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FIRMS' DECISIONS ON ENERGY SYSTEMS UTILISATION AND IMPLICATIONS ON BUSINESS PERFORMANCE IN THE GREATER ACCRA REGION FROM 2015 TO 2021

BY

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DECLARATION

I hereby declare that this thesis is the result of my independent investigation undertaken with meticulous supervision. I have consulted and used other scholarly works which have been duly acknowledged. I confirm that this thesis is original and has never been submitted, in part or whole, at the University of Ghana or any other institution for the award of an academic degree.

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ABSTRACT

According to the Intergovernmental Panel on Climate Change, keeping global warming below 1.5°C is necessary for human continuous survival because each of the last four decades has been successively warmer than any decade that preceded them since 1850 due to anthropogenic factors. Central to achieving this target is Goal 12.6 of the SDGs which encourages intentional transformation of world economies from fossil-fuel dependent economies to green economies, where the utilisation of renewable energy and energy efficiency technologies drive growth and development. This green agenda is, however, threatened by scholars who argue that Africa will need its newly discovered oil and gas resources to expand its economies, significantly lift millions of its citizens from poverty trap, and close the gap between itself and the developed world. Businesses, like governments all over the world, are therefore faced with the important decision of investing in the right energy systems that are either friendly to the environment, facilitate growth or both. In the local context, Ghanaian enterprises are very reliant on the national grid system for their electric power needs, supported by own power generations. However, there is very little evidence on the utilisation of RETs by Ghanaian firms despite the abundance of RET resources and the fact that RETs are fast becoming the lowest-cost sources of power generation in recent times. After sampling 404 businesses and 15 key informants in the Greater Accra Region, the study explored the fundamental reasons behind Ghanaian firms' energy decisions, and how their financial and environmental performances are consequently affected from 2015 to 2021.

Blackouts and voltage fluctuations are undesirable energy services of the grid system that limit the productivity of capital and labour factors. The firms in the Greater Accra Region experienced these unwanted services for about 621 and 1,070 hours per month during the power crisis era. The fixed-effects regression results reveal that blackout hours decreased both financial and environmental performances of firms in the power crisis (2015-2017) and post-crisis (2019-2021) eras, whereas the environmental performance of firms was negatively affected by firms that use generators. On the other hand, energy efficient machinery, lighting, and air-conditioning systems are useful energy services that are as important as capital, labour, information technology (IT) and research and development (R&D). These factors were positively associated with the financial and environmental performances of the firms from 2015 to 2021.

The grid system was overwhelmingly subscribed because it was regarded as a relatively cheaper and guaranteed system with sheer monopoly presence that makes it every firm's first choice. About 22% of the firms used generators because they can afford to do so, and because of the unreliability of the grid system. Alternative systems like renewables were less utilised because of their high upfront and maintenance costs. Beyond costs, the lack of trust in RETs due to very few well-functioning systems in existence and poor-quality installations, unsupportive policies, and shallow knowledge of the technologies among businesses have greatly limited the popularity, and use of RETs among firms in the region. Renewable energy policies should be tailor-made to enforce international standards in RET materials importations and installations while targeting the grassroot stakeholders for RETs educational campaigns. There should also be an industrial energy efficiency strategy targeting the firms' machinery systems for sustainable productivity.

Keywords: firms' decisions, RETs, energy efficiency technologies, enterprises performance.

This work is dedicated to my God, family, and friends.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
1D1F	One District One Factory
AAF	Automatic adjustment formula
AC	Air conditioning system
AfDB	African Development Bank
AMERI	Africa Middle East Resources Investment
ATK	Aviation turbo kerosene
CAPI	Computer assisted personal interview
CEO	Chief Executive Officer
CFL	compact florescent lights
CI	Confidence interval
CL	Confidence level
CO_2	Carbon dioxide
EC	Energy Commission of Ghana
ECG	Electricity Company of Ghana Ltd.
EE	Energy Efficiency
EETs	Energy efficiency technologies
EP	Environmental performance
ERP	Economic Recovery Programme
FDI	Foreign direct investment
FE(M)	Fixed-effects (model)
FP	Financial performance
FPSO	Floating production storage and offloading
G/A (R)	Greater Accra (Region)
GDP	Gross Domestic Product
GHG	Greenhouse gas
GLSS	Ghana living standard survey
GPRS I	Ghana Poverty Reduction Strategy

GPRS II	Growth and Poverty Reduction Strategy
GSGDA	Ghana Shared Growth and Development Agenda
GSS	Ghana Statistical Service
IBES	Integrated Business Establishment Survey
IDIs	In-depth interviews
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPPs	Independent power producers
IRENA	International Renewable Energy Agency
KIIs	Key-informant interviews
KLEMS	Capital, Labour, Energy, Materials, and Services
LPG	Liquefied petroleum gas
MBV	market-based view
NDCs	Nationally determined contributions
NDPC	National Development Planning Commission
NGOs	Non-governmental organisations
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary least square
PPP	Purchasing power parity
PSRP	Power Sector Reform Programme
PURC	Public Utilities Regulatory Commission
QUAL	Qualitative
QUAN	Quantitative
RBV	resource-based view
RE	Renewable energy
RE(M)	Random-effects (model)
RETs	Renewable energy technologies
RFO	Residual fuel oil
SAP	Structural Adjustment Programme

SDGs	Sustainable Development Goals
SLT	Special load tariff
SMEs	Small and medium scale enterprises
SSA	Sub-Sahara Africa (n)
StdDev	Standard deviation
SUREP	Scaling-up renewable energy project
TEN	Twenneboa, Enyenra, and Ntomme
TOR	Tema Oil Refinery
UN	United Nations
UNDP	United Nations Development Programme
USA	United States of America

Unit	**Meaning**
GHp	Ghana Pesewas
GHS	Ghana Cedis
GW	Giga Watt
kWh	Kilowatt hours
m^2	Meter-squared
MW	Mega Watt

CHAPTER ONE

INTRODUCTION

1.1 Background information

Human activities are estimated to have caused about 1.0°C of global warming above pre-industrial levels, and the warming level is projected to reach 1.5°C between 2030 and 2052 at the current business-as-usual rate of emissions (IPCC, 2018). In his address to the United Nations (UN) General Assembly in 2018, the Secretary-General, António Guterres pointed out that "*Climate Change is moving faster than we are …we must listen to the Earth's best scientists*" (IPCC, 2018 p. v). According to scientists, widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have unequivocally occurred due to human activities (IPCC, 2021a). It is also reported that each of the last four decades has been successively warmer than any decade that preceded them since 1850 (IPCC, 2021b). These changes have had and continue to have adverse effects on the human society, environment, ecosystem, and biodiversity (IPCC, 2021a; Wei et al., 2016). Keeping a global warming below the target of 1.5°C, therefore, became a global priority for human continuous survival (IPCC, 2018). In Paris on December 12, 2015, 160 countries took the decision to cut down on emissions in what has become known as the Paris Agreement.

In the development of the intergovernmental climate change mitigation policy, mitigation targets are assigned to countries based on the 'common but differentiated responsibilities' approach (Wei et al., 2016) in which countries are grouped by economic status or historical contribution to greenhouse gas (GHG) emissions. This approach acknowledges the fact that some countries are major contributors and should assume more responsibilities. Historically, advanced countries have been generally identified to have contributed more to climate change than developing countries. For example, (den Elzen et al., 1999) found that developed and developing countries should bear 54% and 46% of the historical contribution to global warming from 1890 to 2000 respectively. Höhne and Blok (2005) also estimated the contribution of developed countries to climate change at 60% from 1750 to 2000 after they used the GHG concentrations and their effects on radiative forcings and changes in global temperature. Recent evidence suggests that the two largest economies in the world currently, China and the United States, are the biggest CO_2 emitting economies in the world (11.5billion metric tons of CO_2 emitted by China and 5.0 billion metric tons of CO_2 emitted by the U.S in 2021[1]). The combined emissions from these two countries account for about 45 percent of the global 36.4 billion metric tons of CO_2 emitted in 2021[2]. Accordingly, the United States pledged to cut economy-wide emissions of GHG by 26-28 percent below its 2005 level by 2025 per the Paris Agreement. China also pledged to increase non-fossil fuels to 20% of its energy mix and reduce carbon emissions per unit of gross domestic product (GDP) to 60-56 percent by 2030. Other significant pledges made by countries to cut GHG emissions include: India's pledge to reduce GHG emissions intensity by 33-35% from its 2005 levels by 2030; the European Union's pledge to reduce GHG emissions to at least 40 percent below 1990 levels by 2030; Brazil's pledge to reduce economy-wide GHG emissions by 37 percent below its 2005 levels by 2025 while South Korea, Indonesia, Japan, and Australia had all pledged to cut GHG emissions by 37%, 29%, 26%, and 26-28% by 2030 respectively (IPCC, 2021b).

