,586	114	20,986
Non-Poor	23,412	29,858	319	53,589

Total	27,976	60,837	560	89,373

Source: Secondary data from NISR(EICV5)

Household in severely poor 1,278 of them use modern energy, 13,393 use traditional and 127 use unspecific, moderately poor 3,286 use modern energy, 17,586 use traditional, 114 use unspecified energy, non-poor 23,413 use modern energy, 29,858 use traditional energy and 319 use unspecific energy for home lightening

Table 5. Household size and lightening

Household size	Modern energy	Traditional energy	Unspecified energy	Total
Household size > 10	840	477	17	1,334
Household size <=10	27,136	60,360	543	88,039
Total	27,976	60,837	560	89,373

Source: Secondary data from NISR(EICV5)

Household with more than 10 individuals 840 among them use modern energy, 477 use traditional and 17 use unspecified energy, and for household with individual less or equal to 10, 27,136 household use modern, 60,360 use traditional and 543 use Unspecified energy.

Table 6. Household cooking energy and Education

Main source of cooking fuel	Education Level		Total
	Yes	No	
Modern Energies	704	9	713
Traditional energies	65,101	15,310	80,411
Unspecified energy	241	29	270

Total	66,046	15,348	81,394

Source: Secondary data from NISR(EICV5)

Educated people 704 use modern, 65,101 use traditional and 241 use unspecified and for the uneducated people15,310 use tradition energies for cooking and 29 households use unspecified energy.

Table 7. Household cooking energy and Location

Location	Main source of cooking fuel			Total
	modern Energy	Traditional	Unspecified	
Rural	120	76,124	120	76,364
Urban	633	12,213	163	13,009
Total	753	88,337	283	89,373

Source: Secondary data from NISR(EICV5)

The table shows that 753 use modern energy for cooking among the 120 lives in rural and 633 in urban, 88337 use traditional where among them 76,124 live in rural and 12,213 in urban, 89,373 use unspecific energy among them 120 lives in Urban, 163 in urban.

Table 8. Household cooking energy and income level

Main source of cooking fuel	Income Level			
	Severely poor	Moderately poor	Non-Poor	Total
Modern Energies	0	13	740	753
Traditional energies	14791	20937	52609	88337
Unspecified	7	36	240	283

Source: Secondary data from NISR (EICV5)

This table shows when there is a change in income level the cooking energy changed to the increase.

Table 9. Household cooking energy and household size

Main source of cooking fuel	Household size		
	Household size > 10	Household size <=10	Total
Modern Energies	40	713	753
Traditional energies	1278	87059	88337
Unspecified	16	267	283
Total	1334	88039	89373

Source: Secondary data from NISR(EICV5)

This table shows that with the increase of the household members the energy type using for cooking will change.

4.2. Determinants of household energy use

4.2.1. Determinants of cooking energy used

For cooking fuel, the multinomial logit model for household energy types is utilized. The three energy types that have been modelled are traditional energy, modern energy, and unidentified energy. The estimates are, on the whole, reliable. The likelihood ratio statistics' values, all of which are statistically significant at one percent.

Table 10. Regression for Logit model cooking fuel

VARIABLES	(1) Main source of cooking fuel
Location	-0.0349***
	(0.00224)
Household size	0.0118**
	(0.00543)
Education Level	0.00527***
	(0.000535)
Income Level	-0.00263***
	(0.000258)
Constant	1.988***
	(0.00535)
Observations	81,394
R-squared	0.015

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Secondary data from NISR(EICV5)

The same variables are statistically significant in each model with respect to the significant level at 5%, 10% and 1%. Because the coefficient is approximate the same, we can interpret the model by using the coefficient of linear probability of the model.

- Location: The likelihood of using one type of cooking energy decreases by 0.349 percent as a household according to the location of a household.

