UNIVERSITY OF GHANA
COLLEGE OF HUMANITIES

REGIONAL SECTORAL ELECTRICITY CONSUMPTION PATTERN IN NORTHERN GHANA: A LOGARITHMIC MEAN DIVISIA INDEX (LMDI) APPROACH ANALYSIS.

BY

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DECLARATION

I solemnly certify that this work is the result of my research. It has not been submitted for any professional certification or the reward of a degree in any university. However, all references used in the study have been fully acknowledged.

I bear sole responsibility for any shortcomings.

....
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27/06/2022
Date

CERTIFICATION

I hereby certify that this thesis was supervised in compliance with University of Ghana norms.

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27/06/2022

Date

DEDICATION

I dedicate this work to my lovely mum, Mrs. Felicia Atampugre, and Mr. Evans Rahman Kurubuni. Thank you for your love, hold-up, and encouragement throughout my life. Thank you for believing in me and supporting me financially at all times.

ACKNOWLEDGMENT

The successful completion of this thesis could not have been possible without the support of some influential and dedicated people. I would therefore wish to thank some individuals who, in different ways, have contributed to making this work a success.

First, I am thankful to the almighty God for granting me the wisdom and strength to complete this work successfully.

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LIST OF ABBREVIATIONS

EC	Energy Commission
ECG	Electricity Company of Ghana
EIA	Energy Information Administration
GDP	Gross Domestic Product
GLSS	Ghana Living Standard Survey
GRIDCO	Ghana Grid Company
GSS	Ghana Statistical Service, 2021
GWh	Gigawatt hour
IDA	Index Decomposition Approach
IEA	International Energy Agency
KWh	Kilowatt-hour
LMDI	Logarithmic Mean Divisia Index
MoE	Ministry of Energy
MiDA	Millennium Development Authority
MW	Megawatt
NEDCo	Northern Electricity Distribution Company
NITS	National Interconnected Transmission System
OECD	Organization for Economic Co-operation and Development
PURC	Public Utility Regulatory Commission
SLT	Special Load Tariff
SSA	Sub Sahara Africa
TWh	Terawatt hour

UNDP	United Nations Development Programme
UN-SDGs	United Nations Sustainable Development Goals

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ABSTRACT

Electricity consumption is an essential metric for tracking any country's economic development. As a result, knowing the methods and factors that influence this consumption is critical for energy planning and national policy development. This study, therefore, employed the LMDI method to decompose the factors that influence energy consumption into activity effect, intensity effect, and structural effect considering Northern Ghana's electricity consumption from 2016 to 2020. The results show that the activity effect strongly influences electricity consumption. Besides, the consumption dynamics in the various sectors in the regions follow the same trend as the activity effect is the major driving factor of consumption changes in the non-residential sector.

On the other hand, the intensity effect significantly drives consumption changes in the southern part of Ghana. Furthermore, the number of subscribers influences the growing trend in electricity consumption. Therefore, while the study informs policymakers on the factor(s) and the sectors driving electricity consumption changes, it is recommended the creation and awareness of electricity efficiency among households and businesses in Ghana should be heightened and sustained.

CHAPTER ONE

INTRODUCTION

1.0 Background

Electricity provision has gradually become the key focus of many countries worldwide and is one of the significant indicators of a country's development and welfare. It is a target under goal 7 of the United Nations Sustainable Development Goals (UN-SDGs). The prevalence and usage of electricity continue to increase worldwide, contributing immensely to economic prosperity. For instance, consumption within the Organization for Economic Co-operation and Development (OECD) countries increased from 48.4% in 1974 to 62.6% in 2018 (IEA, 2020). The world's total electricity consumption grew annually at an average rate of about 3.3 percent between 1974 and 2018 (International Energy Agency [IEA], 2020). The worldwide total electricity consumption as of 2018 reached 22,135 TWh showing a 4 percent increment in the 2017 figures (IEA, 2020). Electricity consumption is expected to double in the next 10 to 20 years, projecting some countries' electricity consumption to increase significantly in a year or two (IEA, 2019).

Electricity consumption in Africa is 700 TWh, with countries in North Africa and South Africa accounting for the most significant consumption (IEA, 2018). Sub-Saharan Africa (SSA) electricity consumption grows at an average annual rate of 6.5% (IEA, 2018). Except for South Africa, SSA countries account for the least of the total electricity consumed in Africa.

The IEA groups electricity consumption into residential, non-residential (commercial and public services), industrial, and transport sectors. These sectors are associated with different consumption patterns. For instance, in 2018, final electricity consumption worldwide for the industrial sector was 31.7%, becoming the highest electricity consumer, with 31.5% and 31.1% of electricity consumed by residential and non-residential (commercial and public services) sectors, respectively (IEA, 2020).

Consumption is high among households in the urban areas compared to the rural areas in most African countries. Also, the residential and non-residential sectors account for the highest electricity consumption in Africa. On the other hand, the industrial sector accounts for the minimum consumption due to the low industrialization drive of many African countries (IEA, 2018). However, an effort by developing countries to improve their industrial sectors has witnessed some significant gains hence industrial consumption of electricity from developing countries is picking momentum.

Ghana is no exception when it comes to rising electricity consumption trends. Except for the street lighting, the remaining sectors are in tandem with the IEA classification. The Residential sector consists of household electricity consumers in rural and urban regions, whereas the non-residential sector refers to services or commercial facility consumers. The industrial sector, also known as the Special Load Tariff (SLT), consists of electricity consumers for industrial purposes. The street lighting sector captures electricity consumed across the country by street lights (Kumi, 2017a). In Ghana, the industrial sector has been the highest consumer of electricity, followed by the residential sector and the non-residential, with street lighting consuming the least electricity (Energy Commission, 2020). Like many Sub-Sahara African countries, Ghana faces a rise in electricity demand due to the increased population access to electricity, culminating in the country's electricity consumption changes. The increasing electricity demand is a manifestation of the level of industrialization and growing population. The government, over the years, has made attempts to tackle electricity supply challenges to meet increasing demand. Like most countries in

Sub-Saharan Africa, the problem with Ghana's electricity demand and consumption challenges is the lack of analysis of electricity consumption changes in various sectors to guide the planning and allocation of energy resources (Kebede, Kagochi, & Jolly, 2010).

Analysis of electricity consumption in northern Ghana is integral due to the nature of development in the area. In the wake of rising urbanization, Northern Ghana has received considerable development in the area of electricity generation and consumption, spanning rural electrification projects to urban energy supply. For instance no region in Ghana recorded an electrification rate below 49% in 2010 (Ghana Statistical Service, 2012). In the year 2019, less than 70% of the population across northern Ghana had access to electricity (Ghana Statistical Service, 2019).

In recent times, urbanizing nature of northern Ghana, coupled with a successful rural electrification Programme and the rising industrialization, makes energy particularly electricity consumption analysis, a worthwhile venture. However, Gyamfi et al. (2015), in support of the need for effective energy consumption analysis indicates that most analysis, is premised on the uncertainty of rainfall and rise in demand due to rising population and development, neglecting keys variables such as interregional and inter sectoral analysis.

Therefore, understanding consumption patterns in northern Ghana is a necessary and crucial area of energy research. In this study, the analysis employs the decomposition method to examine the driving factors of sectoral consumption of electricity (Ang, 2005). The approach will aid in energy decision-making or planning to bridge different electricity consumption changes in the various sectors in Northern Ghana. Furthermore, comprehending sectoral electricity consumption factors will help design appropriate policies to influence consumption behaviors in Northern Ghana. It will also lead to the efficient and effective use of electricity and further help improve electricity distribution challenges and management in Ghana.

1.1 Problem Statement

Electricity remains a critical component of Ghana's economic growth. Electricity has contributed to human existence by delivering quality healthcare, education, transport, and many more in Ghana (Kumi, 2017b). It has therefore become almost a need for industries and households. The quest to provide sustainable electricity supply to all sectors often faces policy, reliable and valid consumption analysis for long-term planning, and generation mix investment.

The Ghana Living Standards Survey [GLSS] (Ghana Statistical Service, 2019) on regional access to electricity indicates that the southern parts of Ghana have much higher access to electricity than the northern part. Based on the survey, several studies have been conducted on electricity consumption in Ghana, with much focus on the southern or urban sector. For instance, Sakah, de la Rue du Can, Diawuo, Sedzro, & Kuhn (2019) examined the determinants of electricity consumption and appliance ownership of households in urban Ghana. However, while most analyses have focused on the southern sector, few studies have concerned consumption patterns in northern Ghana due to inadequate electricity consumption analysis. As a result, these studies do not provide a comprehensive view of the national perspectives of electricity consumption determinants and do not help with planning and resource allocation. To fill the literature gap, one or two studies have attempted to analyze electricity consumption in northern Ghana. Such studies have centered on the drivers of electricity consumption or household energy choice from the perspectives of household appliances. For instance, Abdul-hanan, Yeboah, Zakaria, & Ibrahim (2014) examined the drivers of household electricity choice in northern Ghana, particularly the West Mampurisi District. The study used household survey data and found radio, television, and tenancy type to be the driving factors of electricity consumption. Unfortunately, the scope of such studies is limited to the district level and does not include the sectoral electricity consumption; hence does not provide a complete view of the electricity consumption pattern in northern Ghana.

Also, various electricity consumption studies use data at the household level from sources like the Ghana Living Standards Survey (GLSS) data. Most studies focus on consumption drivers from cross-sectional data. Still, they do not decompose factors into separate effects that enable a proper analysis of the drivers of electricity consumption using the decomposition methods, thus the 'Laspeyres Index' and 'Divisia Index.' Electricity structure and changing consumption trend is better analyzed using LMDI to identify the influential factors of electricity consumption changes within and between each sector in northern Ghana (Hasanbeigi, Price, Fino-Chen, Lu, & Ke, 2013). Understanding the driving factors responsible for energy consumption changes, specifically in Northern Ghana, will provide an acumen about reliable sectoral consumption patterns and inform targeted energy policies dealing with demand and consumption challenges (Zhou, Liu, Zhou, & Wang, 2017).

Various studies have analyzed the different aspects of energy consumption, applying index decomposition methods to decompose factors into activity effect, structure effect, and intensity effect to explore their study. However, very few studies have focused on northern Ghana's electricity consumption pattern and the sectoral consumption of the various regions. Decomposing factors into activity, structure, and intensity effect leads to a better comprehension of changes and drivers in electricity consumption (Ang and Choi, 1997). The activity effect exposes the consumer population dynamics that influence electricity consumption. On the other hand, the structure effect reveals the nature of the activities within the various sectors, while the intensity effect accounts for each sector's electricity use per unit. For instance, a study conducted by Akrofi, Ackah, & Sakyi

(2018) analyzed the drivers of energy demand change between 2008 and 2014 using the decomposition method and found that the activity effect is the primary driver of Ghana's energy demand change. Nonetheless, the study focused on general energy demand and its contribution to Ghana's Gross Domestic Product (GDP).

In view of the advantages of using index decomposition methods and coupled with the scarcity of literature on decomposition methods in electricity consumption analysis in northern Ghana, it becomes necessary to obtain accurate and dependable data on energy consumption dynamics which provides a better view of northern Ghana's future energy landscape as the economy continues to expand with rapid development. The study results serves as a planning tool for policymakers to improve consumption in northern Ghana, which will lead to socio-economic development. In addition, the study uses the LMDI to analyze electricity consumption trends on Ghana's future electricity consumption/demand outlook to know how the increasing access to electricity in these regions is influencing consumption in the various sectors for policy formation. The study is thus significant as it influences efficient and effective electricity consumption policy in Northern Ghana.

1.2 General Objective

The study investigates factors influencing Northern Ghana's electricity consumption changes, decomposing the factors into activity effect, structure effect, and intensity effect for energy planning and national policy formulation.

The study examined the following specific objectives;

1.2.1 Objectives

1. To decompose changes in electricity consumption in Northern Ghana over the last half-decade (2016-2020) into Activity, Structure, and Intensity effect.
2. To examine the within and between electricity consumption variations among the regions in Northern Ghana (Brong Ahafo, Northern, Upper West, and Upper East region).

1.3 Research Questions

1. What is the contributing effect of the major drivers of electricity consumption (Activity, Structure, and Energy intensity) on changes in electricity consumption in Northern Ghana?
2. What accounts for the variations in the yearly electricity consumption within and between the regions in Northern Ghana?
3. What is the difference in electricity consumption patterns between Northern and Southern Ghana?

1.4 Limitations of the study

Like every other study, this study is no exception to some limitations.

The study is limited to the northern part of Ghana and the yearly electricity consumption of the various sectors for five years (2016-2020).

1.5 Significance of Study

In the current quest for economic prosperity, accurate and current research, data, and information play a critical role in decision-making by governments, policymakers, and international organizations. The study provides a blueprint for policy review and formulation by knowing and understanding the specific influence of electricity consumption changes in the various sectors of each region.

Secondly, the study helps policymakers know the impact of the factors on the overall changes in electricity consumption and the sectors responsible for electricity consumption changes in Northern Ghana. Such information will lead to the formulation of appropriate energy demand policies that foster sustainable electricity consumption. Finally, the study also adds to the literature in the area of renewable energy.

While future researchers can replicate the methodology, it serves as a reference for academia. Also, future researchers who want to venture into the field of energy will find this study very useful in the academic community.

1.6 Organization of Study

The study is organized in six chapters laid out in the following manner:

Chapter one contains the introduction to the study consisting of the background, problem statement, research objectives and questions, definition of terms, and significance of the study. Chapter two presents an overview of the energy sector in Ghana containing electricity generation, challenges, sectoral consumption, and consumer class trends over the years to guide the analysis of the study. Chapter three has a review of relevant literature on energy consumption. The literature review is consistent with the study area. A conceptual framework was developed to comprehend better the relationships between the theories employed and the research objectives. Chapter four explains the research approach and the research design that was adopted. It contains the procedures followed in collecting data and the ethical considerations upheld in the data collection. Chapter five focused on analyzing data collected and discussing findings concerning the literature reviewed. Chapter six provides a summary, conclusion, and recommendations of the study. The study further discusses the contributions and limitations of the study for future research.

1.7 Definition of Terms

Definition of terms or concepts is critical in research, as consumers may not understand concepts or words used. Defining the terms or concepts used in the study provides a broader understanding of the concept used in the study. For this purpose, the definition of several key concepts in the study are below;

Energy is the ability to do work. According to Walker (1996, p.8), "Energy is a property of matter that converts in work, heat or radiation." For this study, energy refers to electricity.

Electricity is the electrical power obtained from the conversion of energy sources, both renewable and non-renewable energy (Energy Information Administration [EIA], 2014).

Economic Growth is the rise in the economic activities of a country. According to Heller (2012), "economic growth is the process of increasing the sizes of national economies, the macro-economic indications, especially the GDP per capita, in an ascendant but not necessarily linear direction, with positive effects on the economic-social sector."