These pledges have been turned into various nationally determined contributions (NDCs) with clear strategies for cutting down on GHG emissions to meet the 1.5°C global warming target. *Sine qua non* to achieving this 1.5°C global warming target is a significant transformation of world economies from fossil-fuel dependent economies to green economies, which emphasises

[1] Statistics obtained from https://www.statista.com/statistics/270499/co2-emissions-in-selected-countries/ [Accessed: 16/03/2021]
[2] Statistics obtained from https://www.statista.com/statistics/276629/global-co2-emissions/. [Accessed: 16/03/2021]

the utilisation of renewable energy technologies (RETs) like solar photovoltaic and wind to drive growth and development (Richter, 2013). However, the compelling evidence of the growth success of advanced countries since the industrial revolution at the back of heavy reliance on fossil fuel, particularly petroleum and coal (Li & Hu, 2017; Osborne & Gupta, 2013; Song et al., 2018) has challenged this green economy agenda. Additionally, poverty reduction in developing countries in recent history is known to go with increased carbon emissions. For instance, as the number of extremely poor people in East Asia and the Pacific declined from 1.1 billion to 161 million between 1981 and 2011, per capita CO_2 rose from 2.1 tons to 5.9 tons (Davey, 2016). Abokyi et al. (2019) also show how uni-directional causality runs from fossil fuel consumption to emissions of CO_2 during the financial sector development in Ghana. Many African economies are heavily dependent on fossil fuel development for their economic growth. Other scholars argue that Africa will need its newly discovered oil and gas resources to expand its economies, create jobs for millions of its unemployed youths, and significantly lift millions of its citizens from poverty trap (Cooper, 2019; Eigen, 2014; Khatib, 2014).

Not only governments, but enterprises, especially in developing countries are, therefore, faced with the important decision of investing in the right energy systems that are either friendly to the environment or facilitate economic growth. This is because energy is at the heart of all production and consumption activities (Asghar, 2008; Twerefou et al., 2018). Fossil fuels that propelled industrialisation in Europe and Asia are considered cheap and readily available productive energy systems (Ai et al., 2021; Y. Li & Xia, 2013; Perkins & Tang, 2017; Stern & Kander, 2012; Zafar et al., 2020; Zhou et al., 2012). However, they are also responsible for most of the GHG emissions that have unsettled the global climate (IPCC, 2021b). Cheng et al. (2021) argue that investing in low-carbon energy resources is a green initiative but places industries at a cost disadvantage compared to those using fossil fuels. However, research and development have ensured that low-carbon energy resources like renewables are fast becoming the lowest-cost sources of power generation in recent times (International Renewable Energy Agency [IRENA], 2021). Additionally, the application of energy efficiency technologies (EETs) in both developed and developing countries has been found to significantly enhance firm productivity in the long run (Filippini et al., 2020; Zhang & Wang, 2008).

Understandably, the choice of businesses regarding energy systems utilization could have implications on their ability to achieve their business objectives, the environment, and the climate. Studying why certain fuels are preferred by businesses to others and the effects of such preferences is, therefore, crucial to the businesses themselves, policy makers and the international community. Successive governments in Ghana have attempted to strengthen the capacity of firms and the private sector in general through policies like the Private Sector Development Strategy (Danida, 2018), Public-Private Partnership (Government of Ghana [GOG], 2011), and recently, the One District One Factory initiative. Critical to these policies achieving their set targets is the investment in reliable, efficient, and cost-effective fuel systems. Understanding the decisions of businesses in Ghana regarding energy systems utilisation has, therefore, become imperative.

1.2 Statement of the problem

The Sustainable Development Goals (SDGs), Goal 12.6 specifically encourages companies to adopt sustainable practices including mainstreaming sustainability information into their reporting cycle. Tracking the progress of these targets were to be assessed by the number of companies publishing sustainability reports, adopting sustainable energy practices, and minimizing waste generation through prevention, reduction, recycling, and reuse of materials (United Nations, 2018). According to (Bang et al., 2000), consumers are consciously rewarding businesses that address environmental concerns with loyalty and this is encouraging companies to 'green-market' their products with 'made with renewable energy' labels to enhance the image of their brands (Brannan et al., 2012; p.1). Additionally, Esty and Winston (2009) suggested companies that operate with an environmental lens are generally more innovative and profitable than their competitors. These varied positions highlight the potential benefits of investing in sustainable energy systems.

Scanty evidence across different geographical regions suggests that firms are appreciably answering to the global sustainability call. A cross-sector study of 220 United Kingdom small and medium scale enterprises (SMEs) by Revell et al. (2010) suggests that a high percentage of owners-managers are actively involved in recycling, energy efficiency, alternative clean energy sources and other practices in a bid to reduce carbon emission. Millar & Russell (2011) examined the adoption of sustainable practices of 76 manufacturing companies in the Caribbean. A little over 50 percent of the sample were found to invest in energy efficiency and renewable resources to improve both the quality of their products and production efficiency, increase market share, differentiate products, and lower cost of production. In 2012, Brannan et al. (2012) found that nearly 50 companies in the Unites States of America are communicating the use of renewable energy in their production process to their customers via product packaging and their products are identical to other conventional products in quality and performance. Sehnem et al. (2016) surveyed 300 enterprises in Southern Brazil and argued that sustainable practices, and eco-innovations like the use of clean energy and energy efficiency technologies are being adopted by these enterprises in satisfaction of regulatory requirements, pressures from customers, shareholders, and Non-Governmental Organisations (NGOs), in order to increase operational efficiency, reduce cost, and impact the corporate image.

Unequivocally, the sustainability practices, be they sustainable energy, reuse, reduce, and recycle strategies, have been adopted more by firms in the developed world. Specifically with energy strategies, firms in developing countries have been heavily reliant on fossil fuel systems despite their cost related challenges and the perceived harm they cause to the climate. Ghana boasts of an estimated total oil reserve of 700 million barrels and 800 billion cubic feet of gas (Tallow Oil, 2017 cited in Skaten, 2018). However, much of the refined petroleum products like petrol, diesel, and liquefied petroleum gas (LPG) consumed by business enterprises are imported and, thus, exposed to international crude price volatility. The ex-pump price for petrol, diesel and LPG increased from 310.1 GHp/Liter, 301.9 GHp/Liter, and 268.3 GHp/kg respectively in 2015 to 589.9 GHp/Liter, 589.8.2 GHp/Liter, and 686.8 GHp/kg respectively in 2021 (Energy Commission [EC], 2022). By November 2022, the prices respectively rose to 1,799 GHp/Liter, 2,349 GHp/Liter, and 1,210 GHp/kg[3]. These volatilities have cost implications for businesses that use petroleum products.

Businesses in Ghana also rely heavily on the national electricity grid for their electric power needs regardless of its reliability and high tariff characteristics. The power crises experienced in the 2007 and 2012-2016 periods are still fresh in the memories of most businesses and households due to the widespread cost implications they came with. Limited power was distributed among businesses and residential customers through a load- shedding exercise that infamously came to be known as *dumsor*[4]. These power crises have been estimated to cost the Ghanaian economy about 1.8-2% loss in Gross Domestic Product (GDP) (Ackah, 2017) and about 10% output loss for businesses (Abeberese et al., 2017, 2021). Costs comparisons across Africa also shows that electricity tariff for commercial and industrial establishments in Ghana (which averages $0.24) is higher than the African average of $0.14 and some specific countries

[3] Available online at https://citinewsroom.com/2022/11/fuel-prices-up-again-as-diesel-hits-gh%C2%A223-49-per-litre/. Accessed: 02/11/2022
[4] This translates as 'off-on' in the Akan Language in Ghana

like South Africa ($0.08-0.10 per kWh) and Cote d'Ivoire (US$0.15 per kWh) as of 2019 (PURC, 2022).

Meanwhile, very little is known about Ghanaian businesses' investments in sustainable energy options. As of 2010, the country was known to be endowed with about 832 million tonnes of biomass, 4.4-5.6 kWh/m^2/day of monthly average solar radiation, 5,640 MW of gross wind resource potential, 837 MW of small- and mini-hydropower energy, and over 5,000 tonnes of organic municipal waste generated daily (Aboagye et al., 2021; IRENA, 2015). Altogether, these potential renewable energy resources can generate about 10,044 GWh of electricity annually as the production cost of renewable energy technologies (RETs) continues to decline (Pueyo et al., 2016). Despite the abundant resource base of renewable energy generation and utilisation in the country, there is a paucity of empirical evidence about businesses' interest in investing in renewable energy technologies in Ghana. On the contrary, existing literature reveals that other energy systems like the national grid electricity (Bawakyillenuo, 2012), petrol/diesel powered generators (Abeberese et al., 2021; Kumi, 2017), and to some extent energy efficiency technologies (Gyamfi et al., 2018; Owusu et al., 2022), are preferred by businesses in Ghana, particularly in the big cities like Accra, Tema and Kumasi. Understanding the dynamics of the energy systems used by businesses in relation to the per unit of output costs and reliability issues vis-à-vis the implications on financial and environmental performances is, therefore, imperative to the sustainable development of the business sector in Ghana.

1.3 Aim and objectives

1.3.1 Aim

The overarching aim of the research is to examine selected business establishments in the Greater Accra Region of Ghana to understand the factors that underpin their decisions regarding the different energy systems they utilise for their productive activities and their relative effects on financial and environmental performances from 2015 to 2021.

1.3.2 Specific objectives

Specifically, the thesis seeks to achieve the following objectives:

i. To explore the underlying factors behind the decisions of firms to invest, or not invest in different energy systems during the most recent power crisis period (2015-2017) and post-power-crisis period (2019-2021) in the Greater Accra Region of Ghana.

ii. To assess the effects of the per unit of output costs and reliability of different electricity sources as well as different energy efficiency technologies utilised by firms on their financial performances in the Greater Accra Region from 2015 to 2021.

iii. To examine the effects of the per unit of output costs and reliability of different electricity sources as well as different energy efficiency technologies utilised by firms on their environmental performances in the Greater Accra Region from 2015 to 2021.