- Household size: the results show that an increase of one person at 5% of significance increases the source of cooking fuel at 1.118%.
- Education: the results shows that a year at 1% of significance increase the probability of using cooking fuel at 0.527%
- Income level: the table shows that if the level of income increases the probability of cooking fuel decrease at 0.263%.

4.2.2. Determinants of lightening energy chosen

The multinomial logit model for home energy types is used for lighting fuel. Traditional energy, modern energy, and unidentified energy are the three categories of energy that have been modeled. On the whole, the estimates are accurate. The values of the likelihood ratio statistics are all statistically significant at one percent as shown in table 11.

Table 11. Regression for Logit model Lightening

VARIABLES	(1) Loc	(2) Hhs	(3) Educ	(4) IL
1bn._predict	0.00278***	-0.000556***	-0.00212***	0.00211***
	(0.000448)	(0.000186)	(0.000390)	(0.000212)
2._predict	-0.00636***	0.00119*	0.00267***	-0.00365***
	(0.000548)	(0.000668)	(0.000535)	(0.000315)
3._predict	0.00358***	-0.000632	-0.000546	0.00155***
	(0.000318)	(0.000636)	(0.000366)	(0.000233)
Observations	81,394	81,394	81,394	81,394

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.

Source: Secondary data from NISR(EICV5)

Results of the regression output from STATA are shown above. The same variables are statistically significant in each model with respect to the significant level at 5%, 10% and 1%. Because the coefficients are approximate, interpret the model by using the coefficient of linear probability of model.

- Location: probability of using modern as source of lightening decrease at 0.278%, tradition al energy the probability decreases at 0.636% and then for unspecific energy the probability of using it increase at 0.358%
- Household size: an increase of one household member decreases the probability of using modern energy for lightening at 0.05%, also an increase of one household member increases the probability of using traditional energy for cooking at 0.119% then for unspecific energy the increase of household member reduces the probability of using the unspecific energy for lightening at 0.06% decrease in lightening.
- Education: As someone's degree of education rises, the likelihood of using traditional energy reduced at 0.2% for lighting, also the probability of using modern energy increase by 0.2675% in lightening, then for unspecific energy the probability reduced at 0.0546% for every increase in education level.
- Income level: for every increase in income level, the probability of using modern energy for lightening increased at 0.0212%, and also an increase in income level, there should be a reduction in using traditional energy at 0.365%, lastly for every increase in income there is a percentile increase of 0.15% increase in unspecified energy using for lightening.

CONCLUSION AND RECOMMENDATION

This chapter will include a summary of key findings as well as a conclusion in relation to the study's goals. The order in which the tasks in this dissertation were accomplished resulted in a more coherent and comprehensive study.

Even tough determinants of household energy consumption have been studied through in many parts of the world, but to the part of Rwanda especially have not been carried on. The continue rise of using dirty energy for home activities like cooking and lighting is an issue to the global and in this study, we have analyzed the determinants or factors that lead to someone to use one energy types either modern, traditional or unspecific for both lightening and cooking.

The goal of this is to assess the determinants of household's energy use in Rwanda at assessing the socio-economic factors such as income of household, location, household size and the level of education of household member. Descriptive statistics and multinomial logit were used to analyze the data.

The results revealed that educated people use clean energy compare to uneducated people where results shows that 34% of educated people use modern though 19% of uneducated are the only, also uneducated people use dirty energy for lightening at high rate compare to educated people where results shows that 80% of uneducated people use traditional energy for lighting compare to 65% of educated people as, due to the location of household urban people tend to use modern energy for lighting at the rate of 72% whereas the rural areas 24.2% only use modern energy but rural areas use traditional energy at high rate where 75% though urban are at 27.2% , according to the income of household member the non-poor tend to use modern energy at high rate 43% , moderately poor at 8.6% whereas severely poor are at 8.6% but severely poor use traditional energy at high rate 90.5%, moderate at 83.7%, non-poor at 56.3%. For household that has more than 10 members the 63% use modern, 36% use traditional energy and only 1% use unspecific energy type for home lightening. And for the household with less or equal to 10 31% of them use modern energy, 68% use traditional around 1% use unspecific energy type for home lightening. And also, for cooking the results show the household that use modern energy for cooking 98.7%