Terawatt hour (TWh) is a unit of measurement for energy representing one trillion watt-hours of power.

Gigawatt hour (GWh) is a unit of measurement for energy. It refers to current (power) measured at one billion watts per hour.

Kilowatt-hour (KWh) is a measure of energy consumed in one thousand watts per hour.

Megawatt (MW) is a unit of measurement for energy representing one million watts.

CHAPTER TWO

CONTEXT OF STUDY

2.0 Introduction

Since this research focuses on drivers of electricity consumption in various sectors, it is essential to understand the dynamics of the electricity supply chain in Ghana as an overview. Given this, chapter two of the study provides an overview of the electricity sector of Ghana. It covers the structure of the energy sector and looks at the number of electricity subscribers and electricity consumption trends for both national and Northern Ghana. The chapter also discusses the sectoral consumption trends and their development over time.

2.1 Overview of the Ghana Electricity Sector

The Electricity sector of Ghana has contributed to national economic growth and increased industrialization over the years. Due to its strategic importance, several efforts have been made over the years to ensure the country's electricity demand is met. Electricity is generated through hydro, thermal plants, and renewable sources. At the end of 2019, Ghana's electricity generation capacity stood at 5,172 MW, made up of a combination of thermal (68.6%), hydro (30.5%), and solar (0.8%) plants (Energy Commission, 2020). Despite the increased generation capacity, the electricity sector has faced some difficulties over the past years due to droughts and increased reservoir evaporation (Eshun & Amoako-Tuffour, 2016). Hydro makes up a significant portion of the total generation capacity. The country's hydro plants are also used primarily for baseload, increasing the electricity cost when hydro generation is significantly curtailed.

2.2 Structure of Ghana's Electricity Sector

A thriving energy sector of a country requires policies, institutions, and good governance driven by quality leadership to undertake suitable investment decisions. Ghana is no exception. The Ministry of Energy (MoE) oversees the energy sector's operations to monitor, evaluate, and implement policies. The ministry's mission is to increase energy distribution, particularly in rural communities and municipalities. The MoE also seeks to stimulate private sector participation in energy infrastructure development and ensure future energy supplies (Ministry of Energy, 2010).

The Energy Commission (EC) regulates the activities of the energy sector and enlightens the Energy Ministry on related energy policies. The EC's primary responsibility is to provide a legal, regulatory, and supervisory framework for energy providers in Ghana, including issuing licenses to all energy operators and formulating and enforcing performance criteria for public and private utility companies (Energy Commission, 2016). Besides establishing the EC, the Public Utility Regulatory Commission (PURC) was also found to assist the EC in formulating utility performance requirements and promoting and sustaining a healthy competitive power sector that balances the interests of utilities and consumers (Eshun & Amoako-Tuffour, 2016).

The PURC, on the other hand, is an independent regulatory agency that monitors and enforces performance standards for utility service providers and protects the interests of both consumers and providers of utility services (PURC, 2016). The PURC also regulates electricity pricing so that consumers pay fair prices for what they consume. To a large extent, their prices control the rate of electricity consumption by the consumers. Thus, these institutions serve as regulators to the players in the energy sector.

2.3 The Electricity Supply chain

Ghana's electricity sector players depict the general global electricity supply chain. The supply chain consists of Generators, Transmitters, Distributors, and Consumers. The interactions between players in the supply chain are often the result of varying sector player motives. In addition, the players are regulated by the government and its political institutions, which sometimes interfere in the supply chain process via policies and regulations. The generators, thus Volta River Authority, Bui Power Authority, and the Independent Power Producers, are responsible for producing electricity from hydropower plants, thermal power plants, and solar photovoltaic power plants. GRIDCo transmits electricity from the country's generation centers to the two prominent state-owned distribution companies, namely, the Electricity Company of Ghana (ECG) and the Northern Electricity Distribution Company (NEDCo), responsible for distributing electricity to consumers in the southern and northern parts of the country respectively (Eshun & Amoako-Tuffour, 2016). GRIDCo also exports electricity to neighboring countries through the National Interconnected Transmission System (NITS).

2.4 Electricity consumption in Ghana

Electricity consumption has over the years surged continuously due to the increased level of industrialization, population growth, and household dynamics (Asumadu-Sarkodie & Owusu, 2016). Urbanization, reconstruction of city centers, reasonably strong economic growth, and new investments, mainly in crude oil and other extractive minerals, increased electricity consumption (Millenium Development Authority [MiDA], 2012). Electricity serves as a fuel to household sustenance and a lifeline to the operations of many businesses and manufacturing firms. Total electricity consumption rose from 6,336 GWh in 2000 to 12,314 GWh in 2019, representing about 94.3% increment (Energy Commission, 2020). This translates into an annual increment of about

4.2% on average within the period, as shown in Figure 2.1. Given the national consumption data, the Ministry of Energy, Energy Commission, & UNDP (2019) estimates electricity consumption to rise to about 40,000 GWh by 2030.

Figure 2.1 shows the electricity consumption trend in Ghana from 2000 to 2019. Ghana's electricity consumption dropped sharply from 6,512 GWh in 2006 to 5,586 GWh in 2007, a loss of about 14.2 percent, before slowly increasing by an annual average rate of 5.2% till 2014 (Energy Commission, 2020). However, total electricity consumption increased by about 120% between 2007 and 2019, with a marginal decline in 2015 (Energy Commission, 2020) when the country faced a significant electricity supply shortage. Also, as shown in Figure 2.1, consumption decreased by 7.8% from 2014 to 2015 before increasing by 16.6% in 2016. The decline in consumption between 2014 and 2015 can be linked to Ghana’s yearlong power crises, negatively affecting economic development (Kumi, 2017a). It is, therefore, necessary to understand the reasons behind changes in the period. Consumption in all sectors has since risen from 2016 to date (Kumi, 2017a). Electricity consumption is herein estimated to increase by 10 percent per annum. The Energy Commission stipulates a 200 MW additional capacity annually to meet medium to long-term consumption increments (Ministry of Energy [MOE], 2019). As consumption continues to rise, the total electricity consumed does not tally with the total electricity generated, and this is due to electricity lost in the transmission and distribution channels (Kumi, 2017a). Transmission and distribution losses constitute an annual average of 21.9 percent of total power distributed (Energy Commission, 2017).

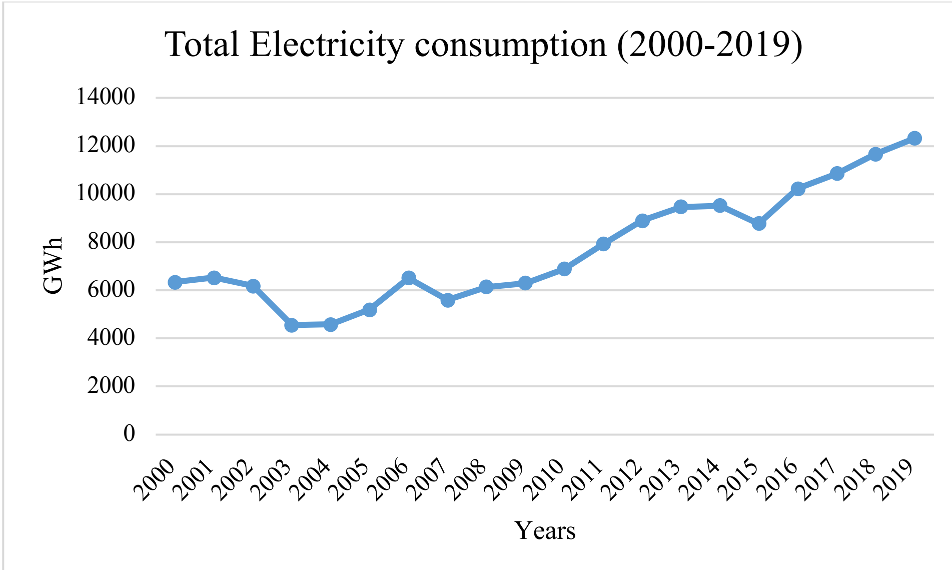


Figure 2.1: Total Electricity Consumption (National)
Source: (Energy Commission, 2020).

It must be noted that vast growth in the total electricity consumption is driven by the southern part of Ghana since significant portions of northern Ghana consist of poor households and is mostly rural-based. On the other hand, electricity consumption in the northern sector has increased due to increased subscribers (NEDCo,2013). As a result, consumption in northern Ghana grew from 60 GWh in 1990 to 1,190 GWh in 2017 (NEDCo,2019). The average annual electricity consumption for northern Ghana is; 1,115 KWh, 824 KWh, 720 KWh, and 804 KWh for Brong Ahafo, Northern region, Upper West, and Upper East, respectively (Energy Commission, 2015). Figure 2.2 shows that Brong Ahafo (48%) and the Northern region (29%) are the highest electricity consumers, followed by Upper East and Upper West, accounting for 14% and 9% of the total electricity consumed in Northern Ghana. This is because the population size and industrialization in Brong Ahafo and Northern regions are more than in the Upper East and Upper West regions. However, significant growth in electricity consumption in the northern sector is aided by improved access and rural electrification programs (MIDA, 2012).

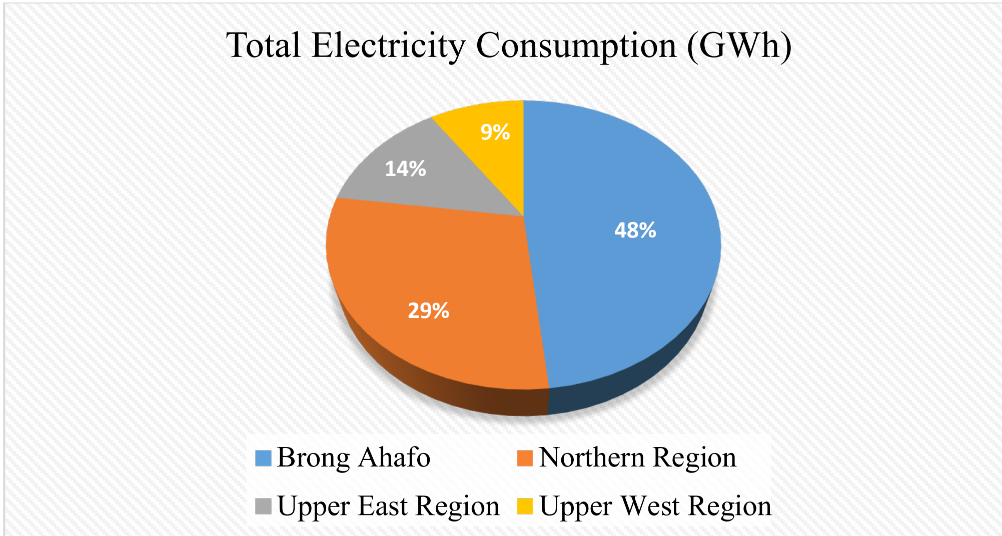


Figure 2.2: Northern Ghana Total Electricity Consumption
Source: Author with data from Energy Commission

2.5 National Sectoral Electricity Consumption

Electricity consumption is categorized in Ghana into residential, non-residential (commercial and service), special load tariff (industrial) sectors, and ‘others.’ The electricity consumption trend depicted in Figure 2.3 shows that the industrial, residential, and non-residential sectors have emerged as the country's top three electricity consumers during the last decade while ‘others’ accounts for the least (Energy Commission, 2020). Consumption by each sector increased as follows; residential (163%), non-residential (90%), and special load tariff (97%) between 2007 and 2019 (Energy Commission, 2020). Residential and special load tariff consumption declined in 2015, but non-residential usage remained steady. In 2016 and 2018, consumption in the non-residential sector also declined. From Figure 2.3, it is shown that while the special load tariff category witnessed a marginal increase in consumption between 2017 and 2018, residential electricity consumption increased significantly and was at par with the special load category in 2018 but declined in 2019. Therefore, it can be deduced from Figure 2.3 that most of the rising total consumption can be attributed to the residential and special load sectors as these continue to witness an increasing trend in consumption.

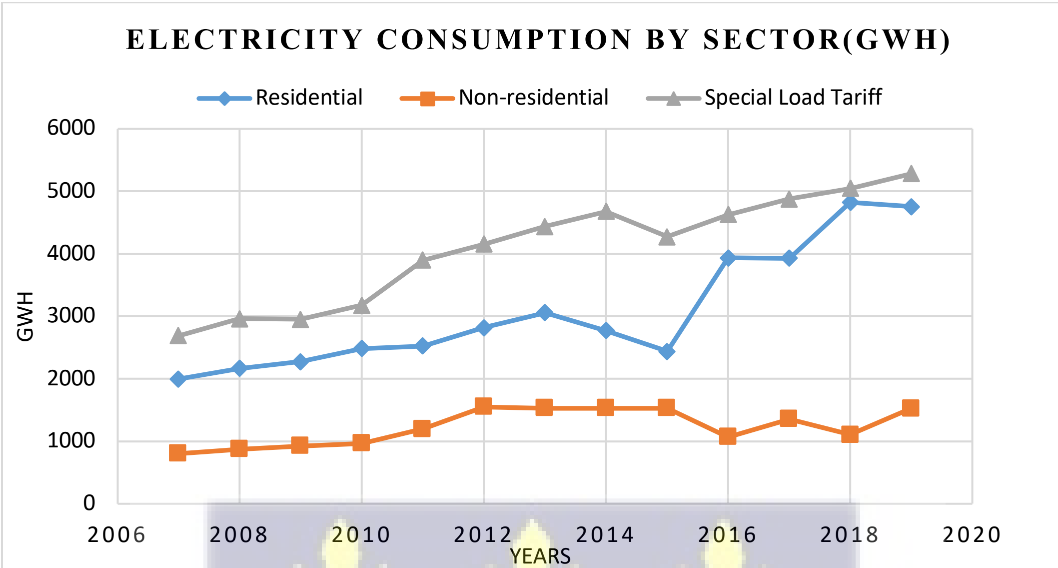


Figure 2.3: Electricity Consumption by Sector
Source: (Energy Commission, 2020)

2.6 Sectoral Consumption in Northern Ghana

Among the regions in Northern Ghana, the domestic (residential) and commercial (non-residential) sectors have been the highest electricity consumers. Out of the total 1,190 GWh of electricity consumed in Northern Ghana in 2017, the residential category accounts for 64.35 percent, the Non-residential sector accounted for 29.18 percent, while the Special Load Tariff accounts for 6.47 percent of the total electricity consumption of the total NEDCo electricity consumption (NEDCo, 2019). Due to these regions' few industries or manufacturing activities, the industrial sector is the least electricity consumption sector. However, Brong Ahafo and the northern region represent the highest electricity consumers and have the highest electricity billed for the residential, non-residential, and industrial sectors (NEDCo, 2013). From 2016 to 2018, total residential consumption for regions within the northern sector increased by about 15.9%, 5.4%, 17.6%, and 17.7% for Brong Ahafo, Northern Region, Upper East, and Upper West Region, respectively, as shown in Figure 2.4. While the non-residential sector increased by about 12%, 7.8%, 3.6%, and 8.6% for Brong Ahafo, Northern Region, Upper East, and Upper West Region, respectively, as shown in Figure 2.5. Consumption decreased in 2019 in all the regions and increased steadily in 2020 for residential and non-residential sectors.