1.4 Research questions

Achieving the set objectives stated in the preceding section is essential to understanding and finding solution to the following questions that have inspired the researcher's interest in exploring the dynamics of Ghanaian firms' energy decision-making. These questions (and sub-questions) essentially define the scope of the research work, determine the methodology, and guide all stages of the inquiry, analysis, and reporting of the findings.

- ***What factors underlie the utilisation of different productive fuels and energy efficiency technologies among businesses in the Greater Accra Region of Ghana during the most recent power crisis and post crisis period (2015-2021)?*** The sub-questions explored include: Which electricity types did firms in the G/A Region predominantly utilised during the most recent power crisis period (2015-2017)? How did the electricity utilisation change in the post-crisis period (2-19-2021)? Why did the firms decide to invest in these electricity sources during these periods? What energy efficiency technologies (EETs) did firms in the G/A Region invest in during the 2015-2021 period? Why are other alternative energy systems not considered by these firms during the most recent power crisis and post-power-crisis periods?

- ***To what extent did the per unit of output costs, and the reliability of different electricity sources used by firms in the Greater Accra Region affect their financial and environmental performances from 2015 to 2021?*** The sub-questions investigated include: How did the per unit of output costs of the different electricity sources utilised by the firms in the G/A Region of Ghana vary from 2015 to 2021? How reliable, in terms of the hours of outages experienced, were the different electricity sources to the firms' operations from 2015 to 2021? To what extent did the per unit of output costs and the reliability of the different electricity sources affect the financial and environmental performances of firms from 2015 to 2021?
- ***To what extent did the different energy efficiency technologies adopted by businesses in the Greater Accra Region affect their financial and environmental performances from 2015 to 2021?*** The sub-questions explored include: What were the levels of utilisation of the EETs in the productive activities of the firms? To what extent did the utilisation levels of the different EETs affect the financial and environmental performances of the firms in the Greater Accra Region from 2015 to 2021?

1.5 Testable Hypotheses

Based on the specified objectives two and three stated in sub-Section 1.3.2, the following hypotheses were statistically tested during the analysis stage of the study. Only the null hypotheses are stated below. The respective alternative hypotheses (unspecified) are the opposite of the null hypotheses.

i. Ho: The per unit of output costs of the electricity sources utilised by firms in the G/A Region from 2015 to 2021 did not significantly influence their financial and environmental performances.

ii. Ho: The reliability of the grid-power system utilised by firms in the G/A Region from 2015 to 2021 did not significantly influence their financial and environmental performances

iii. Ho: The adoption of energy efficiency practices by firms in the G/A Region from 2015 to 2021 did not significantly impact their financial and environmental performances.

1.6 Justification of the study

Scholars have explored the energy-development nexus in different regions across the globe during different periods. Electricity usage has been identified as a catalyst for growth in Sub Sahara Africa (Bildirici, 2013; Enu & Havi, 2014; Esso, 2010) and developing the oil and gas industry is considered vital to the growth and development of the continent (Ba Geri et al., 2019; Graham & Ovadia, 2019). Meanwhile, grid electricity is widely used by businesses in Africa even though there are fundamental issues with its accessibility and the supply infrastructure (Ebhota, 2019; Hafner et al., 2018). Ghana's electricity access rate of 87% as of

2021 (EC, 2022), is well above the sub-Sahara African (SSA) average of around 40%[5] and tipped to become one of the SSA countries to soon achieve its target of universal access to electricity (Bukari et al., 2021; Kemausuor & Ackom, 2017). However, unfavourable climatic conditions (like low volumes of rainfall), infrastructure challenges (such as disruption in the transmission of gas from Nigeria due to damage caused to the West African Gas Pipeline), and exponential growth in electricity demand have resulted in electricity supply shortages to the growing customers (Kumi, 2017), hence, the power crisis experienced in 2007 and 2012-2016.

Short term measures were vigorously pursued to reverse the power crisis because of public outcries and political pressures. Some *ad hoc* emergency power contracts were signed by the government which resulted in excess power available at higher costs with increased debt (International Monetary Fund [IMF], 2021). Tariffs charged to electricity consumers, particularly business enterprises are among the highest in the sub region (Acheampong et al., 2021). Yet, very few scholars like Abeberese et al. (2021), Pueyo et al. (2020) have explored the impacts of energy, specifically, electricity used by businesses on their performances in Ghana. Additionally, there is very little information regarding firms investing in alternative energy systems such as renewables that are rapidly becoming competitive with the traditional fuels. It is, therefore, worth investigating the behaviour of firms regarding their energy choices and how those decisions affected and continue to affect their financial and environmental performances during the power crisis and post-power-crisis periods. Understanding these energy choice dynamics will inform policy decisions at the national and firm levels towards sustainable development of the business sector.

[5] World Bank Data (2022). Available at https://data.worldbank.org/country/ghana?view=chart

1.7 Organization of the study

The study is structured in seven (7) different chapters as described below.

Chapter One – Introduction: This chapter sets the tone for the research. It provided a brief background to the subject matter from a global to local perspective and clearly described the problem statement. The aim and objectives of the study were clearly stated followed by the delineation of the research questions, and the testable hypotheses. The chapter concluded with the justification, and organization of the study.

Chapter Two – Literature review and Conceptual framework: The chapter begun with a brief overview of Ghana's energy systems and business sector development. This was followed up with a description of the theories that explain firms' investment decisions, adoption of new technologies and their productivity. Related empirical studies that have been done in Ghana, SSA and the rest of the world were reviewed next. Finally, the researcher's conceptual framework developed out of the reviewed theoretical and empirical literature was presented in the last section of the chapter.

Chapter Three – Methodology: Beginning the chapter was a description of the researcher's philosophical disposition. This determined the research design, the research subjects and types of data required, as well as the methodological procedures that the study adopted.

Chapter Four – Underpinning factors of energy systems choices by firms in the Greater Accra Region of Ghana: This is the first empirical chapter. It explored the fundamental reasons why certain energy systems were preferred and others ignored by firms in the Greater Accra Region during the most recent power crisis and post crisis periods.

Chapter Five – Financial performances of firms in the Greater Accra Region from 2015 to 2021 vis-à-vis the utilisation of different energy systems: This is the second empirical chapter that examined the effects of the costs and reliability of different electricity sources, as well as the different energy efficiency technologies used by firms in the Greater Accra Region on their financial performances from 2015 to 2021.

Chapter Six – Environmental performances of firms in the Greater Accra Region from 2015 to 2021 vis-à-vis the utilisation of different energy systems: This is the third empirical chapter that explored the relationship between the environmental performances of the firms and the different energy systems used in the Greater Accra Region from 2015 to 2021.

Chapter Seven – Summary, Conclusion, and Recommendations: This chapter concluded the research. The entire work was summarised and conclusions as well as recommendations were drawn out of the empirical findings presented and discussed in the empirical chapters. The limitations of the work were clearly stated in addition to the opportunities for future studies.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 Introduction

This chapter discusses theories, facts and works of other scholars that give context to the study. The chapter begins with a discussion of the concepts of energy systems and firm performance. This is followed by a review of Ghana's energy systems and development of the business sector. The next section reviews empirical works that have been done by other scholars on why firms prefer certain energy systems to others, and the implications on their performances. To provide theoretical context to the empirical literature, relevant theories that explain businesses' decision-making regarding key production inputs and how such decisions affect their performances are reviewed in the next section. The study is, therefore, grounded on these theories that serve as its backbone The last section presents and discusses the conceptual framework which draws on the theoretical foundations and empirical studies reviewed.

2.2 The concepts of energy systems and firms' performances

Energy system is understood to mean the flow of different types of energy and energy services in a defined space according to Bruckner et al. (2014) and Kullmann et al. (2021). It is described as a complex system because it involves combinations of different types of energy, sourced differently, and used variedly for different anthropogenic purposes (Bruckner et al., 2014). In this study, energy systems are conceptualised and operationalised into two broad categories:

- *Fuel*, which include electricity from the national grid, mini-grid, generators, and renewables like solar, wind, biogas; petroleum fuels (diesel, petrol, LPG); coal (if any); and nuclear (if any).

- *Energy efficiency technologies*, which include technologies such as energy efficient lighting, refrigeration, air-conditioning systems, as well as other energy efficient machineries or technologies that are used in the production process.

The study assesses the impact of the per unit of output cost and reliability of different fuels and energy efficiency technologies used by firms on their performances, where fuel is treated as a generic term to include national grid electricity, generators, renewables, petroleum fuels and others. Each of these energy sources would, therefore, be understood and used as ‘a fuel’ in this study. When firms switch between these fuels or continually use multiple fuels, they are eventually practicing fuel stacking (Yadav et al., 2021). The study, therefore, assesses the extent of fuel stacking among firms in Ghana, which fuels are often stacked, and how these fuel stacking services affect the performance of the firms.

The performance of companies is essential for sustainable growth and development because profitable enterprises create value, generate opportunities, employ people, promote innovation, and generate revenue for the government through taxes (Lazăr, 2016). It has, therefore, attracted a substantive interest from scholars across the fields of corporate finance, economics, and development. The discourse broadly discusses firm performance from two theoretical perspectives: market-based view (MBV) and resource-based view (RBV) (Lazăr, 2016). Whiles MBV places emphasis on the firm’s external environment and market characteristics (Cano et al., 2004; Grinstein, 2008) RBV focuses on firm-specific resources such as assets, capabilities, organizational processes, firm attributes, information, and knowledge available to the firm to enhance its performance (Barney, 1991; G. S. Day, 2011; Peteraf, 1993).