of them are educated whereas 1.3% are uneducated household member. For traditional energy use for cooking 80.9% are educated household, 19.1% are uneducated households, then for unspecific 89.25% of them are educated while 10.75% are uneducated, rural household living use modern energy for cooking at 15.87% on the other hand urban living household use modern at 84.13% for cooking, also 86.17% of rural household living use traditional energy, 13.83% of urban living households use traditional energy for cooking. Then 42.4% of rural living household use unspecific energy, 57.5% in urban area also use unspecific energy for cooking, modern energy severely poor household category 0% of them use modern energy for cooking,1.726% use traditional and 98.27% use unspecific and for traditional energy severely poor are 16.7%, 23.7% are for moderately poor ,59.5% of them are for non-poorly, 2.4% use unspecific energy are from severely poor, 12.7% are from moderately poor and 86.95 are from non-poor category, the use of modern energy for the household that has more than 10 members, as a source for cooking is equal to 5.32%, and 94.68% for the household that has less or equal to 10, traditional energy household that has more than 10% are 1.44% and 98.55% are less than 10 individuals, and for unspecific type of energy using for cooking 5.65% of them are household that composed of more than 10 members and 94.34% are less than 10 individuals.

The literature issues were to be considered in the achievement of this study as needs to ensure that there have been previous researchers who did the same topic and saw the gaps within their works and where these gaps needed to be covered in the current research.

This was especially evident in the empirical review, where previous researchers' work was emphasized and criticized in the critical review section, where the vacuum that they left was recognized and how it was filled within the current research.

I've noticed that some determinants influence energy consumption, such as level of education, which causes people to use modern energy for both cooking and lighting in both rural and urban areas, income level, which also causes people to switch to modern energy, and household size, which may affect energy consumption but at a low level.

Recommendations

Government of Rwanda should encourage its rural people to use modern energy for cooking and lightening by providing LPG and teaching them the benefits of using modern energy and how to use them. Government of Rwanda should also regulate the price of modern energy so that the people who start to enjoy them will not loss the satisfaction and return to traditional energy due to price fluctuation of energy products like LPGs.

REFERENCES

Administration, U. E. (2021). *Off-grid electricity development in Africa:UNCERTAINTIES AND POTENTIAL IMPLICATIONS FOR ELECTRIC POWER MARKETS.* Washington Dc: U.S. Department of Energy.

Astrid Kander David I. Stern. (2014). Economic growth and the transition from traditional to modern energy in Sweden. *Energy Economics*, 10.

Atlas, G. (2017). *Rwanda.* Macmilan.

Bailis, R. (2004). *Encyclopedia of Energy 1st edition.* Elsevier Science.

Baland. (2007). Managing the Environmental Consequences of Growth: Forest Degradation in the Indian Mid-Himalayas. *India Policy Forum*, 215-277.

Baldwi. (1986). *Biomass Stoves: Engineering Design, Development and Dissemination.* Arlington: VITA.

Barnes. (2010). Energy Access, Efficiency and Poverty. How Many Households are Energy Poor in Bangladesh? *World Bank Research Working Paper* , 5332.

Bensch, G., & Peters, J. (2010). *Socio-economic impacts of rural electrification in Rwanda: An ex-ante assessment of GTZ activities.* econstor.

Bhattacharyya, S. C. (2011). *Energy Economics, Concepts, Issues, Markets and Governance.* London: Springer-Verlag London Limited.

cherry, k. (2021, september 20). *How Does the Cross-Sectional Research Method Work?*

Contributor, T. t. (2021, september 14). *energy*.

Davis, M. (1998). Rural household energy consumption the effects of access to electricity evidence from. *Elsivier*, 11.