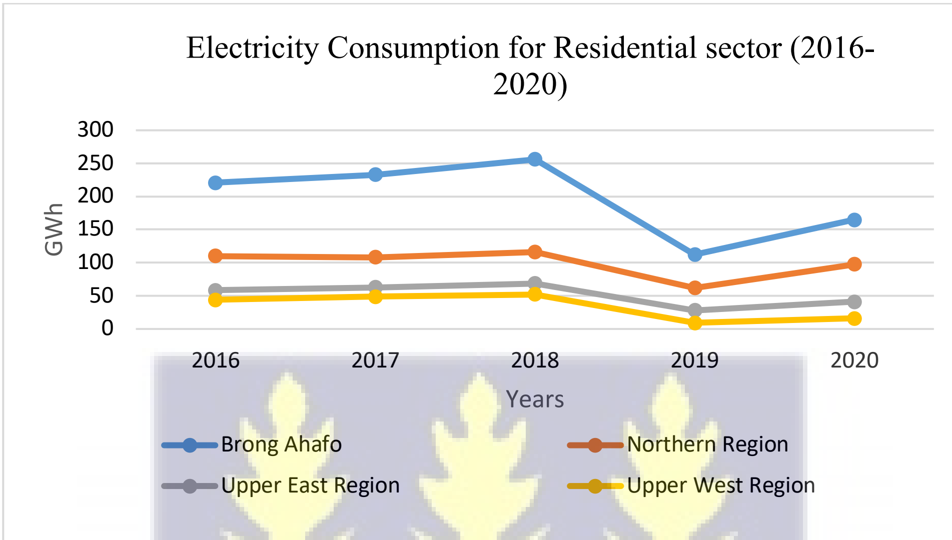


Figure 2.4: Residential Electricity Consumption in Northern Ghana.
Source: (Author with data from Energy Commission).

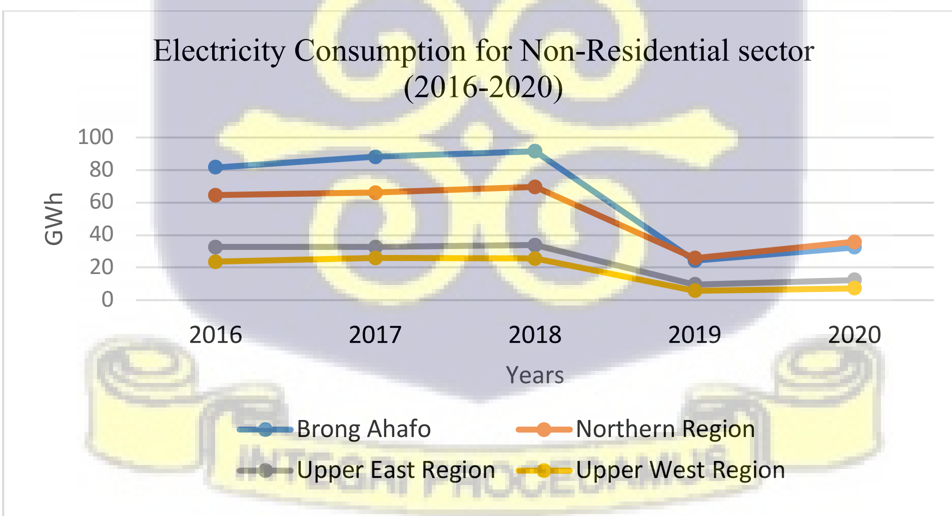


Figure 2.5: Non-Residential Electricity Consumption in Northern Ghana.
Source: (Author with data from Energy Commission).

Industrial electricity consumption grew within the period 2016 to 2020 with a growth rate of about 21.4% (Brong Ahafo), 13.4% (Northern Region), 46.1% (Upper East), and 2379.4% (Upper West Region). The large percentage change in the industrial consumption of the Upper West region of Ghana may be due to the introduction of mining activities and other emerging industrial activities in the region. However, it can also be observed from Figure 2.6 that consumption declined in the Brong Ahafo region in 2019 before increasing steadily in 2020. The steady growth in industrial consumption is good for Northern Ghana as it will lead to job creation, thereby reducing poverty levels in these regions.

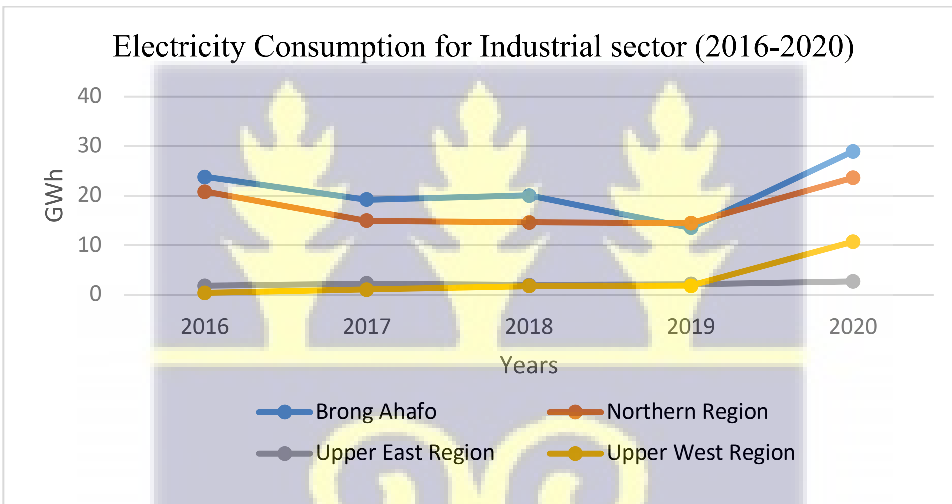


Figure 2.6: Industrial Electricity Consumption in Northern Ghana
Source: (Author with data from Energy Commission)

2.7 Consumer Population Growth Trends

The consumption trends predict the future demand and influence the investment required to drive power production. The consumption trends are also influenced by the number of consumers or subscribers and lifestyle within the sectors. In Ghana, subscribers increased from 932,598 in 2000 to 4,740,148 in 2019, with an annual growth rate of about 9% on average (Energy Commission, 2016). In terms of sectoral subscriber growth, there is high growth in the number of users in the residential sector, followed by the non-residential sector. On the other hand, the industrial (special load tariff) sector witnessed a relatively slow increment rate, as evidenced in Figure 2.7. In the period 2001 and 2019, the number of subscribers for the residential sector increased by about 486%, the non-residential sector increased by 264%, and the industrial sector increased by 111%. In 2016, the number of subscribers for the non-residential and industrial sectors declined while the number of residential subscribers decreased in 2017. However, all the sectors have since experienced steady growth in subscribers from 2017 to date.

On average, there is an annual consumer population increment of about 9.3 percent for the residential sector, 8.1 percent for non-residential, and 4.8 percent for the industrial sector between 2001 and 2019, as shown in Figure 2.7. Consumer growth in the industrial sector indicates intense industrialization, which positively influence economic growth. This shows an increment in the number of industries and commercial activities, leading to increased production and job creation. While the growth in the residential sector improves the living standards of households, it is a manifestation of the increased population access to electricity and an indication of population growth.

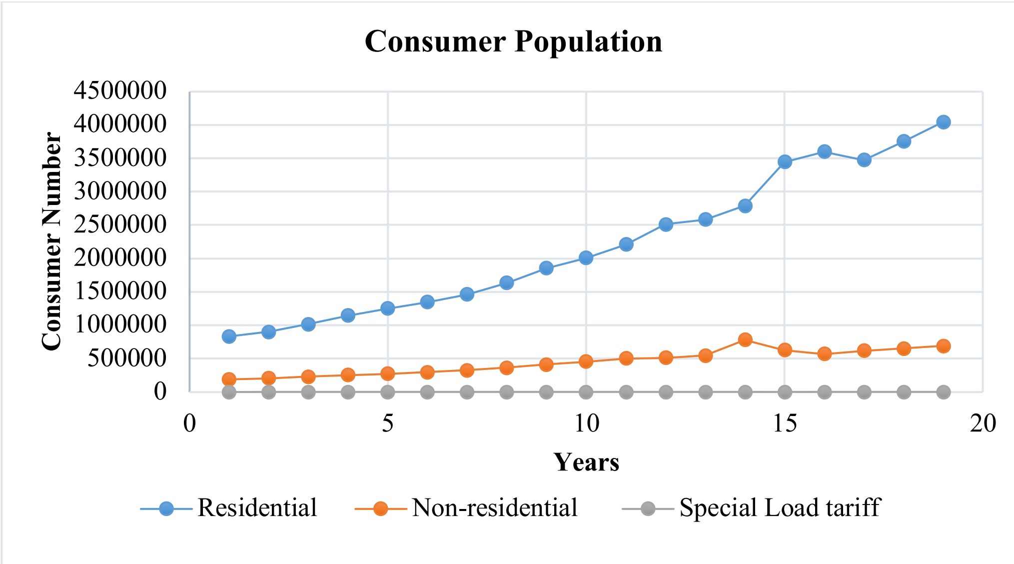


Figure 2.7: Consumer Population.
Source: Energy Commission (2020).

2.8 Electricity Consumer Growth in Northern Ghana

The number of electricity subscribers in northern Ghana has increased significantly over the years. The number of subscribers grew from less than 20,000 in 1987 to 888,023 in 2019, showing an average subscriber population growth rate of about 13 percent per annum (NEDCo, 2019), reflecting increasing population growth over the years. From Figure 8, Brong Ahafo accounts for the highest subscribers, followed by Northern Region, Upper East, and Upper West. The residential sector accounts for significant growth in the subscriber base in the northern sector. While the residential subscribers make up 81.39 percent of all customers, the non-residential customers make up 18.60 percent, and Special Load Tariff (SLT) consumers make up only 0.01 percent (NEDCo, 2019). This is a manifestation of the low level of industrialization in the northern part of the country compared to the southern sector; hence consumer growth in the northern industrial sector is low. While studies have revealed important growth trends, not much has been unearthed regarding the activities behind the growth trends.

From Figure 2.8, between 2016 to 2019, the number of subscribers for the residential sector increased by about 961% in Brong Ahafo, 826% in Northern Region, 1044% in Upper East, and 918% in Upper West. In 2020, all the regions experienced a decline in the number of subscribers in the residential sector. Figure 2.9 also reveals that the number of subscribers for the non-residential sector increased by about 959% in Brong Ahafo, 1,090% in Northern Region, 1,005% in Upper East, and 846% in Upper West between 2016 to 2019. The industrial sector in Northern Ghana has experienced growth in the number of subscribers. This indicates that industrial activities are beginning to pick up in these regions. The difference between national electricity consumption and the northern sector consumption suggests that the southern sector contributes a higher consumption level than the northern sector. This is reflected in all sectors of electricity consumption. Intuitively, the southern sector is more developed and densely populated compared to the northern sector.

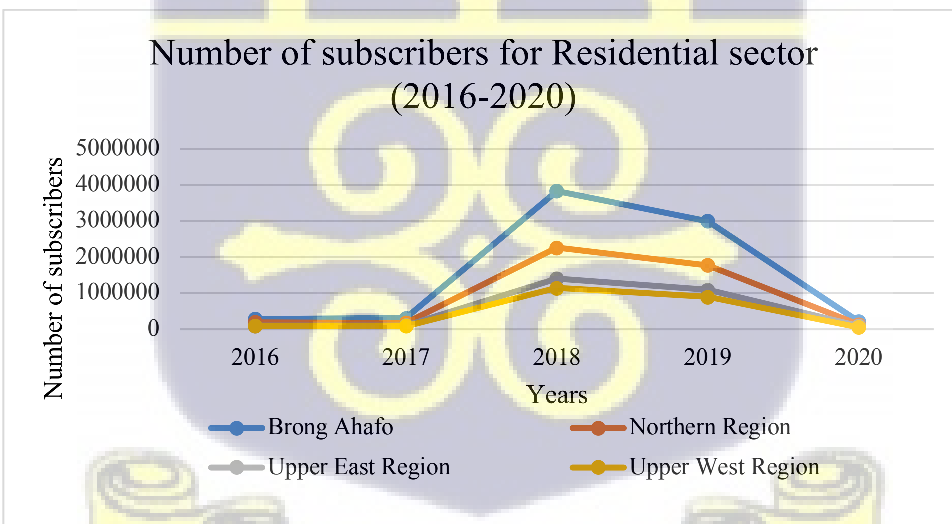


Figure 2.8: Number of subscribers for the Residential sector
Source: Author with data from Energy Commission

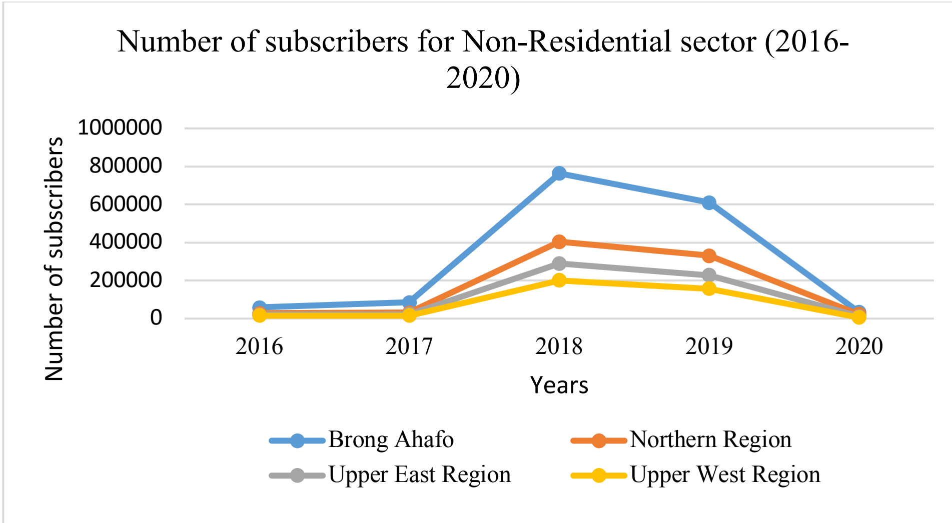


Figure 2.9: Number of subscribers for the Non-Residential sector
Source: Author with data from Energy Commission

2.9 Summary

This chapter presented an overview of the structure of the electricity sector in Ghana. It also outlined the national and sectoral electricity consumption and the subscriber population trends in Ghana and Northern Ghana. A cast at the overall electricity consumption and subscriber population changes in Ghana over the past decades reveals the importance of assessing the influential factors of electricity consumption in Northern Ghana among various sectors for appropriate electricity demand policies and optimal electricity generation.