Though there is overwhelming evidence of the RBV in which firm-specific factors matter more than market characteristics partly due to the instability in most market indicators even in market economies (Grant, 1991; Hawawini et al., 2003; Makhija, 2003), the present study combines both RBV and MBV perspectives, yet, maintaining the dominance of the firm-specific factors.

The reason for the combined perspective is that external factors and market conditions play a critical role in cost structures, especially when energy is involved as an input, and resource acquisition which ultimately affect the performance of the firm.

In the literature, firm performance is mostly measured as a financial ratio such as return on asset, return on investment, earnings per share, net income, and net income to asset ratio (Asimakopoulos et al., 2009; Makhija, 2003; Yazdanfar, 2013). This study, however, considers the performance of the firm beyond its financial muscles to include its environmental performance, adopting the methods of Selvam et al. (2016) in the process. As Neely and Adams (2000) noted, including both financial and non-financial performance measurements provide better perspectives in linking performance systems to organizational strategy. This approach, thus, looks at the performance of the firm with a sustainable development lens rather than just with a financial or economic lens.

Selvam et al. (2016) developed a subjective model of the determinants of firm performance after reviewing extant literature on the subject. They identified nine (9) different performance indicators that can be treated as unidimensional or multidimensional: 'profitability performance, growth performance, market value performance, customers' satisfaction, employees' satisfaction, environmental performance, environmental audit performance, corporate governance performance and social performance' (p. 93). They were further classified into two dimensions: financial performance (which consist of the first 3 performance indicators) and strategic performance (which consist of the last 6 performance indicators). The measurement indicators of the profitability and strategic performance dimensions are shown in Table 2.1. The study primarily used monthly revenue as a proxy for financial performance. This is because it is easier for firms to keep records of total revenue, which makes data gathering on this indicator relatively easy. Some previous studies like Prajogo and Sohal (2006) and Baker and Sinkula (1999) have utilised total revenue as a proxy for firms' financial success while others like Topalova and Khandelwal (2011) and Melitz (2003) have used total revenue as a measure of firms' output. For the purposes of reliability and robustness, monthly profit (that is, revenue minus costs) was also used as a proxy for financial performance to assess how the monthly profit model compares to the monthly revenue model. Environmental performance was selected to represent the strategic performance of the firms. Accordingly, an environmental performance index was generated from nearly all the measurement indicators in Table 2.1 to represent the firms' environmental performance.

Table 2.1: Financial and environmental performance indicators and measurements

Broad dimension	Specific dimension	Measurement indicators
Financial performance	Profitability performance	Return on Assets, EBTIDA Margin, Return on Investment, Net Income/Revenues, Return on Equity, Economic Value Added (EVA)
Strategic performance	Environmental performance	Number of projects to improve or recover the environment, Level of energy intensity, Use of recyclable materials, Recycling level and Reuse of residuals, Volume of energy consumption, Number of environmental lawsuits

Source: Adapted from Selvam et al. (2016)

2.3 Overview of Ghana's energy systems and business sector development

2.3.1 An overview of productive energy systems in Ghana

This sub-section provides an overview of the different electricity sources available to business enterprises in Ghana.

2.3.1.1 The power (electricity) sector

The power sector in the period before the 1980s in many SSA countries was fraught with years of protracted rigidity, stagnation as well as poor financial and technical performance (Acheampong et al., 2021). As a result, major reforms were undertaken in the 1980s and 1990s as part of the structural adjustment and economic transformation policies with the purpose of creating a vibrant power sector capable of truly supporting private sector development, economic growth, and poverty reduction in the sub region (Acheampong et al., 2021). The sector got liberalised and the market became favorable for private sector participation. Ghana adopted the Power Sector Reform Programme (PSRP) in 1995 which decoupled the generation, transmission, and distribution sub-sectors and to be managed by different institutional frameworks but with strong coordination among them. This reform introduced competition into the power sector through the introduction of the independent power producers (IPPs) scheme (Acheampong et al., 2021). The supporting policy instruments that were developed to guide the development of the sector include the 2010 National Energy Policy, which is closely linked to the 2010 Energy Sector Strategy and Development Plan, the Strategic National Energy Plan (2006 – 2020), the 2015 Sustainable Energy for All Action Agenda and the 2019 Renewable Energy Master Plan (EC, 2006, 2015; Ministry of Energy [MOE], 2010a, 2010b, 2019).

The energy reforms led to a notable development in the power supply infrastructure in Ghana. The total electricity installed generation capacity significantly increased from 1,652MW in 2000 to 5,481MW in 2020. There were as many as 15 installed thermal plants constituting about 68 percent of the total installed generation capacity in 2021 compared to only 7 installed as of 2012 (EC, 2022). While the role of the reforms in the development of the power sector has been significant, it can be argued that the increased investment in the power infrastructure can be attributed partly to the response by the government of Ghana during the power crises experienced in 2007 and 2012-2016 in the country. For example, during the 2012-2016 power crisis era, the government entered into some emergency power purchase agreements including, the Karpowership, AKSA Power, Africa Middle East Resources Investment (AMERI) Group and Early (Bridge) Power to ensure guaranteed supply of electricity to the country (Acheampong et al., 2021). As depicted in Figure 2.1, electricity sourced from thermal plants dominated the grid electricity landscape in Ghana since 2016. Although some renewable energy (RE) resources have been added since 2013, the share of renewables in the total grid generated electricity as of 2021 is about 0.55 percent (EC, 2022).

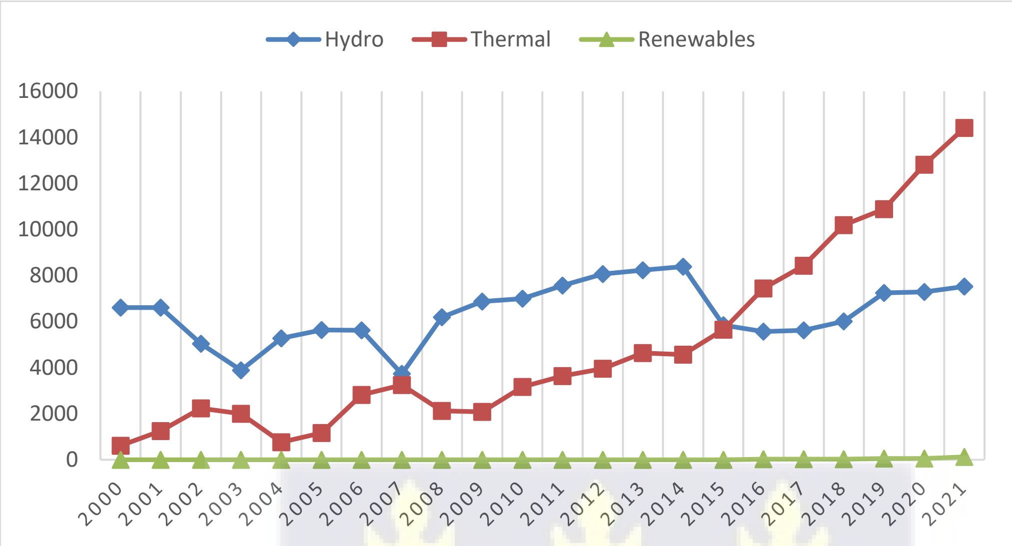

Figure 2.1: Grid electricity generation (GWh) 2000-2021

Source: Author's construct based on Energy Commission (2022)

The electricity generation sources have implications on power pricing in Ghana. Power from thermal plants via IPPs that guarantee reliable supply usually has higher generation costs compared to power generation from the traditional hydro plants. An automatic adjustment formula (AAF) which considers the fuel mix (crude oil, natural gas, or distillate fuel), the Ghana Cedi-US Dollar exchange rate, hydro-thermal generation mix, and changes in consumer price index, has been introduced since 2002 to compute end-user tariffs in Ghana (Public Utilities Regulatory Commission [PURC], 2011). However, the AAF had not been used effectively due to government's intervention in the market to cushion the consumer rather than passing on the true cost of electricity to the end-users (Acheampong et al., 2021; Gyamfi et al., 2018). This move was a major disincentive to power generation especially for the IPPs who feared they might not be able to breakeven.

Despite the government absorbing some part of the electricity cost, end-user tariffs have grown at an average of about 10% per annum since 2000 from US$ 0.024 per kWh to about US$ 0.13 per kWh in 2021 (see Figure 2.2), reflecting the growing thermal proportion in the power generation mix. Broken down further, non-residential activities with 0-300 kWh consumption range were charged 25 GHp/kWh in 2011 compared to 80 GHp/kWh in 2020. Activities with 600+ kWh consumption were charged 42 GHp/kWh in 2011 compared to 134 GHp/kWh in 2020 (see Figure 2.3). These non-residential tariffs combined with their corresponding service charges (1,243 GHp/month in 2020)[6] were among the highest in the sub region (EC, 2022).