Demirel. (2012). *Energy and energy types.* Elsivier.

Evaluation, I. (August 2014). *Access to Energy in Rwanda, Impact evaluation of activities supported by the Dutch Promoting Renewable Energy Programme.* The Hague, Netherlands: Ministry of Foreign Affairs of the Netherlands.

Fournier, D. a. (2011). Poverty and Firewood Consumption: A Case Study of Rural Households in Northern China: . *China Economic Review*, 512-523.

George Kilama, Peter et Al. (2019). Quantification and characterization of cocoa pod husks for electricity generation in Uganda. *Energy, Sustainability and society*, 11.

Heltberg. (2005). Factors Determining Household Fuel Choice in Guatemala. *Development Economics*, 337-361.

Inayatullah Jan1, Humayun Khan, Shakeel Hayat. (2011). Determinants of Rural Household Energy Choices: An Example From Pakistan. *Polish Journal of Environmental Studies*, 9.

James P. Dorian,Herman T. Franssen, Dale R. Simbeck. (2005). Global challenges in energy. *Energy Policy*, 8.

Kipondya, H. a. (1993). Household Fuel Choice in Zimbabwe:An Empirical Test of the Energy Ladder Hypothesis. *Resources and Energy, 9(4),* , 347-361.

Kir. Chafe,Tord,KMichael. (2016). Energy and Human Health. *The Annual Review of Public Health*, 36.

Leach. (1992). The Energy Transition. *Energy Policy*, 116-123.

LumenCandela. (2021, july 20). *Challenges and Impacts of Energy Use.* Retrieved from lumenlearning: www.lumenlearning.com

Mazimpaka, E. (2014). Woodfuel in Rwanda: Impact on Energy, Poverty, Environment and policy instruments analysis. *Int. Journal of Renewable Energy Development (IJRED)*, 12.

Merriam-websiter. (2021, April 29). *household*.

MININFRA. (2018). *ENERGY SECTOR STRATEGIC PLAN.*Kigali: MININFRA.

NISR. (2018). *Population cencus.*National Institutue Statistics of Rwanda.

Ome, A. M. (2009). Energy use and environmental impacts: A general review. *Journal of Renewable and Sustainable Energy*, 30.

Ouedraogo, B. (2006). Household Energy Preference for Cooking in Urban Ouagadougou, BurkinaFaso. *Energy Policy, 34(18),* , 3787-3795.

Pappis, I., Howells, M., Sridharan, V., Usher, W.,Shivakumar, A., Gardumi, F., Ramos, E. (2019). *Energy projections for African countries.* Westerduinweg Netherlands: European Commission.

RDB. (2017). *Renewable energy* . Kigali.

REG. (2021, May 5). *Rwanda energy situation*.

Riahi, V. K. (2010). Determinants of household of household energy consumption in India. *energy Policy*, 14.

Samuel Bimenyimana et al. (2018). The State of the Power Sector in Rwanda. *Frontiers in energy research*, 14.

Teba, C. (2021, march 16). *energy consumption*.

Tommi Ekholm, Volker Krey, Shonali Pachauri, Keywan Riahi. (2010). Determinants of household of energy consumption in India. *Elsivier*, 14.

USAID. (2020). *POWER AFRICA FACT SHEET.* USA: USAID.

Weerahewa, R. a. (2007). Household Energy Consumption Patterns in Sri Lanka. *Srilanka Journal of Agricultural Economics*, 9(1), 55-77.

worldcounts. (2021, July 20). *Global energy consumption*.

worldometers. (2021, July 20). *Rwanda energy consumption*.

Xiaowei Ma et al. (2019). A Summary on Research of Household Energy consumption. *sustainability*, 17.

Xinpeng Xing, Jianhua Wang et al. (2019). How Energy Consumption and Pollutant Emissions affect disparity of public health in countries with high fossil energy consumption. *international journal of environmental research and public health*, 18.