CHAPTER THREE

LITERATURE REVIEW

3.0 Introduction

This thesis chapter deals with a literature review by analyzing the theoretical and empirical literature on electricity consumption. It contains the conceptual and theoretical framework that underpins the study, and the reviewed empirical literature is consistent with the study's objectives. It ends with an assessment of the literature. Finally, the theories are put together to create a conceptual framework.

3.1 Theoretical considerations

A theory is defined as the blueprint for a research work. It provides a structure for a research study, and also serves as an analytical and methodological approach for a study (Osanloo and Grant, 2016). As this study connects consumer and consumption trends, the study combines the theory of the consumer and the theory of the firm in providing a more comprehensive understanding of the research.

3.1.1 Consumer Theory

From the literature on microeconomics, the theory of the consumer can be understood from the analysis of demand and supply, where consumers and firms interact to produce an equilibrium. The theory expounds on the interaction between the firm and the consumer of goods and services. It further provides the conditions/laws under which consumers will behave. The law of demand provides an inverse relationship between price and quantity of goods demanded. The higher the commodity's price, the lower the quantity demanded, and vice versa, all things being equal (Schudson, 1984). One cannot forget consumer perceptions of the commodity, which may likely influence demand. For example, explaining energy dependence presupposes that consumers will consume more electricity based on the price, all things being equal.

Demand and supply of electricity, or simply electricity consumption, depends on a host of variables such as household size, price, availability, appliances used, and poverty status of the household (Soltani et al., 2019). These variables are relevant in understanding consumption trends. For instance, Poku et al. (2018) conducted a study on the energy demand scale-up in Ghana and suggested price and location as the main factor affecting energy demand.

At the national level, an essential variable in analyzing and forecasting electricity consumption trends is population growth, which contains the consumers. Malthus (2013) shares that population grows exponentially while resources grow arithmetically; hence if population growth is not checked, resources will be outstretched. Therefore, more electricity generation capacity should be installed to meet rising population growth. This is to buttress the point that the population growth rate should meet future electricity needs.

3.1.2 Theory of the firm (Resource-Based View)

The theory of the firm is fundamentally linked to the existence, boundaries, and internal organization of the firm and particularly the objectives of a firm (Seth and Thomas, 1994). The Resource-Based View (RBV) views the firm as a unit with a host of resources (Conner and Prahalad, 1996; Penrose, 1959). The resources could be physical materials (finished goods, natural resources, and land) and human resources (skilled and unskilled), as well as intangibles (capabilities) (Sanchez and Heene, 1997). On the RBV of the firm's theory, the firm's significance is in the firm's ability to produce a good at a reduced cost (Demsetz, 1988), with some resource development being long-term in nature (Dyllick & Hockerts, 2002). In applying the theory to the study, NEDCo is viewed as a firm with resources distributing electricity to consumers at a reduced cost of operation. The company has human resources and other materials.

3.2 Conceptual Framework

A conceptual framework is an analytical tool that combines and uses the various theories applied to organize ideas that help better understand the study by explaining relevant variables relating to the study (Beyer & Trice, 1982). The theories employed in the study have been put in a conceptual flow diagram to understand electricity consumption in Northern Ghana. It shows the supply chain from distribution to consumption with its mediating variables. From Figure 3.1, electricity produced is distributed by the distribution company (NEDCo) to customers in Northern Ghana, grouped into residential, non-residential, and industrial. The electricity consumption in these regions depends on the intervening variables such as activity, structure, and intensity effects. Activity effect is the basic human activities that influence the electricity consumption in a specific sector; structure effect represents the various activities undertaken within a particular sector that drive electricity consumption. The intensity effect reflects the per-unit use of electricity for a specific activity (Trotta, 2020). An increase or decrease in any intervening variable has a corresponding effect on electricity consumed. The production of electricity coupled with its consumption turn to impact the economic growth considering the key influence energy has on economic growth. When industries and other electricity consumers increase their productivity, demand for electricity increases, leading to a rise in economic development and vice versa.

Conceptual Framework

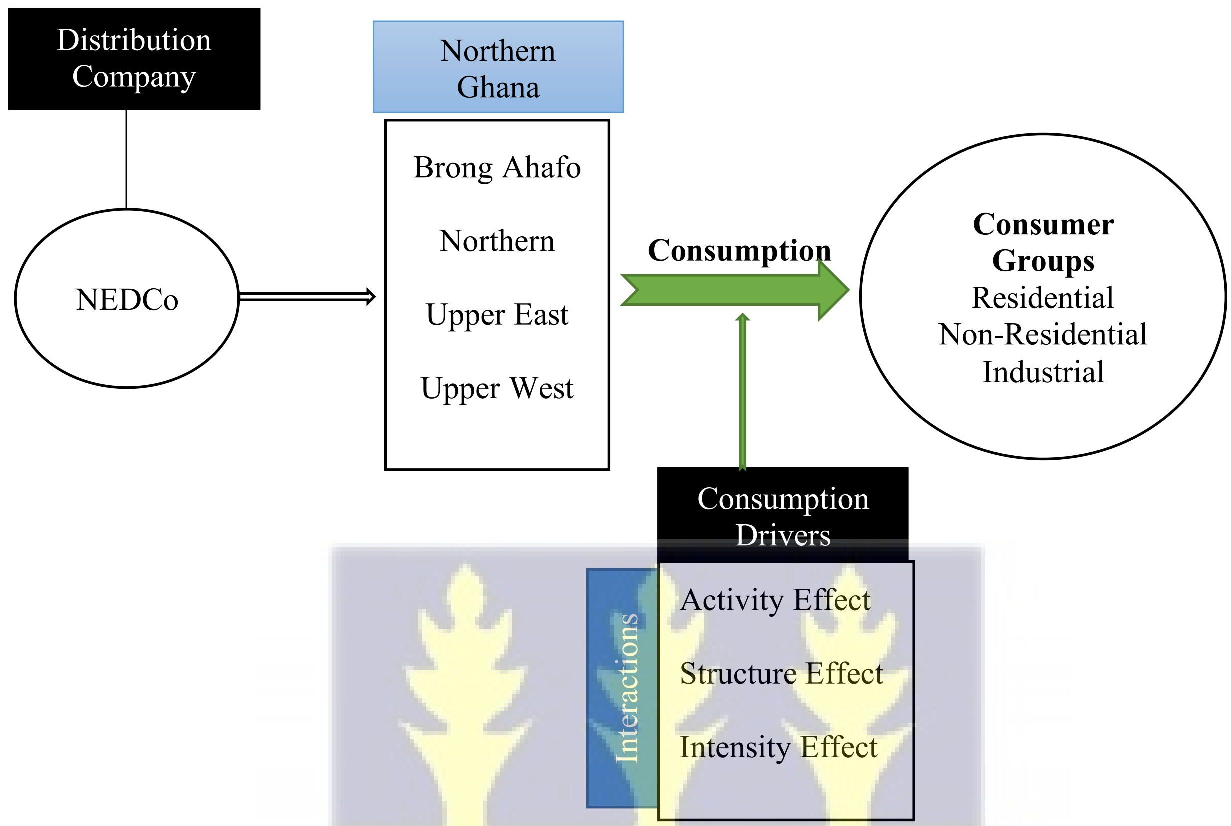


Figure 3.1: Conceptual Framework

Source: Author Construction

3.3 Review of Relevant empirical literature

Electricity has become an integral life ingredient and has gained much attention from researchers and policymakers. Over the past years, researchers have delved into assessing the sustainable electricity supply of countries relative to the specific targets under the Sustainable Development Goals. The aim is to provide adequate and reliable information for countries to assess the performance of policies in the energy sector. The United Nations and World Bank reports have become an annual activity that helps evaluate and rank countries' energy sector performance. In addition, several other independent institutions and researchers have contributed significantly to knowledge in energy. The proceeding paragraphs detail the relevant literature review.

3.3.1 Sectoral Electricity Consumption

In energy consumption analysis, it is imperative to understand the consumption pattern of the various sectors considering their contributions to a country's development. However, very few studies have attempted to delve into the sectoral analysis of electricity consumption dynamics, especially in Ghana. This is because the nature and consumption trends of electricity vary between and within sectors. Enu (2014) estimated the sectoral impact of electricity consumption in the Ghanaian economy using the Ordinary Least Squares (OLS) method. Population, the size of the Ghanaian economy, foreign inflows, the general price level, and trade influenced sectoral electricity consumption (Enu, 2014). Other factors that contribute to an increase in electricity demand include rapid urbanization, economic growth, and government flagship policies such as rural electrification projects (Nejat, Jomehzadeh, Taheri, Gohari, & Majid, 2015).

Electricity demand in the residential sector is influenced by improved modern access to electricity (Mikhail, Gallego-schmid, Stamford, & Azapagic, 2020). Nonetheless, the electricity consumption of various sectors may be driven by varying factors depending on the jurisdiction. Chen (2017) examined the factors affecting electricity consumption and the consumption characteristics in the residential sectors in Taiwan using two approaches, a socio-economic perspective, and a direct use perspective. First, the study's findings showed that GDP, employment rates, residential space, and the implementation of energy labeling schemes affected residential electricity consumption, notwithstanding the effect of electricity price and energy efficiency standards on residential electricity consumption. Secondly, home appliances such as air conditioners, refrigerators, and rice cookers accounted for high residential electricity consumption. In support, a study by Diawuo, Sakah, Pina, Baptista, & Silva (2019) on disaggregating and characterizing residential electricity demand using scenarios to test the electricity end-use between 2015 to 2050, applying a bottom-up approach based on a stock accounting model and a technological-based top-down approach. The study results indicate that lighting technology and seven other appliances, namely refrigerator, air conditioner, television, freezer, fan, electric iron, and washing machine, accounted for about 93% of residential electricity consumption in 2015 and are further estimated to represent 90% share of residential electricity consumption by 2050. The increased use of home appliances by households increases the amount of electricity consumed.

In the last couple of decades in the European Union, electricity consumption in the non-residential sector has contributed immensely to the overall consumption level (Gutiérrez-Pedrero, Tarancón, del Río, & Alcántara, 2018). Gutiérrez-Pedrero, Tarancón, del Río, & Alcántara (2018) examined factors affecting non-residential electricity consumption intensity in Europe and found that a higher degree of technological progress in the production systems and higher retail prices of electricity reduced the electricity intensity, whereas the stock of physical capital and the lagged gross fixed capital formation increased electricity intensity.

Non-residential electricity consumption varies among countries due to the nature and number of service and production activities in a country. The use of electricity for street lighting also helps reduce crime and ensures the safety of citizenry at night, in effect reducing the crime rate (Welsh & Farrington, 2008).

3.3.2 Rural and Urban Electricity Consumption

Electricity in both rural and urban regions improves the quality of life significantly. Access to electricity at the household level can impact the lighting quality, economic development, and increase income in the long term (Van de Walle, Ravallion, Mendiratta, & Koolwal, 2017). Due to the increased access to electricity over the years, consumption has also increased significantly. On the international front, rural and urban sector electricity consumption is a widely studied area. A large body of literature that has recently studied electricity consumption drivers in the rural and urban sectors includes a study by Agrawal, Harish, Mahajan, Thomas, & Urpelainen (2020) on the influence of improved supply on household electricity consumption in rural India. The study analyzed rural electricity consumption in 200 villages in four Indian states. The Tobit model was employed to investigate the determinants of consumption. Findings of the study indicate that every 1 percent increase in supply hours increases consumption in rural India by 1.245 percent, showing a positive influence of improved supply on rural electricity consumption. Studies on rural and urban electricity consumption determinants among other countries are; Tesfamichael, Bastille, & Leach (2020), Roth, Yildiz, & Lowitzsch (2021), Conevska & Urpelainen, J. (2020), Nie, Kemp, Xu, Vasseur, & Fan (2016), Yoshida et al. (2020), as well as Jones & Lomas (2016). These studies examined the drivers of rural and urban electricity consumption. Although their findings may vary, the common factors revealed from their studies include; price, income, and population are among the factors influencing electricity consumption.

Ghana's electricity consumption in both rural and urban settings varies based on several factors. It is expected that consumption in the rural areas will be lower than those in the urban centers. But with the government policy and intervention in rural electrification, many rural areas are connected to the national grid; hence the gap in electricity access between rural and urban will not be wide.

Kemaeusuor & Ackom (2017), in a review paper on electrification in Ghana, found urban areas to have more access to electricity than rural areas. Also, it is indicated that in Ghana, electricity access in the urban areas is about 27 percent more than in the rural areas (World Bank, 2018). However, access to electricity in these areas has a significant positive effect on economic development (Rehman, Deyuan, Chandio, & Hussain, 2018). Studies have attempted to analyze the impact of increased electricity access on development in both rural and urban areas. For instance, Kankam & Boon (2009) studied the dynamics of energy delivery and utilization and examined the extent to which energy consumption patterns contribute to rural development. The study was conducted based on a survey in some selected rural communities in Northern Ghana. Findings suggest that lighting services improve conditions for education at communities and household levels due to energy use. Secondly, surveyed communities reveal that energy use patterns inhibit job creation, gender goals, and health care in rural Ghana (Kankam & Boon, 2009). Also, Riva, Ahlborg, Hartvigsson, Pachauri, & Colombo (2018) revealed in a study that electricity access in rural areas interconnects with socio-economic development in areas such as education, population, health, market production, income generation, etc. In the urban areas. Since access to electricity has proven to be a contributor to the development of a nation, several other studies have delved into analyzing the impact of electricity access on some sectors of the economy, such as Baafra Abeberese (2020) and confirms the positive impact of electricity access on some economic sectors.

Growth in electricity consumption in the urban sectors is attributed to appliance ownership and electricity consumption capacity (Gyamfi, Modjinou, & Djordjevic, 2015). The urban sector accommodates about 55 percent of the total population and consumes about 70 percent of the total electricity supply for the residential sector (Gyamfi et al., 2015; World Bank, 2017). Household appliance ownership continues to increase electricity consumption in the urban sector. The Ghana energy survey indicates that the average annual electricity consumed by households in the urban locality is 1200 KWh and 880 KWh in the rural locality (Energy Commission, 2015). Sakah, de la Rue du Can, Diawuo, Sedzro, & Kuhn (2019) conducted a study using residential electricity consumption survey (RECS) combined with electricity end-use to monitor 60 households in Tema. The study further used multiple linear regression to analyze the statistical significance of electricity consumption indicators. The study shows that ownership of appliances such as air conditioners, freezers, fans, refrigerators, and television shows high statistical significance in households' total electricity consumption and socio-economic changes such as income, household size, and floor space (Sakah et al., 2019).