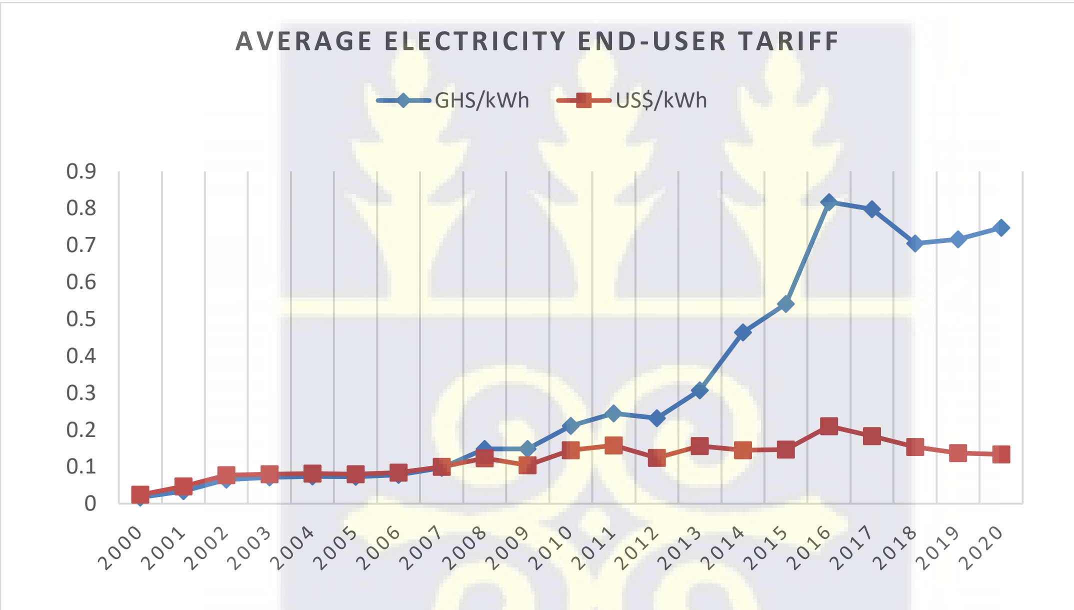

Figure 2.2: Average electricity end-user tariff

Source: Author's construct based on Energy Commission (2022)

[6] According to the Bank of Ghana, the average exchange rate for 2020 was 1 US$ equivalent to GHS 5.57. Available at https://www.bog.gov.gh/treasury-and-the-markets/historical-interbank-fx-rates/ (Accessed: 09/11/2022)

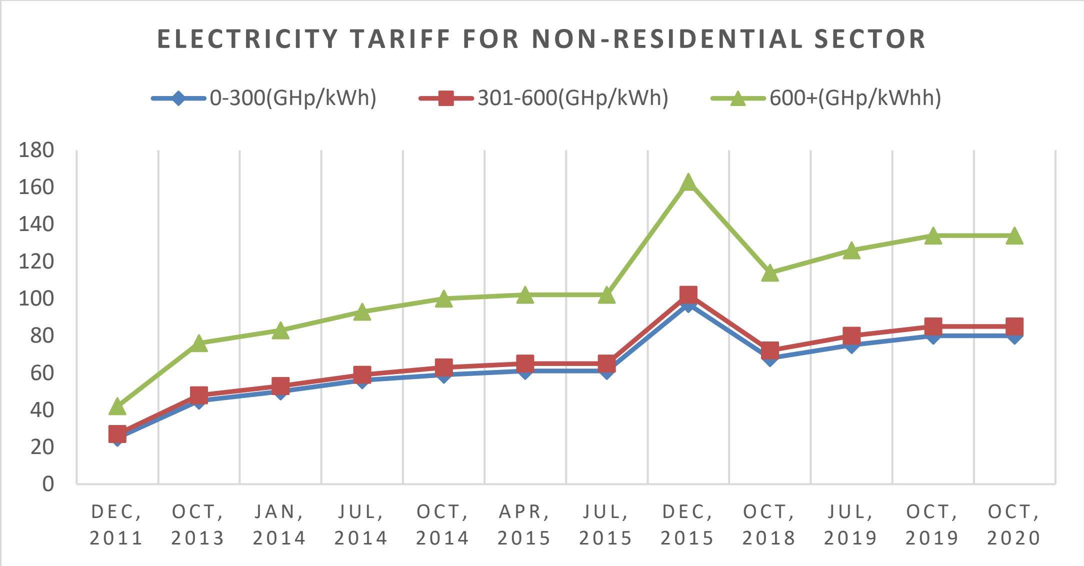

Figure 2.3: Electricity tariff categories for the non-residential sector

Source: Author's construct based on Energy Commission (2022)

2.3.1.2 The petroleum sector

The petroleum sub-sector has been a major contributor to Ghana's growth and development in recent years. Ghana grew at an average of 5.5 percent in the pre-oil production era (2001-2009) but averages 8 percent per annum since oil production began in 2010 (Ghana Statistical Service [GSS], 2018). Ghana started production of oil from the Jubilee Field in 2010 before the Twenneboa, Enyenra, and Ntomme (TEN) fields came onstream in 2016 and Sankofa field in 2017. These additional fields have an estimated 740 MMbo and 1.846 trillion cubic feet of gas in reserves[7]. Unlike crude oil which is mostly exported (see Figure 2.4) per the production contract agreement, natural gas is produced and transported via the Kwame Nkrumah floating production storage and offloading (FPSO) to the onshore Atuabo Gas processing facility to be processed mainly for the domestic gas needs of households and thermal power plants for electricity production.

[7] These were reported by Tullow Oil (2017), 'TEN fields'. Sourced from https://www.tullowoil.com/operations/west-africa/ghana/ten-field (Accessed: 21/08/2020)

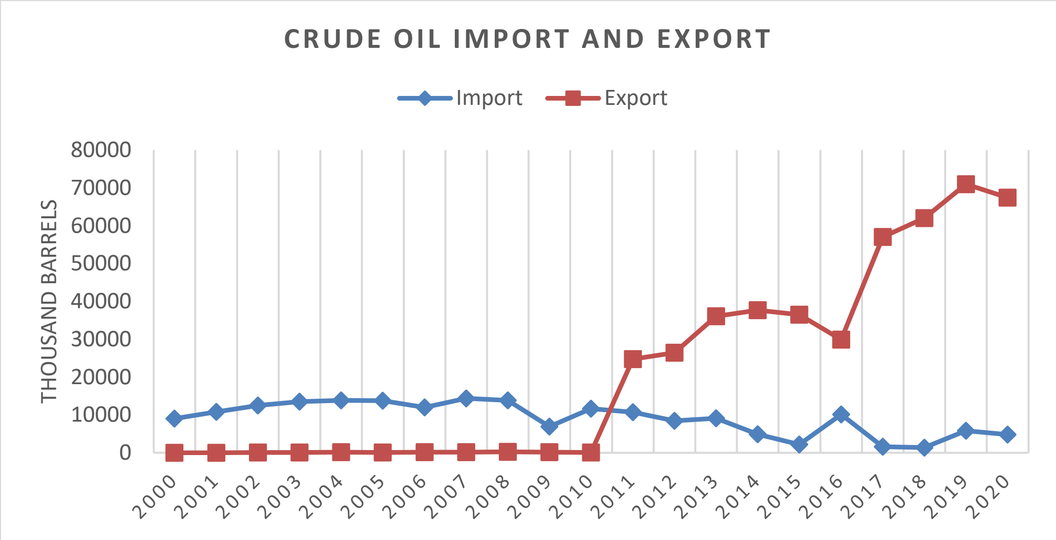

Figure 2.4: Crude oil imports and exports (2000-2021)

Source: Author's construct based on Energy Commission (2022)

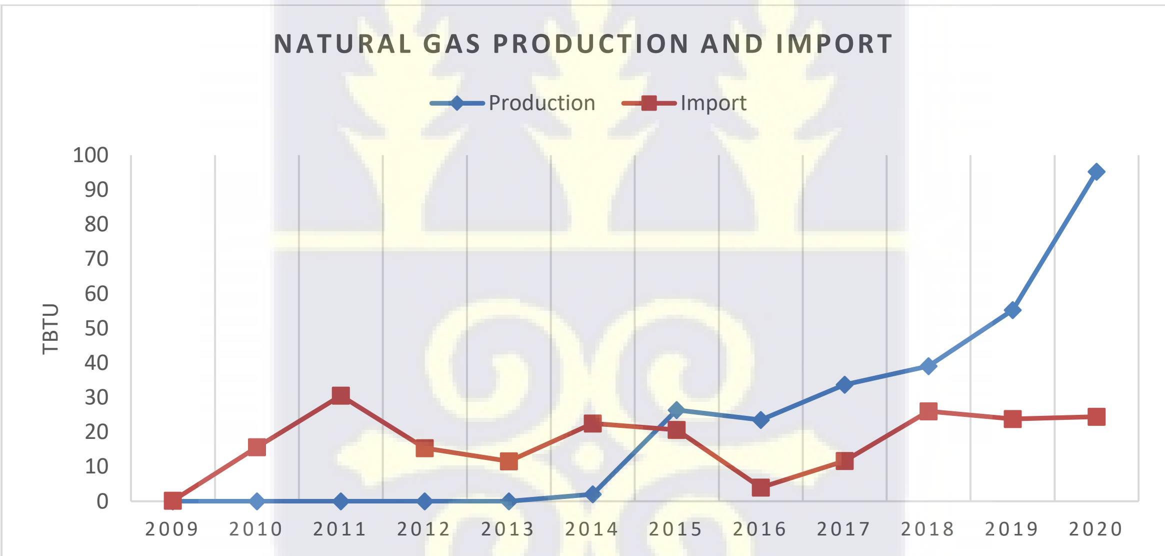

Figure 2.5: Natural gas production and imports (2000-2021)

Source: Author's construct based on NPA and Petroleum Commission data (2022)

Various petroleum products have been produced, imported, exported, and consumed in Ghana. These include liquefied petroleum gas (LPG), gasoline, kerosene, aviation turbo kerosene (ATK), gas oil, and residual fuel oil (RFO). As observed in Figure 2.6, imports and consumption of petroleum products have trended in a similar pattern. This is because most of the petroleum products consumed are imported since the Tema Oil Refinery (TOR) has remained ineffective for years. As a result, not many of the final products of petroleum are produced for domestic consumption or exportation.