Abdul-hanan, Yeboah, Zakaria, & Ibrahim (2014) also analyzed the drivers of household electricity choice in Northern Ghana, particularly the West Mampurisi District of Ghana, using household survey data. Data were obtained from 295 households for the study. The Probit model revealed that tenancy type, radio, TV and fridge ownership, perception about electricity, duration, and cost of electricity use were among the factors that positively influenced household electricity choice in Northern Ghana. Series of other studies have used similar methodologies to estimate household appliance ownership and socio-economic factors as the determinants of urban and rural areas' electricity consumption. These include Gyamfi et al. (2018), Dash (2015), and Diawuo, Pina, Baptista, and Silva (2018).

It can be concluded that electricity consumption from the literature is driven by a host of factors such as household size, income, ownership of appliances, and the space occupied with the domestic electricity consumption. From literature, consumption analysis has often not been holistic as they do not encompass rural and urban sectoral analysis but focus on national consumption. Therefore, it is beneficial to understand the driving factors of electricity consumption in the various categories to help plan and allocate energy resources to meet the constant need as the economy expands.

3.3.3 Index Decomposition Method

The index decomposition method is very applicable in areas like energy. This method is used to break down factors into different effects. Several decomposition methods have been developed from the Index Decomposition Analysis (IDA) framework. The Laspeyres, Paasche, and Marshall-Edgeworth indices were the earlier methods proposed, and later new methods were also developed based on Divisia indexes. For example, Ang and Choi (1997) developed the logarithmic mean Divisia method (LMDI) approach, an improved version of the classical Divisia index methods. This approach investigates diverse driving factors and harmonized environmental side effects, especially in the energy sector (Ang and Choi, 1997). Among the numerous studies conducted using the LMDI approach include are Achão and Schaeffer (2009) on the analysis of the residential electricity consumption in Brazil from 1980 to 2007 (Praene, Rasamoelina & Ayagapin, 2021). The study's findings showed that activity and intensity effect were the two main factors influencing the variation in residential electricity consumption. Chung, Kam, & Ip (2011) also studied the changes in energy use in the residential sector of Hong Kong between 1990 and 2007 using decomposition analysis. Findings revealed increase in the number of households (activity effect) to be the major contributor and the intensity effect as the second contributor to changes in residential energy use.

Over the last decade, the LMDI approach has become the most popular method used among researchers due to its theoretical and practical advantages demonstrated by Ang et al. (1998). A comprehensive review of studies by Li, Shen, & Zhang (2015), Fernández González (2015), Fernández González, Landajo, & Presno (2014), Robaina-Alves & Moutinho (2014) made use of the LMDI approach in their study to analyzed Greenhouse Gas (GHG) emissions. The numerous use of the LMDI approach to analysis in the energy sector regarding consumption implies the effectiveness or otherwise relevance of the approach. For example, Ang, Huang, & Mu (2009) shared that the method assigns the effects to some predefined factors and decomposes the changes into an aggregate indicator. Similarly, Kim (2017) confirms the benefits of the LMDI approach by indicating that it meets the factor-reversal test and leaves no residual term unexplained. The approach also provides a detailed analysis of the driving forces behind energy consumption from different dimensions.

Although using LMDI provides accurate results, combining it with sensitivity analysis better understands the stipulated results. For instance, Olanrewaju, Jimoh, & Kholopane (2012) assessed and optimized energy consumption in industrial sectors using the LMDI method, combining it with other methods such as sensitivity analysis and neural networks analysis. In their study, LMDI was used to decompose the data on energy consumption into activity, structure, and intensity effects, using them as inputs for the neural networks to measure the actual energy consumption and the corresponding expected energy consumption. The sensitivity analysis was then used to determine the estimated energy consumption and its optimization using the measure-specific and super-efficient DEA model. The activity effect was the primary driver accounting for the substantial growth in energy consumption (Olanrewaju et al., 2012).

Furthermore, other more recent works have used the LMDI approach to decompose factors influencing energy consumption and wind energy production (Lu, McElroy, Peng, Liu, Nielsen,

& Wang, 2016). Nonetheless, in Ghana, limited studies have employed this method in analyzing energy consumption patterns. For instance, Akrofi, Ackah, & Sakyi (2018) decomposed Ghana's energy demand and identified activity effect as the primary driver of change in energy consumption in Ghana using the Laspeyres decomposition method.

It is revealed from the literature that most papers applying this approach have often focused on Greenhouse Gas emissions and energy consumption from a residential perspective, neglecting the service and industry sector. Research on greenhouse gas emissions and energy consumption in Africa using LMDI approaches abound but not much on electricity consumption.

3.4 Summary

The Chapter outlined the theory of consumer and firm as well as the conceptual framework. It also presents reviewed papers on the logarithmic mean Divisia index (LMDI) method. In addition, a review of sectoral electricity consumption and rural and urban electricity consumption drivers in Ghana were also presented in the chapter. The literature reviewed provides vital insights into electricity consumption parameters.

CHAPTER FOUR

METHODOLOGY

4.0 Introduction

This chapter discusses the methodology employed in the study. It presents the proposed Logarithmic Mean Divisia Index (LMDI) approach used to achieve the study objectives. The chapter covers the description of the LMDI approach, the general formulation procedures employed, and the empirical method specification. Also, the research design, source of data, and data collection procedures used in the study are discussed in this chapter.

4.1 Research Design

Research design is an integral part of every research. This refers to the type of research style used in the study. This study employs the quantitative method approach to ascertain the factors influencing electricity consumption changes over time in northern Ghana using the Logarithmic Mean Divisia Index (LMDI).

4.1.1 Source of Data and Data Collection

The electricity consumption data for each sector, including the subscriber data between 2016 and 2020 for northern Ghana, was obtained and used as inputs for the analysis. The specific regions studied in this research are Brong Ahafo, Upper East, Upper West, and Northern region, all of which fall under the Northern Electricity Distribution Company (NEDCo), the body in charge of electricity supply to the northern part of Ghana. Electricity consumers in northern Ghana are divided into three sectors, namely, residential, non-residential, industrial (special load tariff). The special load tariff is further broken down into; low voltage, medium voltage, and high voltage depending on the amount of electricity consumed. Electricity consumption data covering the four

(4) regions in the northern part of Ghana between 2016 and 2020 were obtained from the Energy Commission of Ghana(Energy Commission, 2020). Similar data was used by Akrofi, Ackah, & Sakyi (2018). The data is quantitative and continuous in nature.

4.1.2 Index Decomposition Approach (IDA)

Many energy analysts use the decomposition method to examine the contribution of change of different factors of energy indicators. Index Decomposition Approach (IDA) is the principal technique for studying and quantifying the drivers of changes in aggregate energy consumption (see, for instance, Boyd et al., 1987; Reitler, Rudolph, and Schaefer, 1987; Ang, 1995; Xu, and Ang, 2013). IDA is the widely accepted decomposition tool for policymaking at the national level due to its flexibility of adoption and ease of use (Ang, 2004). The index decomposition methods helps to obtain accurate and reliable results for energy policy planning and aids in the understanding of energy consumption drivers as well as monitoring and measuring performances of policies relating to energy (Ang, Zhang & Choi, 1998). The “Laspeyres index" and the "Divisia index" are researchers' most commonly used decomposition methods. However, the residual values of decomposition are identified to be the major problem with the “Laspeyres index" methods (Ang et al., 1998). In addressing this problem, the Logarithmic Mean Divisia Index (LMDI), which uses the logarithmic mean and Divisia index, as proposed by Ang, Zhang & Choi (1998), Ang & Liu, (2007) and employed by Praene, Rasamoelina & Ayagapin, (2021) in the analysis of electricity consumption in Madagascar. A significant attribute of the LMDI method compared to the other decomposition methods is that the LMDI method leaves no residual term, which may affect the results and interpretations of the study (Ang, 2004). Due to its theoretical foundation, good adaptability, and results interpretation over other methods, LMDI has become the most used method for analyzing energy situations (Zhao, Tan, Zhang, Ji, Liu, & Yu, 2010).

This method can be applied in diverse fields such as construction, agriculture, transportation, industrial and residential sector, etc. Nonetheless, the scope and nature of the study informs the type and nature of variables used.

4.1.3 Logarithmic Mean Divisia Index (LMDI)

The Logarithmic Mean Divisia Index (LMDI) method decomposes electricity consumption into activity, structure, and intensity effects. LMDI-I and LMDI-II are the two variants of the LMDI method. However, the weighting formulae used for each variant differ, although they produce roughly similar results (Ang, 2005). For this study, LMDI-I formulation was employed since it is easier to implement (Ang, 2015). There are two categories of LMDI decomposition. The Additive Decomposition expresses results in terms of quantity, and the Multiplicative Decomposition describes results by intensity indicators. However, both types produce the same results, but the multiplicative decomposition approach has the advantage of not worrying about units and focusing on change.

Formulation Procedure

The formulation is adopted from Praene, Rasamoelina & Ayagapin (2021) and is stated below.

Total electricity consumption is represented by "E." Let different sector categories be represented by the index "i" and the reference time represented by j, where j = 0 (at time 0) and j = T (at time T).

It is assumed E is an aggregate composed of three factors, namely Activity, Structural, and Intensity, so that variation in "E" is quantified by evaluating the impacts of the following effects:

- Overall Activity effect, denoted by Q is determined by the number of subscribers.

  Where Q = total number of electricity subscribers or customers and Qi is the activity level of sector i, which is the number of subscribers of each sector.

- The structural effect, denoted by S which is determined by the percentage of subscribers by sector. Structure of each sector, Si = Qi / Q

- Per subscriber, the electricity consumption determines the intensity effect, denoted by I. Intensity effect of each sector, Ii = Ei / Qi. Where, Ei = electricity consumption per sector

From the works of Ang (2005) and Ang (2015), the LMDI approach is described by the following equations;

Total electricity consumption;

$$E = \sum_i E_i = \sum_i Q \frac{Q_i}{Q} \frac{E_i}{Q_i} = \sum_i Q S_i I_i$$

A change in E (from period 0 to T) can be decomposed into the factors using either the additive or multiplicative decomposition approach.

For Additive decomposition:

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

Activity Effect $(\Delta E_{act}) = \exp\left[\sum_i w_i \ln\left[\frac{Q^T}{Q^0}\right]\right]$

$$= \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln\left[\frac{Q^T}{Q^0}\right]$$

Structure Effect $(\Delta E_{str}) = \exp\left[\sum_i w_i \ln\left[\frac{S^T}{S^0}\right]\right]$

$$= \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln\left[\frac{S^T}{S^0}\right]$$

Intensity Effect $(\Delta E_{int}) = \exp\left[\sum_i w_i \ln\left[\frac{I^T}{I^0}\right]\right]$

$$= \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln\left[\frac{I^T}{I^0}\right]$$

$$\text{where}, w_i = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0}$$

Multiplicative decomposition:

$D_{tot} = \frac{E^T}{E^0} = D_{act}.D_{str}.D_{int}$

Activity Effect $(D_{act}) = \exp\left[\sum_i w_i \ln\left[\frac{Q^T}{Q^0}\right]\right]$

$$= \sum_i \frac{(E_i^T - E_i^0)/(\ln E_i^T - \ln E_i^0)}{(E^T - E^0)/(\ln E^T - \ln E^0)} \ln\left[\frac{Q^T}{Q^0}\right]$$

Structure Effect $(D_{stru}) = \exp\left[\sum_i w_i \ln\left[\frac{S^T}{S^0}\right]\right]$

$$= \sum_i \frac{(E_i^T - E_i^0)/(\ln E_i^T - \ln E_i^0)}{(E^T - E^0)/(\ln E^T - \ln E^0)} \ln\left[\frac{S^T}{S^0}\right]$$

Intensity Effect $(D_{int}) = \exp\left[\sum_i w_i \ln\left[\frac{I^T}{I^0}\right]\right]$

$$= \sum_i \frac{(E_i^T - E_i^0)/(\ln E_i^T - \ln E_i^0)}{(E^T - E^0)/(\ln E^T - \ln E^0)} \ln\left[\frac{I^T}{I^0}\right]$$

$$\text{where}, w_i = \sum_i \frac{(E_i^T - E_i^0)/(\ln E_i^T - \ln E_i^0)}{(E^T - E^0)/(\ln E^T - \ln E^0)}$$

The difference between the two decompositions is that all the effects are summed up under the additive decomposition, while the multiplicative decomposition is the product of all the effects. The LMDI is used to identify the driving effects of electricity consumption changes in northern Ghana from 2016 to 2020. A time series decomposition approach is used to conduct the LMDI decomposition analysis. In other words, the period of analysis uses the LMDI decomposition equation applying it to each pair of the year being reviewed. Using the time series decomposition approach provides accurate visualization and interpretation of the influencing factors on the decomposed data (Steenhof, 2006). The year of reference is dynamic.

CHAPTER FIVE

DATA PRESENTATION, ANALYSIS, AND DISCUSSION

5.0 Introduction

This chapter employed the Logarithmic Mean Divisia Index (LMDI) method to decompose electricity consumption changes in Northern Ghana. The decomposed analysis covered activity, intensity, and structural effect. In this chapter, presentation of the data used in the study is outlined. The analysis further includes residential, non-residential, and industrial contributions to electricity consumption changes. The chapter is organized according to the study's objectives and findings discussed alongside the southern sector electricity consumption findings for policy planning and management. The chapter starts with analysis of electricity consumption within each of the regions in the northern sector covering the activity, intensity, and structural effect. This is followed by consumption analysis between and within the regions and finally, concludes with a sectoral comparative analysis between northern and southern Ghana.

5.1 Data Presentation

5.1.1 Electricity Consumption

Table 5.1 presents the electricity consumption data used for residential, non-residential, and industrial analysis for all the regions in northern Ghana from 2016 to 2020.

Table 5.1: Northern Ghana Electricity Consumption Data (GWh)

		Region			
Year	**Sector**	**Brong Ahafo**	**Northern Area**	**Upper East Area**	**Upper West Area**
2016	Residential	220.88	110.17	58.26	44.09
	Non-Residential	81.68	64.56	32.73	23.49
	Industrial	23.84	20.83	1.88	0.43
2017	Residential	232.85	108.30	62.93	48.72
	Non-Residential	88.05	66.11	32.72	25.94
	Industrial	19.22	14.95	2.30	1.08
2018	Residential	256.00	116.14	68.50	51.92
	Non-Residential	91.50	69.64	33.91	25.52
	Industrial	20.05	14.67	2.01	1.83
2019	Residential	112.24	61.93	27.92	9.33
	Non-Residential	24.27	25.76	9.54	5.73
	Industrial	13.52	14.46	2.16	1.84
2020	Residential	164.77	97.68	41.25	15.92
	Non-Residential	32.46	35.78	12.40	7.25
	Industrial	28.95	23.62	2.74	10.73

Source: Energy Commission (2020)

5.1.2 Number of Electricity Customers in Northern Ghana

The number of customers for each sector in each region in northern Ghana is represented in Table 5.2.

Table 5.2: Number of Customers in Northern Ghana

		Region			
Year	**Region**	**Brong Ahafo**	**Northern Area**	**Upper East Area**	**Upper West Area**
2016	Residential	282195	191342	95681	88345
	Non-Residential	57497	27727	20671	16535
	Industrial	27	8	9	5
2017	Residential	309319	176248	108907	92809
	Non-Residential	84497	31188	22416	16517
	Industrial	29	7	18	6388
2018	Residential	3829868	2264554	1404605	1148555
	Non-Residential	763271	404191	289550	200188
	Industrial	427	96	239	166
2019	Residential	2995929	1772186	1095333	899606
	Non-Residential	609298	330170	228529	156570
	Industrial	369	99	195	125
2020	Residential	4207975	2311667	1463397	1025114
	Non-Residential	830392	411144	278705	139512
	Industrial	433	163	397	116

Source: Energy Commission (2020)

5.1.3 National Electricity consumption

Table 5.3 presents the national electricity consumption (GWh) data used for the study from 2000 to 2019. Data for residential and non-residential is presented in graphs. Figures 5.4 and 5.5 provide the trends in the data.

Table 5.3: Electricity Consumption (GWh)

Year	Residential	Non-residential	Special Load Tariff	Total
2000	1464	551	4305	6320
2001	1594	580	4337	6510
2002	1648	602	3903	6154
2003	1696	620	2206	4521
2004	1798	660	2086	4543
2005	1905	676	2559	5140
2006	2022	790	3592	6404
2007	1996	802	2687	5485
2008	2168	876	2963	6007
2009	2275	924	2951	6150
2010	2483	966	3174	6623
2011	2527	1199	3901	7627
2012	2819	1549	4153	8521
2013	3060	1532	4435	9026
2014	2772	1529	4680	8980
2015	2436	1531	4274	8240
2016	3932	1068	4626	9627
2017	3931	1356	4880	10168
2018	4824	1103	5046	10973
2019	4755	1523	5282	11559

Source: Energy Commission (2020)

Figure 5.1 shows the trends in residential consumption of electricity. Residential consumption has been on the increase from the year 2000 up to the year 2013. However, a massive decline in consumption occurred in 2014-2015, a period that coincides with Ghana's power crisis. After 2016, consumption began to peak ad became stable between 2018-2019.

For the non-residential sector consumption as found in figure 5.2, it can be observed that the sector experienced similar trends like the residential sector up to the year 2013, with a slight decline between 2013 to 2015. Between 2016 to 2019, there have been inconsistent consumption trends with 2019 having a higher consumption.

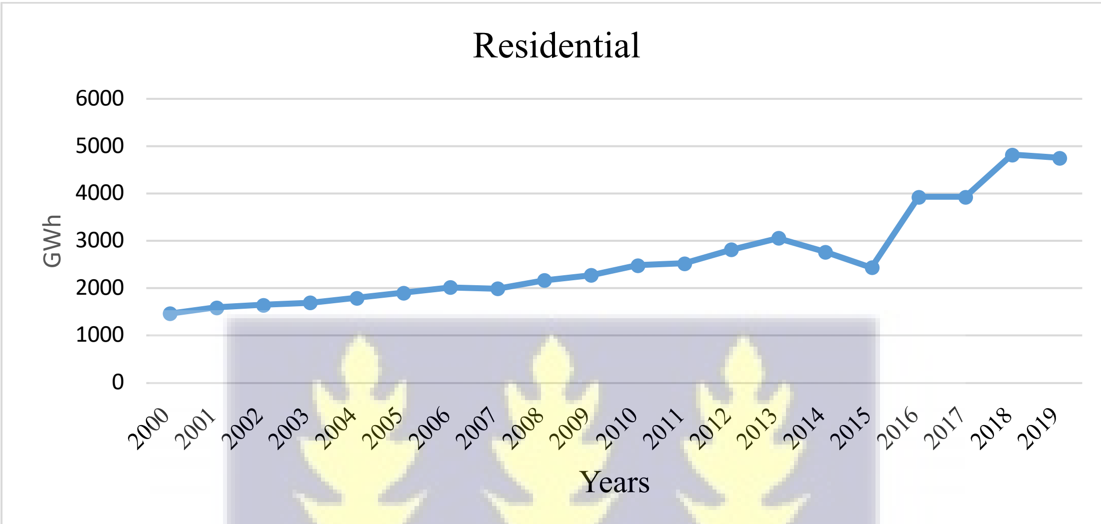


Figure 5.1: Electricity Consumption (GWh) for Residential
Source: Author with data from Energy Commission (2020)

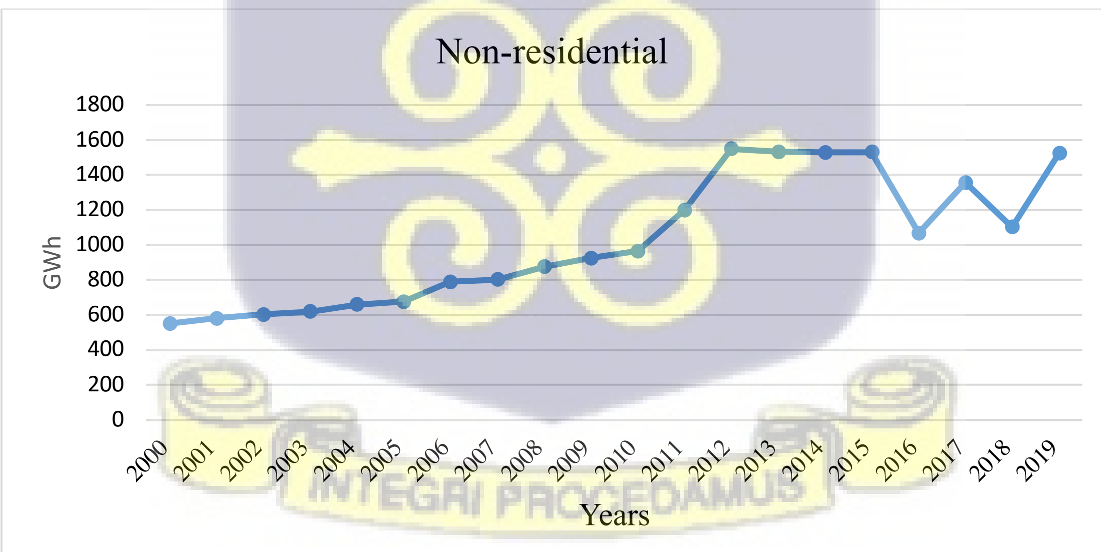


Figure 5.2: Electricity Consumption (GWh) for non-residential sectors
Source: Author with data from Energy Commission (2020)

Table 5.4 contains data on consumer population used for the study. The data for the residential and non-residential sector consumers are also presented in Figures 5.3 and 5.4.

Table 5.4: Customer Population

Year	Residential	Non-residential	Special Load tariff	Total
2000	758558	173245	795	932598
2001	832212	189807	828	1022847
2002	902815	205687	855	1109357
2003	1014404	230651	880	1245935
2004	1146016	253340	902	1400258
2005	1253330	272442	964	1526736
2006	1347067	295703	1016	1643786
2007	1463679	328511	1055	1793245
2008	1634407	365844	1157	2001408
2009	1856962	413634	1233	2271829
2010	2006972	454430	1369	2462771
2011	2209957	505447	1481	2716885
2012	2511208	514492	1647	3027347
2013	2582294	545665	1882	3129841
2014	2789913	779780	2034	3571727
2015	3445423	630518	2115	4078056
2016	3600185	568473	1438	4170096
2017	3477300	619255	1494	4098049
2018	3753138	652716	1544	4407398
2019	4046358	692046	1744	4740148

Source: Energy Commission (2020)

Figure 5.3 shows a rising trend in the non-residential consumer population between 1995 to 2014 where the population was at its highest peak. There was a massive decline in the non-residential population between 2015 and 2016 but afterward, steadily increased until 2020. The residential sector consumers provide similar trends from figure 5.4 with a slight decline in 2013 and 2017. The decline in both the residential and non-residential consumers also coincides with Ghana's power crisis period between 2013 through to late 2016, as such consumers might have switched to other sources of power.

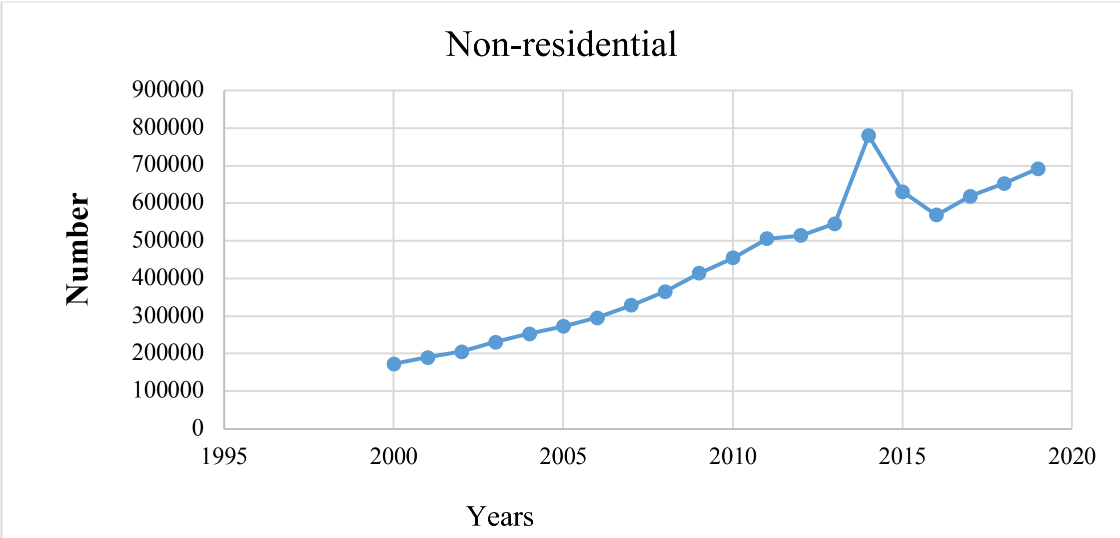


Figure 5.3: Number of Customer in the Non-residential
Source: Author with data from Energy Commission (2020)

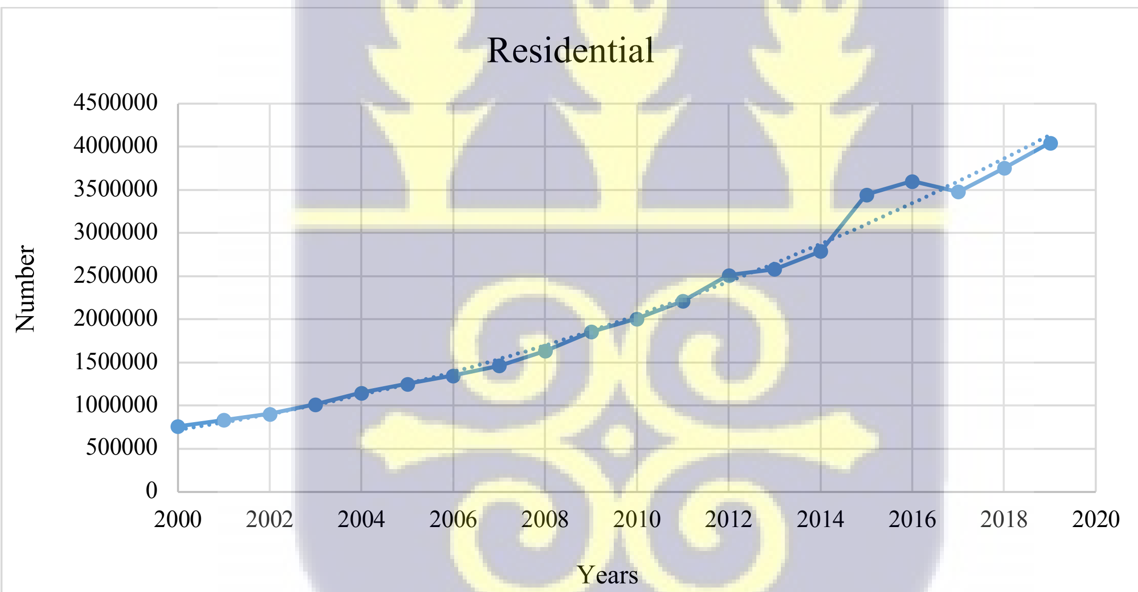


Figure 5.4: Number of Customer in the Residential Sector.
Source: Author with data from Energy Commission (2020)

5.2 MODEL ANALYSIS

5.2.1 Decomposed changes in electricity consumption in Northern Ghana

To ascertain the changes in electricity consumption in northern Ghana, electricity consumption data spanning from 2016 to 2020 was obtained and decomposed using the LMDI approach. Results of the addictive decomposition method are shown in Figures 5.5, 5.6, 5.7, and 5.8. While Figure 5.5 shows the Additive decomposition results of total electricity consumption of all sectors, Figure 5.6 and Figure 5.7 shows the regional effect of electricity consumption changes within the northern regions and the regional electricity consumption change (GWh's) for activity, intensity, and structural effect between 2016 to 2020 respectively. The effect of electricity consumption changes in the sectors between northern and southern Ghana is shown in Figure 5.8.

The study is deconstructed according to a defined reference year to keep track of structural changes in electricity consumption and extract general trends. The result shows an intriguing outcome on the influence of the various effects. The activity effect measures the influence of changes in the number of subscribers on energy consumption(ΔE_{act}). The structure effect(ΔE_{stru}) gauges the compositional shift in energy, and the amount/quantity of energy used is measured by the intensity effect(ΔE_{int}).

It can be deduced from Figure 5.5 that changes in total electricity consumption (total effect ΔE_{tot}) in northern Ghana and the trend are dynamic. A positive peak was observed in 2017 (33.58 GWh) and 2018 (123.93 GWh), followed by a negative peak in 2019 (-646.36 GWh) which signifies decreased electricity consumption. This decline was followed by a sharp increase in consumption in the next year, 2020 (272.52GWh). It is worth noting that the significant decrease in 2019 can be attributed to the negative intensity effect in that year. This implies that the per-unit consumption of electricity in the sectors declined. Factors that can account for the reduction in per-unit electricity consumption include the price and modern efficient electronic gadgets, among others. Acheampong, Menyeh, and Agbevivi (2021) found an increasing average electricity end-user tariffs. Since electricity consumption is also based on demand and supply, it presupposes that increasing prices coupled with the use of efficient electricity gadgets could lead to the decline in the per unit electricity consumed in 2019.