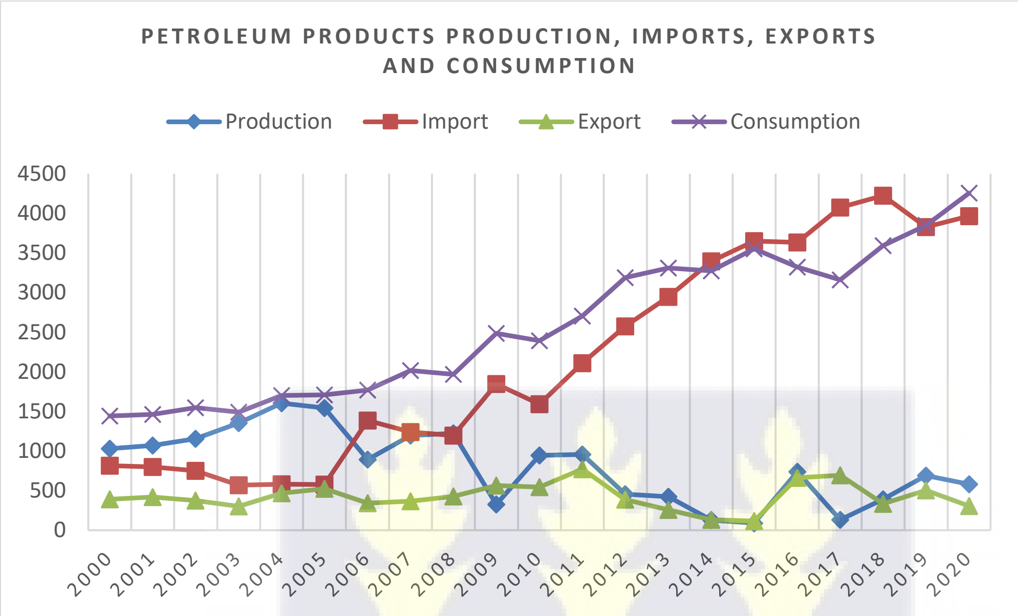

Figure 2.6: Petroleum products production, imports, exports, and consumption (2000-2021)

Source: Author's construct based on EC (2022)

The international crude oil prices have trended irregularly since 2010. It increased from 43.3 US$/lt in 2008 to 125.9 US$/lt in April 2012, plunged to 31 US$/lt by January 2016 before averaging 64.2 US$/lt in 2019 and 70.8 US$/lt in 2021 (EC, 2022). The international crude oil prices affect the Ghanaian economy in two-folds. Firstly, increased crude oil prices since 2010 means increased revenue from the 12.5 percent royalties, 48.64 percent carried and participating interest, and 35 percent corporate income tax that comes to Ghana from the oil proceeds (Ministry of Finance, 2019). However, since Ghana remains a net importer of crude oil and petroleum products, increased crude oil prices translate to inflated prices of other goods and services which eventually lead to increased cost of doing business. Evidence from the ex-pump price statistics in Figure 2.7, the ex-pump prices of all the petroleum products have steadily been increasing from 2000, peaking in 2019, slumping in 2020 largely as a result of the global COVID-19 pandemic, before rebounding again in 2021.

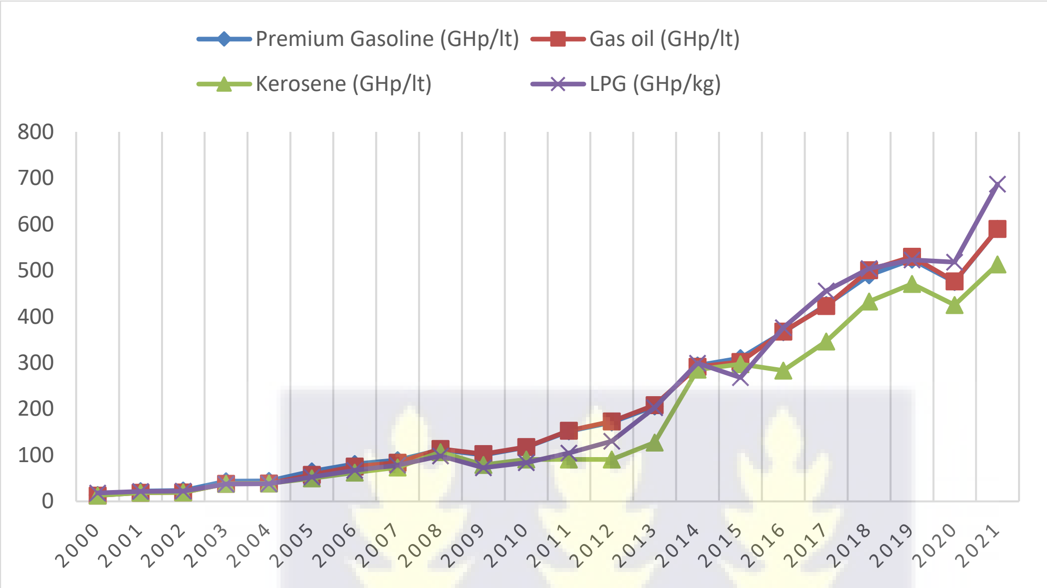

Figure 2.7: Average ex-pump prices for petroleum products (2000-2021)

Source: Author's construct based on EC (2021)

2.3.1.3 Energy efficiency and renewable energy systems

Outside of the conventional energy systems discussed above, there are relatively new energy systems that are being discovered, developed and available to energy users in Ghana due to the advancement in technology. Ghana is well endowed with solar, wind, mini-hydro, biomass, and waste resources that could generate substantial electric power to complement the traditional grid system (Aboagye et al., 2021; Asumadu-Sarkodie & Owusu, 2016; Gyamfi et al., 2018; IRENA, 2015a; Kuamoah, 2020). To support the development of these resources and the promotion of the use of renewable energy, the Renewable Energy (Amendment) Act, 2020 (Act 1045) was passed and assented to by the President as a supportive framework to create the enabling environment that will attract investment in the renewable energy sector (Government of Ghana [GOG], 2022). Additionally, the 2019 Renewable Energy Master Plan (MOE, 2019) and 2015 Sustainable Energy for ALL Action Agenda (EC, 2015) were specifically designed with clear policy targets to promote the adoption of renewable energy technologies in Ghana. The Ghana Renewable Energy Handbook, which is updated periodically, offers comprehensive information on major policies governing the renewable energy market in the country. One of the primary RE targets is 10% renewable energy in the energy mix by 2030. However, very little had been achieved at the national level regarding the achievement of this target since there was only 0.55% of renewable in the energy mix as of 2021 with only nine (9) years remaining till the end of the target period (EC, 2022).

Additionally, very little has been documented on the adoption of RETs at private levels. Some limited businesses, especially those in the hospitality industry, have been reported to have installed solar water heating systems while others have also installed solar panels to power lights and other non-heavy equipment. The most cited reason for the adoption of these technologies is cost saving (I. K. Ofori et al., 2022; Pueyo et al., 2016) and the most reported factor for the non-adoption is again installation and maintenance costs (Asante et al., 2021; I. K. Ofori et al., 2022; Pueyo et al., 2016; Willis et al., 2011). The other technologies that have received far more recognition are energy efficiency technologies. Following the passing of the air-conditioners and compact florescent lights (CFLs) regulation in 2005 and the Energy Efficiency Standards and Labelling Regulation in 2010 in Ghana, different energy efficient technologies with respect to refrigeration, air-conditioning, and lighting have been adopted by businesses in the country (Gyamfi et al., 2018). To stimulate the adoption of these technologies by businesses and households, the Energy Commission (EC) led the CFL replacement programme in 2007 which saw some 6 million incandescent lamps replaced with CFLs leading to the reduction of 124 MW in peak load and saved about US$ 33million annually (EC, 2019).

The EC also championed the Refrigerator Rebate and Exchange Scheme in 2012 for Ghanaians to replace their old power-consuming refrigerators with new energy-efficient ones. The scheme reportedly saved 400 GWh of electricity, 1.1 million tonnes of Carbon dioxide and recovered 1500kg of Chlorofluorocarbon for the country (EC, 2019; Tamakloe, 2022).

2.3.2 An overview of Ghana's historical economic and business structure

Ghana's business sector players include individuals, small and big organizations, private and public actors whose activities cut across local, national, and international levels either as part of informal or formal sectors (Hoedoafia, 2019). The business sector has gone through many developmental phases akin to Ghana's economic development. In the pre-independence and immediate post-independence eras state-owned enterprises were established with the intention of transferring them to the private sector only after the latter had become a viable entity (Killick, 2010). As early as 1960, this idea was abandoned as the state-owned enterprises were deemed best for Ghana's industrialization drive and as many as 280 state-owned enterprises were in operation as of 1980 (Brownbridge et al., 2000), some of which were tasked to produce goods that can substitute for imported goods at the time (Fosu, 2013b). But this strategy proved unsustainable as Ghana witnessed poor performances of the state enterprises that contributed to negative growth rates recorded in the 1970s (African Development Bank [AfDB], 2011; Fosu, 2013b).

The Washington Consensus was adopted in 1983 in the forms of the Economic Recovery Programme (ERP) and the Structural Adjustment Programme (SAP). It was sponsored by the Bretton Woods institutions led by the World Bank and the International Monetary Fund (Fosu, 2013a; Hoedoafia, 2019). At the heart of this reform was the minimum role that government was supposed to play in formulating conducive policies while the private sector and market forces were charged to drive growth and development (Sawyerr, 1999). Over 70 percent of some 324 state owned enterprises were diversified by 2000 (Appiah-Kubi, 2001) and the real economy improved steadily following the adoption of the SAP/ERP. The purchasing power parity (PPP) adjusted per capita income which was lower than the SSA average by 1983 increased steadily from US$ 1,387 in 1983 to US$ 2,300 by 2006 (Fosu, 2013a).

Beyond the SAP/ERP, other economic policies have contributed to the development of the business sector in Ghana. The Ghana Poverty Reduction Strategy I (GPRS I: 2003 – 2005) and the Growth and Poverty Reduction Strategy II (GPRS II: 2006 – 2009) aimed to increase the capacity of firms to be able to operate efficiently and effectively through medium term Private Sector Development Strategies I & II (National Development Planning Commission [NDPC], 2005). The Ghana Shared Growth and Development Agenda I & II (GSGDA I: 2010-2013; GSGDA II: 2014 – 2017) sought to improve the private sector's domestic and global competitiveness, pursue accelerated industrial development, develop micro, small, and medium enterprises, pursue and expand market access among other strategies (NDPC, 2010, 2014). The Coordinated Programme of Economic and Social Development Policies (CPESDP): Agenda for Jobs I (2017 – 2024) and Agenda for Jobs II (2021 – 2025) sought to revamp Ghana's economic and social infrastructure, transform the agriculture and industry sectors. One of the industrial-focused initiatives under the CPESDP is the "*One District, One Factory (1D1F)*" which is to be implemented through public-private partnerships to establish at least one industrial enterprise in each of the 216 districts in Ghana. This initiative was launched in 2017 with the intention of changing the Ghana's economy from one of import dependence and export of unprocessed goods to one that focusses on manufacturing, value addition and export of processed goods.

The business sector has generally improved in terms of number, size, and performance over the years. From a documented 26,493 industrial establishments censused in the 2003 national industrial census report (GSS, 2006), the number of industries has increased to 108,242 as of 2014 (a 309% increment) whiles 527,161 and 2,831 services and agricultural establishments were also reported in 2014 respectively (GSS, 2017). Businesses in the services sector continue to dominate the business landscape in Ghana with wholesale and retail trade; accommodation and food; education; financial; and insurance as some of its dominant activities. Manufacturing; construction; mining and quarrying; electricity and gas; water supply; sewerage; and waste management are the main activities of the industry sector while crops and livestock dominate the agricultural sector (GSS, 2017).

Business enterprises across all sectors are categorised into large-sized (More than 100 persons engaged), medium-sized (31-100 persons engaged), small-sized (6-30 persons engaged), and micro-sized (5 or less persons engaged) by the Ghana Statistical Service (GSS, 2017). As of 2014, nearly 80% of all business establishments are micro-sized followed by small-sized firms (18%) (GSS, 2017). In terms of profitability, all establishments in the three sectors have together kept profit margins above 60 percent with gross revenues far exceeding gross costs incurred in the production of the goods and services (GSS, 2015, 2017). Finally, about 3,383,206 persons (representing about 23% of the adult population of Ghana) were engaged by the business establishments as of 2014 (GSS, 2015, 2017). There has been noticeable growth in the business sector since 2003 in terms of the population of enterprises and employment generation. However, the sector has fallen short of delivering the level of domestic and global competitiveness that guarantees accelerated industrial development as envisioned in GSGDA I & II. Ghana remains a net importer with little or no value being added to its export commodities which often results in a significant pressure being placed on the local currency (Ghana Cedi) against other trading currencies (Okyere & Jilu, 2020). Additionally, Ghanaian firms are deemed to produce under capacity with high inefficiencies and are often hindered by the lack of adequate finance to expand and power supply challenges that interrupt productive activities (Ackah, 2015; Kumi, 2017).

2.4 Review of Empirical Literature

Under this section, studies that analytically explored the reasons why firms choose to invest in certain energy systems are reviewed as the first strand. This review concentrated on the various energy systems including grid electricity, self-electricity generation systems, RETs, and energy efficiency technologies that are commonly used by firms within a developing country context like Ghana. The second strand of the review focused on empirical studies that examined how firms' performances are affected by the different energy systems. For each strand, the review process focused on available studies within the global context (that is, countries outside the African Region), followed by regional level studies (African countries), and finally, those that looked at Ghana only. In some cases, the review was undertaken on the lines of developed and developing contexts.

2.4.1 Energy systems and preferences by firms

2.4.1.1 Grid electricity

Electricity has been described as an indispensable economic driver (Preuninger, 2014). Predominantly supplied by states' grid facilities, electricity is viewed as a major factor in the overall economic development success of many economies across all regions (Preuninger, 2014; Stern, 2019). The International Energy Agency [IEA] (2020) assessed the global electricity market with clearly delineated regional analysis covering how much of electricity is supplied and consumed in 2020 and by which sectors. What is reported by IEA is that the industrial/commercial sectors are the most electricity intensive sectors across Europe, Americas, Asia Pacific, Southeast Asia, and Africa because businesses are very dependent on the national grid electricity system, albeit, at different degrees.

In the developed world, states' grid power is extensively used by firms because of their comparative cost advantage, reliability, and accessibility. According to Preuninger (2014), 'electricity is almost always on short list of cost considerations when companies scout locations for offices, manufacturing plants and e-commerce hubs' (p. 42). The researcher made an example out of Data centers in the U.S.A as facilities that require massive amounts of power from the state's grid and, therefore, gravitate a lot in Texas where they are assured of affordability and reliability. Bardazzi et al. (2015) assessed how manufacturing firms in Europe, specifically in Italy react to relative price changes before investing in different fuels. By estimating factor and fuel demand elasticities using a microeconomic panel in a two-stage translog model, the researchers concluded that general substitutability exist between electricity, natural gas, and gasoil (except for medium low technology sectors) but electricity and natural gas exhibit lower elasticities because they are more difficult to replace than the other inputs. Apparently, grid electricity in Europe is considered difficult to replace --which encourages increased investment in it-- because they are readily available, easily accessible, and have lower relative prices (Bardazzi et al., 2015; Solnørdal & Foss, 2018).

Similarly in developing countries, firms depend on grid electricity for a large part of their production activities (Baurzhan & Jenkins, 2016). For a long period, it has been studied as a sole proxy for energy and proven to positively impact growth through enhanced productivity from industries and services sectors (Fried & Lagakos, 2020; Twerefou et al., 2018). As of 2018, the combined total electricity production capacity for the SSA sub-region is around 80 GW and South Africa alone accounts for about half of it (Vessat, 2018). Additionally, the per capita production capacity of the sub-region is about 0.08 GW, far lower than per capita production rates in some developed countries for instance 1.94 GW in France (Vessat, 2018).

Firms in developing countries invest in grid electricity for the same reasons observed in developed countries, except for reliability. Eberhard et al. (2011), Fried and Lagakos (2020), and Scott et al. (2014) observed that grid electricity is highly unreliable in developing countries unlike in advanced economies. Yet, most businesses and households find it more convenient to be connected to the national grid electricity in the sub-region because of the ease of access, and the fact that there exist already established grid infrastructure systems (Blimpo & Cosgrove-Davies, 2019). Bawakyillenuo (2012) for instance, observed that potential power consumers (businesses and households) in rural areas in Ghana without electricity will rather wait for the national grid electricity to get to them naturally even if that will take a while instead of accepting other alternative power systems such as off-grid power supply system. Even though studies have found an increased willingness-to-pay for reliable alternative fuels (Deutschmann et al., 2021; Gunatilake et al., 2012), grid electricity is still a first-choice power source for businesses in most developing countries.

2.4.1.2 Own-power generation (diesel/petrol powered generators)

Aside from transportation, firms also depend on petroleum products, particularly diesel, petrol, and LPG for various productive activities. Predominantly, these fuels are used in self-power generation to supply a back-up power if the primary source fails (Fried & Lagakos, 2020). The most pronounced reason for their usage is reliability even if investing in them comes at a relatively higher cost. Alby et al. (2012) reported that most developing countries are unable to meet the energy demands of their businesses due to the unreliability of their first-choice energy source, the national grid electricity. Accordingly, the average power outrages from the national grid per year are as many as 132 in South Asia and 61 in SSA. Also, nearly half of all the firms sampled in their study experience over 30 outages per year (Alby et al., 2012). Because of these power outages, the firms have invested in diesel- and petrol-powered generators as alternative power sources. The researchers used data from enterprise surveys for 87 countries covering a total of 46,606 firms over a 5-year period of 2002-2006. The investigations reveal that 37 percent of all firms selected from SSA own or share a generator compared to 62 percent in South Asia.

In an earlier pooled study, Foster and Steinbuks (2009) examined the prevalence of in-house electricity generated by firms in SSA using the World Electric Power Plants database and the World Bank's Enterprise survey database. The study found that own power generation constitutes 6 percent of the total installed power generation capacity in SSA, exceeding the share in the United States (3.7%) and almost equal to the entire Europe (7.3%). They also found out that the proportion of self-generation power increases to 12 percent for low-income SSA countries. For example, in Mauritania, Equatorial Guinea, D.R Congo, Nigeria, and Swaziland, self-generation power accounts for more than 20 percent of the respective total installed generation capacities. Foster and Steinbuks (2009) and Oseni (2012) identified firm size, the need for emergency back-up and export regulations as key factors that inform the decision to own and operate a generator. Based on these determining reasons, firms in SSA are projected to continue depending on self-generation of power generation because of the inherent structural challenges with the power supply infrastructure (Steinbuks & Foster, 2010).