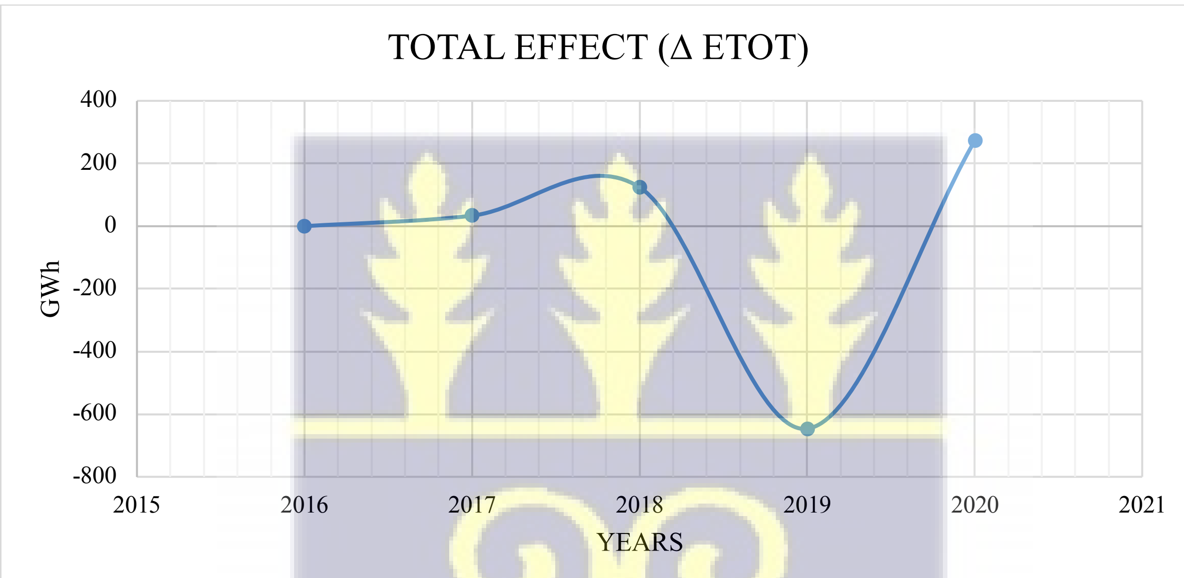


Figure 5.5: Additive decomposition results of total electricity consumption in Northern Ghana, 2016-2020.

5.2.2 Electricity consumption within and between regions in Northern Ghana

5.2.2.1 Comparison within regions in Northern Ghana

This section focused on electricity consumption drivers within each region of northern Ghana. Figure 5.6 shows the within regional consumption findings. It must be noted that any effect below zero (0) is a negative change. It implies that it contributes to a decline in electricity consumption changes and vice versa.

Brong Ahafo Region: from Figure 5.6a, it can be deduced that electricity consumption changes in the region are primarily influenced by the activity effect followed by the structure effect. The non-residential sector (93.3GWh) contributes immensely to electricity consumption changes in the region, followed by the residential sector (83.43 GWh), with the industrial sector accounting for the least contribution to electricity consumption changes regarding the activity effect. Although the structure effect also influences consumption changes, its primary influence is in the non-residential sector (39.41 GWh) and industrial sector (27.81 GWh), except for the residential sector, which contributes negatively to the consumption changes in the region. The contribution of intensity effect is negative and runs through all the sectors, which can be linked to fewer industrial activities undertaken in the regions.

Northern Region: Figure 5.6b shows that the activity effect is the major contributor to electricity consumption changes in the northern region for the residential, non-residential, and industrial sectors. The non-residential sector has the highest contribution with regards to the activity effect with about (97.23 GWh) followed by the industrial (44.55 GWh) and residential sector (21.14 GWh). With a similar pattern to that of the Brong Ahafo Region, the structure effect is the second influential factor to electricity consumption changes in the northern region. However, its major influence is in the non-residential (56.14 GWh) and industrial sector (25.61 GWh), with a negative contribution in the residential sector (-70.52 GWh). The intensity effect contributes negatively to consumption changes in all the sectors in the northern region, considering the type and nature of activities undertaken in the region. In all, electricity in the northern region is driven activity effect mainly in the non-residential sector.

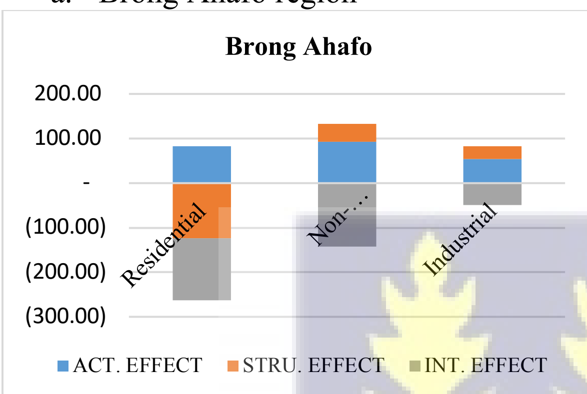
Upper East Region: with similar driving factors of consumption changes to the Brong Ahafo Region, the activity and structure effects positively influence electricity consumption changes. The activity effect is the major factor influencing consumption changes in the residential, non-residential, and industrial sectors in the Upper East region with 26.26 GWh, 36.38 GWh, and 19.46 GWh, respectively, as shown in Figure 5.6c. While the structure effect positively influences consumption changes in the non-residential and industrial sectors, the structure effect contributes negatively to electricity consumption changes in the residential sector. The intensity effect is the major contributor to the decline in consumption changes in all the sectors considering its negative contribution.

Upper West Region: from Figure 5.6d, electricity consumption changes are driven by the activity effect in the non-residential and residential sector, with a chunk of the change being in the non-residential sector (17.51 GWh) followed by the residential sector (11.96GWh). The structure effect also contributes positively to the consumption changes in the non-residential sector (7.11 GWh). The decline in electricity consumption changes in the Upper West region is significantly due to the negative contribution of the structure effect in the residential (-8.08GWh) and industrial sector (-3.40GWh) coupled with the negative contribution of the intensity effect in the residential (-40.14 GWh) and non-residential sector (-33.75GWh). Interestingly, the intensity effect contributes positively to the consumption change in the industrial sector (10.51 GWh) in the Upper West region. This is significant as it implies that industrial activities may be picking in the region described as the poorest region in Ghana.

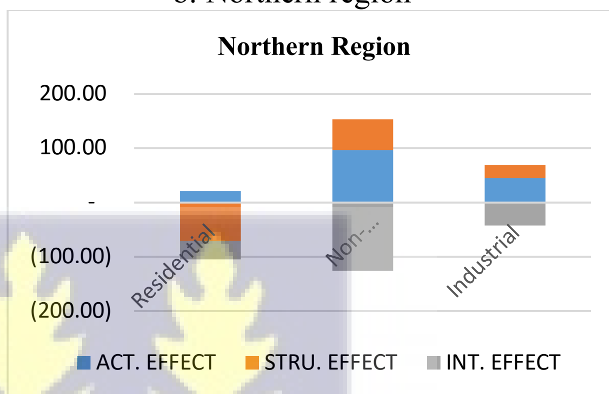
Considering the factors driving electricity consumption change among the regions in Northern Ghana, the activity effect is the major driving factor followed by the structure effect. This pattern of influence runs through all the regions. Although the intensity effect contributed positively to consumption change in the industrial sector in the upper west region, it is the major negative contributor to electricity consumption changes in the residential, non-residential, and industrial sectors among the other regions.

Effect of electricity consumption changes in the sectors within northern regions

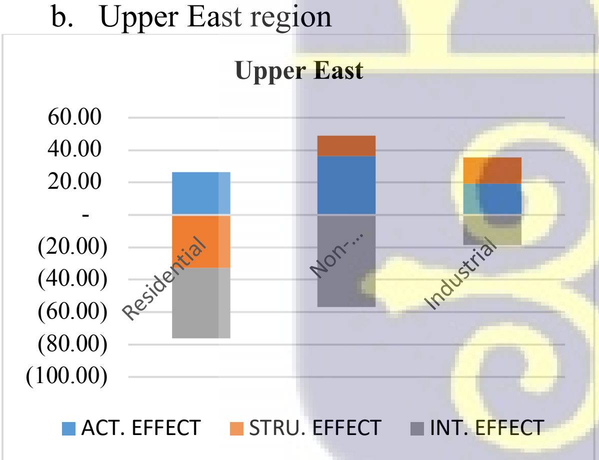
a. Brong Ahafo region



b. Northern region



b. Upper East region



c. Upper West region

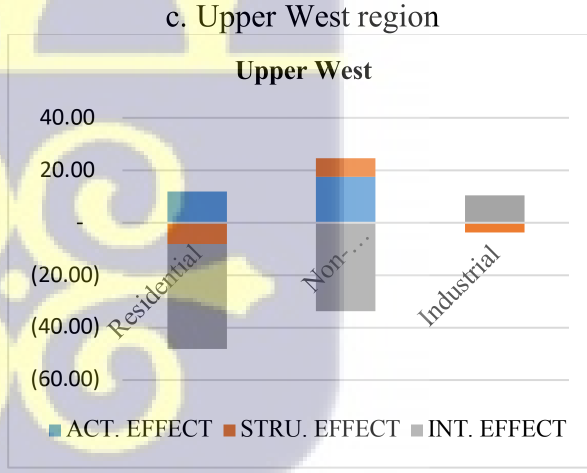


Figure 5.6: Electricity consumption changes in the sectors within northern regions
(ΔE_{tot} <0=negative change: ΔE_{tot} >0=positive change; ΔE_{tot}=0 "no change")
Source: Author with data from NEDCo.

To further test for the significance for the contribution of the activity effect on electricity consumption in the non-residential sector within northern region, the Analysis of Variance statistical technique was used. Results in Table 5.5 shows that the contribution of the activity effect to the non-residential sector in northern regions even though very high is not statistically significant at 0.05 level of significance, P-value =0.22.

Table 4.5:Test of significance (non-residential consumption within Northern region)

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	111288.45	2	55644.225	1.74789036	0.21567843	3.88529383
Within Groups	382020.93	12	31835.0775			
Total	493309.38	14				

Level of sig. 0.05 (p=0.22)

5.2.2.2 Electricity consumption between Regions in Northern Ghana

The consumption changes between the regions are necessary to enable improvement in regions that are not performing and to help plan for adequate and sustainable generation and distribution. The detailed additive decomposition of electricity consumption changes in Northern Ghana (2017 to 2020) is presented below. Figure 5.7 provides the activity, structural and intensity effect in northern Ghana and their regional year-on-year variations.

Activity Effect

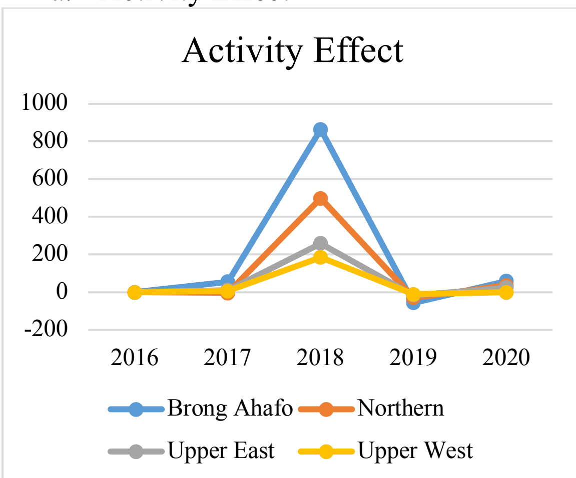
The Brong Ahafo region experienced a growth in electricity consumption changes between 2016 to 2018, except for the year 2019 that showed a decline (-56.65 GWh) in the consumption changes and began to increase again in 2020. Figure 5.7a shows that a similar pattern exists across the rest of the regions of the northern sector. The Upper West region contributes the least activity effect in the sector. All the regions in northern Ghana recorded the highest activity effect in 2018. Activity effect in 2018 (864.93 GWh) in the Brong Ahafo region is responsible for the highest electricity consumption change in northern Ghana.

Structure Effect: The decomposition analysis of the structure effect for the regions is also shown in Figure 5.7b. It is deduced that the structure effect for the Northern region has contributed positively to the electricity consumption changes throughout the years (2017-2020). However, the contribution of the structure effect decreased in 2018 and 2020. The structure effect in the Brong Ahafo region accounted for 5.76 GWh in 2017 and declined in 2018 (-3.12GWh). It increased in 2019 (2.72 GWh) but declined in 2020 (-4.73GWh). Consumption in Upper East and Upper West region least influences electricity consumption changes. Overall, the northern region has the greatest contribution to Northern Ghana electricity consumption changes in terms of structure effect.

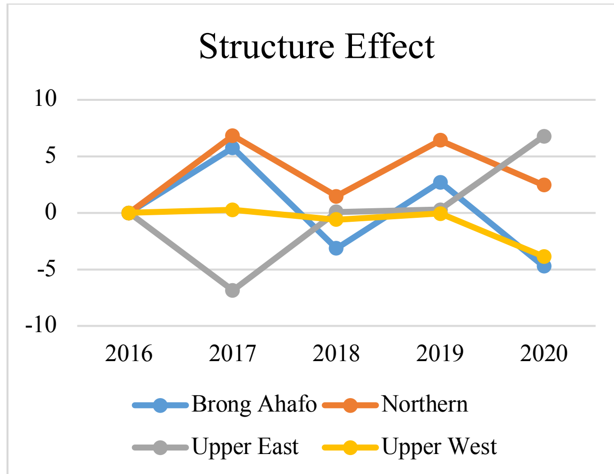
Intensity Effect: Over the past years, industrial activities in the northern part of Ghana have had an insignificant influence on electricity consumption changes. It is observed from Figure 5.7c that the intensity effect has contributed negatively to the consumption changes during the period 2017 to 2019, and this can be attributed to the low industrialization drive in North Ghana. The intensity effect also contributes negatively to the decline in electricity consumption changes. However, the Upper East region and Upper West region intensity effect contributed positively to electricity consumption in 2017 and 2020, respectively. This could be due to the emergence of legal and illegal mining activities in these regions as literature show significant mining activities in the regions (Crawford, Agyeyomah, Botchwey, & Mba, 2015).

Regional electricity consumption change (GWh's) for activity, intensity, and structural effect 2016 to 2020.

a. Activity Effect



b. Structure Effect



c. Intensity Effect

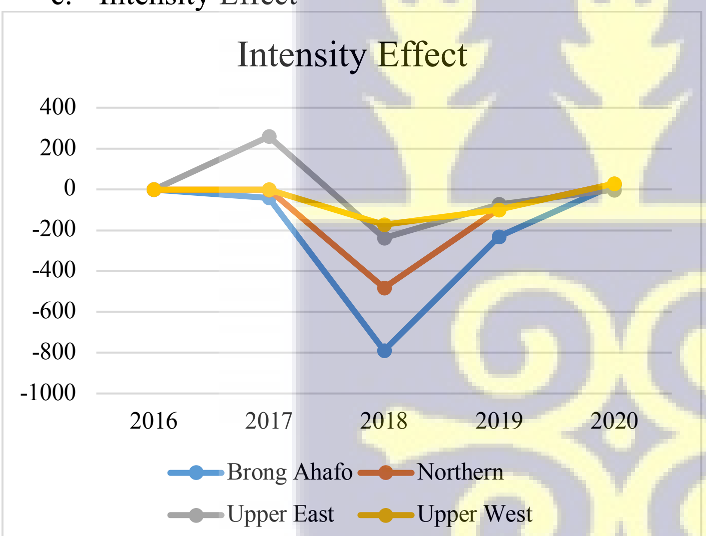


Figure 5.7: Regional electricity consumption change
Source: Author with data from NEDCo.

5.2.2.3 Test of Significance between regions (Activity and Intensity effect)

The findings were further subjected to a test of significance using the analysis of variance statistical technique. A significance level of 0.05 (5%) and confidence level of 95% is applied in all the test. Results are found in Tables 5.6 and 5.7.

The test of significance in terms of activity effect between the regions is found in Table 5.6. With a 0.05 level of significance, it is deduced that even though the activity effect is a major driver of electricity consumption changes in northern Ghana, the difference in the effect is not statistically significant (P-value [0.76] > 0.05) between the regions.

Table 5.5:Test of significance (Activity effect)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	64695.8815	3	21565.2938	0.39715777	0.75684712	3.23887152
Within Groups	868784.97	16	54299.0606			
Total	933480.851	19				

Level of sig. 0.05 p=0.76

With regard to the intensity effect between the regions in northern Ghana, Table 5.7 shows that there is not statistically significant difference between the regions in the influence of intensity effect on electricity consummation in Northern Ghana. P [0.54] > 0.05.

Table 5.6:Test of significance (Intensity effect)

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	111121.637	3	37040.5455	0.74051194	0.54328041	3.23887152
Within Groups	800322.984	16	50020.1865			
Total	911444.621	19				

Level of sig. 0.05 p=0.54

5.2.3 Effects of electricity consumption changes between Northern and Southern Ghana

Comparisons between electricity consumption in southern and northern Ghana provided analysis worth policymakers' attention. Figure 5.8a shows that the activity effect drives electricity consumption in northern Ghana as compared to southern Ghana. The activity effect also contributes immensely to consumption changes in all sectors in northern Ghana. Interestingly, electricity consumption in the residential sector of northern Ghana is highly driven by the activity effect while activity effect contributes negatively to the industrial sector consumption in the southern sector of Ghana. The negative contribution to all the sectors in northern Ghana is driven by intensity effect with the industrial sector contribution in northern Ghana driven by the structure effect. It is worthy to note that the industrial nature of southern Ghana compared to northern Ghana may be the reason for the intensity effect accounting for the consumption in all sectors in the southern sector with particular attention to the industrial sector.

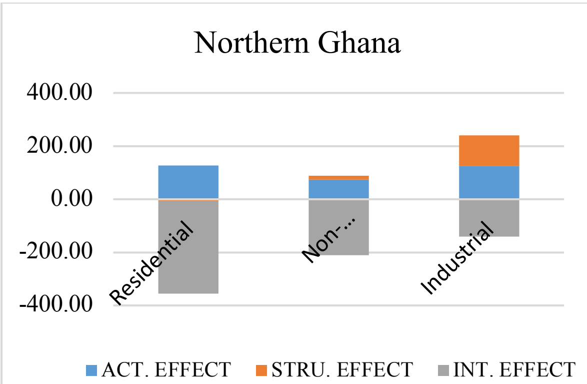
The structure effect also contributes positively to the industrial sector. In southern Ghana, the intensity effect drives electricity consumption changes, as shown in figure 5.8b. While the activity effect contributes minimal influence to the electricity consumption changes in the residential sector of southern Ghana, the structural and activity effect negatively influences consumption changes in the industrial sector. It must be noted that the southern sector remains the most industrialized hence uses much electricity in its operations.

In comparison, northern sector electricity consumption accounts for 5.4% of the national consumption compared to 94.6% of the southern sector contribution. It must be noted that the southern sector of Ghana is densely populated, highly urbanized, and relatively highly industrialized compared to the northern sector. This implies that there are high electricity-driven activities undertaken in the southern sector than the northern sector; hence a chunk of Ghana's electricity consumption changes is driven by the southern part. There is also a consistent decline in the consumption pattern of the northern sector. It thus suggests that activity, intensity, and structure have been reducing, indicating that industrialization and electricity-related activities are weak.

Effect of electricity consumption changes in the sectors between northern and southern Ghana.

a. Northern Sector

b. Southern sector



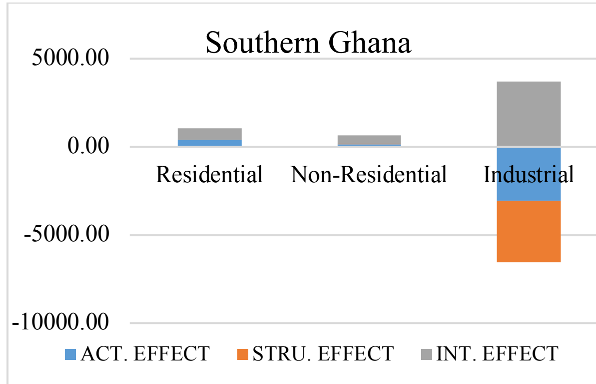


Figure 5.8*:* Electricity consumption changes in the sectors between northern and southern Ghana. Source: Author with data from NEDCo and Energy Commission, 2020.

5.3 Discussion of Findings.

The findings further show that the total electricity consumption has increased over the past half-decade in Northern Ghana due to subscriber increases. Activities in the Brong Ahafo and Northern region are the major contributors to electricity consumption increase in Northern Ghana. Therefore, it is reasonable to link the subscriber increase to population growth and urbanization in the north. For instance, the population in northern Ghana has grown significantly over the years. Per the 2021 population and housing census, it is indicated that northern Ghana's population increased from 1,496,672 in 2000 to 8,802,196 in 2021, representing a growth rate of about 488.1 % (Ghana Statistical Service, 2021). The population growth trends of the various regions within the northern sector also show similar growth patterns as compared to the population of northern Ghana, even though there are some population disparities between the regions. For instance, the population of the northern region increased from 1,820,806 in 2000 to 3,609,473 in 2021 (GSS, 2021) and is the highest compared to Brong Ahafo and the other northern regions. Interestingly, the electricity consumption of Brong Ahafo is the major contributor to electricity consumption increases in the northern part of Ghana, even though the northern region has the biggest population.

The finding implies that population growth is not the only explanatory variable for increased consumption. Some variables, such as the use of electricity and the appliances used account for the electricity consumption. Given the contribution of the activity effect of 771.78 GWh to the total electricity consumption change, activities in the residential sector contribute immensely to Northern Ghana's electricity demand increase. Despite other variables such as price, human activities in the residential sector, such as cooking, heating, ironing, etc., increases residential electricity consumption in northern Ghana.

The finding is in support of Ansu-Mensah, P., & Kwakwa, P. A. (2021), who used in modelling electricity consumption in Ghana using data between 1971 to 2019 and a regression model found that income and population density increase electricity consumption while prices decrease consumption. This supports the correlation between population increase and electricity consumption.

Again, the study finding supports Akrofi, Ackah, & Sakyi (2018), who used the Laspeyres index decomposition method to analyze Ghana's energy demand change from 2008 to 2014. Akrofi, Ackah, & Sakyi (2018) concluded that the activity effect is the most influential factor causing the energy demand increase in Ghana over the period. Therefore, the current study differs from Akrofi, Ackah, & Sakyi (2018) in the decomposition method applied, as the current study further focused on sectoral analysis such as residential, non-residential and industrial sectors. Nevertheless, in line with household activities that contribute to electricity consumption, the finding is also in line with

Abdul-hanan, Yeboah, Zakaria, & Ibrahim (2014), who found that appliance ownership and usage significantly influenced electricity consumption in the West Mampurisi District the northern part of Ghana.

More interestingly, consumption in the industrial sector of northern Ghana compared to the residential and non-residential sectors is driven by the structural effect. The findings presupposes that the per unit consumption of electricity in the industrial sector, accounted for by the number of subscribers in the sector of northern Ghana is higher due to the emerging industrial developments in the north. Upper east region accounts for significant proportions of structural effect contributions, followed by Brong Ahafo region and Northern region. Upper West however recorded negative contribution of structural effect to the industrial sector. The Upper East region in recent times have witnessed tremendous urbanization. Also, the few mixes of electricity-driven activities undertaken within each sector in the regions contribute to the positive contribution of the structure effect to electricity consumption. However, the intensity effect significantly contributes negatively to electricity consumption in northern Ghana.

CHAPTER SIX

SUMMARY, CONCLUSION, AND RECOMMENDATION

6.0 Introduction

This chapter contains the study’s summary, conclusions, and recommendations. In the first portion, the study's objectives and significant findings are described, conclusions drawn from the findings are presented in the second section, and in the last section, recommendations for policy, practice, and future research are provided.

6.1 Summary of Study

This study aimed to examine the influential factors of electricity consumption changes in Northern Ghana, specifically consumption variations between and within the regions in Northern Ghana. The study further compared findings in Northern to Southern Ghana. Although several studies on electricity consumption have been conducted, this study was unique as it was the first to employ the LMDI method in analyzing electricity consumption changes in Northern Ghana.

Data on the electricity consumption of all the sectors in each region in northern Ghana was sourced from Energy Commission of Ghana. In addition, data on residential, non-residential, and industrial sector electricity consumption trends were analyzed for Brong Ahafo, Northern, Upper East, and Upper West region. Data on electricity consumption for Southern Ghana was also obtained from the Energy Commission for a comparison with that of northern Ghana.

6.1.1 Key Findings

Three main objectives underpinned the study. The first objective was to decompose changes in electricity consumption in Northern Ghana over the last half-decade into Activity, Structure, and

Intensity effect. The second objective was to examine the within and between electricity consumption variations among the regions in Northern Ghana. Finally, the study compared electricity consumption variations between Northern and Southern Ghana.

Regarding objective one, it is found that activity and structural effect are the main drivers of electricity consumption in norther Ghana in all the sectors. The negative contribution to consumption changes in northern Ghana is largely influenced by the intensity effect. In 2018, the activity effect accounted for the highest positive influence in the consumption changes between 2016 and 2020.

In terms of objective two, it is deduced that activity effect is responsible for the positive consumption changes in all the regions. Between the regions in northern Ghana, it is found that Brong Ahafo region has the highest activity effect on consumption changes with Upper West region experiencing the least. It is shown that trends in the structural effect have been unstable in all the regions over the period. However, in 2020, Upper East region contributed to consumption changes with the highest structure effect.

Finally, comparing consumption between northern and southern Ghana, it is found that the activity effect and the structural effect contribute to consumption changes in northern Ghana. The intensity effect is the major contributor to electricity consumption changes in southern Ghana although the activity effect also influences consumption changes. It must be noted that the southern sector of Ghana is better industrialized and highly populated than northern Ghana.

6.2 Conclusions

To examine the factors that influence electricity consumption change in Northern Ghana, the LMDI method was used in this study to decompose changes in electricity consumption into Activity, Structure, and Intensity effect because it aids in understanding and measuring the drivers of electricity consumption trends and as well monitor energy-related policies performance over time. The LMDI allowed us to examine the actual variables responsible for the electricity consumption changes in northern Ghana. Interesting conclusions are drawn from the major findings.

Regarding the decomposed electricity consumption covering the entire northern Ghana, it can be concluded that the non-residential sector consumption is mainly driven by activity effect. These activity effect include daily human activities that require the use of electricity. Similar conclusions can be drawn from the between and within regions analysis in northern Ghana.

In comparing Northern Ghana and Southern Ghana electricity consumption drivers, it is interesting to note that the intensity effect significantly drives electricity consumption in southern Ghana, especially in the industry sector. In contrast, the activity effect drives consumption in northern Ghana and also in the non-residential sector in Northern Ghana. Therefore, it can be concluded that industrial activities drives that of southern Ghana consumption while human and commercial activities drives that of northern Ghana.

6.3 Recommendations

Based on the findings and conclusions of the study, some recommendations have been proposed. First, since electricity consumption is driven by demand and supply and further influenced by price, it is relevant that the government of Ghana in attaining SDG sustainable energy for all agenda considers making electricity affordable and available in northern Ghana. Affordability and availability requires policies to aid in the electrification rate, production and pricing for consumers.

Second, in the wake of unstable energy prices in Ghana, electricity must be efficiently used. Therefore, it will be appropriate to sustain and heighten education and awareness on electricity efficiency to households and businesses in Ghana. Education in northern Ghana will help improve the various effect in all the sectors.

Also, industrialization accounts for the driving force of electricity consumption in Southern Ghana and is very low in northern Ghana. The correlation between industrialization, economic growth, and living standards or poverty cannot be underestimated. Therefore, to improve the intensity effect in the industrial sector in Northern Ghana, it is relevant that government formulate and implement policies to improve the level of industrialization. Such policies could include revamping old companies and include them in the one district one factory initiative, provide tax holidays, tax credit, tax waivers and also reduce electricity tariffs to attract more investments in northern Ghana. This will drive growth and electricity consumption in the industrial sector in Northern Ghana.

Finally, it is recognized from the findings that consumption in northern Ghana is on the surge after 2018. Considering the rate of population growth in the sector, the generation and distributions capacity for the future must be planned and implemented to forestall shortage in availability and supply. This should be done for the whole country.

6.4 Thesis Contributions

Contributions of research to development through policy and education are very relevant.

Whereas research on decomposition and energy analysis in Ghana is scarce, the study remains one of the first to apply the LMDI to 'research electricity consumption in Ghana. As such, it will form the basis for further empirical research in the area of consumption analysis.

Policy-wise, the study will stimulate policy formulation in the area of public education on energy usage. In this direction, people will be educated on efficient and effective energy use in the residential sector.

Finally, the study's findings expose the low use of electricity in the industrial sector in northern Ghana. Therefore, policies in the direction of industrialization for growth in all sectors will also be worthy of attention.

6.5 Scope for Future Research

The study results can be improved with more accurate data. Also, there are some exciting possibilities for expanding this research, which is listed below:

First future research should be widened to include different forms of energy to assess the impact of the various forms of energy on economic growth.

Also, the data period can be increased to enable the minute analysis of the year-on-year changes and trends in electricity consumption.

Finally, analysis can also focus on the sectoral comparisons between the north and south regions to help in development planning regarding electricity consumption and industrialization.

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