Oseni and Pollitt (2015) carried out a similar firm-level analysis of outage costs for 2665 firms in eight (8) SSA countries. They observed that owing to the unreliable power supply system in these countries, self-generation of power is very common among SSA countries. As high as 86 percent of the firms selected in Nigeria own generators while 63, 51, 32, 28 and 25 percent of firms selected from Kenya, Senegal, Mali, South Africa, and Ghana also own and use generators respectively. Similarly, Abdisa (2018) reported that firms in Ethiopia adapt to the increased cost of power outages by investing in self-generation plants whiles Abeberese et al. (2021) also found that about 26 percent of 885 small and medium-sized firms surveyed in Ghana used generators as a result of power outages.

2.4.1.3 Renewable energy technologies (RETs)

RETs are more utilised in advanced economies than in emerging and developing economies (Halkos & Tzeremes, 2014). It is established that substitution of fossil fuels by renewable technologies is a cost-intensive investment that will only be undertaken by firms if relative costs of fossil energy sources rise significantly, or hefty subsidies are provided for renewable energy technologies (Horbach et al., 2012; Popp et al., 2010). In effect, a fundamental motivator for investing in RETs is the decreasing cost of the technologies relative to existing energy systems. Germany is one the countries following a decentralised approach of green transition where energy consuming firms are adopting renewable energy technologies thereby actively driving the transition process (Horbach & Rammer, 2018). Having combined Community Innovation Survey 2014 data and district-level data on renewable energy plants in Germany, Horbach and Rammer (2018) found a high and positive correlation between investment in renewable energy technologies and orientation of a region towards green issues, as well as geographical proximity to the renewable energy resources. They concluded that diffusion of renewable energy in firms is not solely driven by hard regulation measures but also the firms' regional environment in the diffusion process.

Nonetheless, the impact of policies and regulations cannot be downplayed in influencing the adoption of renewable energy innovations. Johnstone et al. (2010) analysed the effects of different policy instruments on the development of renewable energy technologies using a patent data for 25 countries spanning 1978-2003 period. Their analysis reveals that feed-in-tariffs led to the development of solar technologies by firms in these countries over the period but more cost-competitive technologies such as wind power are not triggered by this policy instrument. Groba and Breitschopf (2013), Cantner et al. (2016), and Costantini et al. (2017) uncovered the important role of specific renewable energy policies in overcoming market failures and promoting the adoption of renewable energies in Germany. Similarly, Wörter et al. (2017) employed a large sample of firms from Austria, Germany, and Switzerland. They observed that policies promote the decision to adopt green energy technologies, but they are ineffective in driving the size of the investment. The researchers also clarified that the effectiveness of various policies differs across countries. While subsidies turned out to be more effective in Austria, taxes and demand-related factors were more effective in Germany and Switzerland respectively.

Finance has also played a key role in entities investing in RETs. Renewables usually require higher upfront capital investments. Nelson and Shrimali (2014) estimated that upfront capital costs represent 84-93% of total project costs for wind, solar and hydro energy compared to 66-69% for coal and 24-37% for gas. They further argued that most of these technologies are still in their early stages of development, implying higher failure rates as well as higher associated risks. No doubt Ghosh and Nanda (2010) and Nanda and Rhodes-Kropf (2013) discussed how entrepreneurs in renewable energy need risk capital, not only in early stages, but also later to demonstrate that the technology can work. This is less of an issue for fossil fuel technologies that are well established in the energy sector. After carefully analyzing the role of financial constraints in the development of renewable energy technologies using patent dataset for 1,300 European firms spanning 1995-2009, Noailly and Smeets (2016) observed that innovative newcomers in the field of renewable energy are especially concerned by financial constraints "…not solely because they are younger and less mature than other established firms, but mainly because they focus on new clean technologies that are still perceived as more risky by investors than the incumbent technologies based on fossil-fuel electricity generation" (p. 5).

In developing regions, investment in renewable energy technologies by firms are not only less common, but also less documented compared to the developed world. China is the leading country in Asia in terms of the potentials and adoption of renewable energy technologies (Chen et al., 2014; Ng & Tao, 2016). The country made the remarkable transition from being a net importer of renewable energy products from the early 2000s to the world's largest manufacturer and exporter of these products by early 2010s (Dent, 2015). China's state-owned enterprises played a key role in the development of renewable energy systems as large-scale central government corporations and smaller local government-owned companies invested in renewable energy technologies to guard against supply risk, price risk, and environmental risk associated with the traditional and fossil fuel technologies (Dent, 2015).

Ghana, Nigeria, Cameroon, and South Africa are among the African countries endowed with abundant renewable energy resources with the potential to improve their respective electricity generation capacities, yet the potentials are far from fully harnessed (Amankwah-Amoah & Sarpong, 2016; Ibrahim et al., 2021). The development of renewable energy systems in these countries is being carried out at national level via the national grid systems with little known about the their adoption by individuals and firms (Ibrahim et al., 2021; Kuamoah, 2020). East Africa, by virtue of it being the pioneer of innovative business models that disseminated renewable energy technology systems in underserved markets to meet the growing demand (IRENA, 2021; Pueyo et al., 2016), leads in the adoption of these systems. Businesses in this sub-region (East Africa) and Southern Africa, particularly South Africa are encouraged by government subsidies, tariff reliefs, and cost savings to become green energy 'prosumers' i.e., producers and consumers of their own energy (Amankwah-Amoah, 2015; Mukoro et al., 2022; Pedersen, 2016; Pueyo et al., 2016).

The low adoption of renewable energy systems in developing countries is mostly attributed to high initial cost outlay of the technologies (Chen et al., 2014; Mukoro et al., 2022; Njoh et al., 2019), financing constraints (Ahenkan et al., 2021; Halkos & Tzeremes, 2014; Kuamoah, 2020), limited technology capacity and experience (Ahenkan et al., 2021; Kuamoah, 2020; Njoh et al., 2019), unpragmatic policy instruments (Chen et al., 2014; Mukoro et al., 2022), and low public awareness (Ahenkan et al., 2021; Kuamoah, 2020). The United Nations

Development Programme (UNDP) and the Energy Commission in implementing the 'China-Ghana South-South Cooperation on Renewable Energy Technology Transfer' found out from a desktop study that about 48 factors impede the investment and adoption of RETs in Ghana, some of which are high upfront cost, underdeveloped supply chain, poor operations and maintenance of facilities, lack of technical knowhow, and lack of information about cost and benefits of RETs (UNDP & EC, n.d.). Also, Ahenkan et al. (2021) assessed solar energy adoption among SMEs in the City of Accra, Ghana and found inadequate financial support from service providers, limited technical after-sales support, limited consumer credit facilities and low public education on RETs to be important barriers to solar adoption among small businesses. Similarly, Kipkoech et al. (2022) found the development of RETs in Ghana to be hampered by cost of the technologies, financial issues and technical barriers even though the country has seen an increase in the exploitation of RETs compared to past decades.

2.4.1.4 Energy efficiency technologies

What firms seem to lack in one arm (RE investment) of the sustainable energy technology, they compensate for in the other arm, i.e., investment in energy efficiency (EE) technologies. Firms are venturing into energy efficiency technologies due to rising energy prices (Karlsson, 2011; Schulze et al., 2016). Gouws et al. (2012) showed that EE correlates with organizational success after they have surveyed 34 respondents from 10 industrial activities in South Africa. They found that 70% of the surveyed firms engage in energy consumption strategies in their day-to-day operations. According to Gouws et al. (2012), some EE practices undertaken were "retrofitting of equipment, planting automation and control, training on human intervention and behaviour" (p.8). Ninety-six percent of the respondents regard investing in EE to be more rewarding than RETs (ibid). In another study, Adewunmi et al. (2019) reported that EE lighting is the most practiced EE action in facilities management in Johannesburg in South Africa after conducting an electronic survey for the facilities' managers.

Similar to the above studies, Fatoki (2019) and Dippenaar (2018) found many SMEs to be using different EE practices in South Africa after studying immigrant small business owners. Dippenaar (2018) noted that large firms are motivated to invest in EE technologies by non-tax factors rather than the prevailing tax incentives which they found to be unconvincing and non-motivating. In a cross-sectional study of 8174 firms in Ethiopia by Hassen et al. (2018) and a panel study by Adom (2019), the researchers observed that the decision to invest in EE technologies is determined by firm size, income, urbanization and how clustered they set up. Though the findings of a systematic review of USA and Western European countries' literature carried out by Solnørdal and Foss (2018) lend support to the fact that organizational and economic drivers like firm size and income are most prominent stimulus for energy efficiency, other scholars found different drivers. Lopes et al. (2022) found environmental concerns to be the most influential driver for companies in Portugal investing in sustainable innovation strategies after they qualitatively explored nine Portuguese companies, while Maniu et al. (2021) also arrived at the same conclusion after they studied the adoption of green environmental practices in small and medium-sized enterprises in Romania. All the studies, however, agree on the fact that policy instruments and regulations are of lesser importance.

In Ghana, Agyeiwaah (2019) explored the relevance of sustainability practices like using energy-efficient refrigerators, switching off electrical appliances when not in use and the use of EE lighting bulbs to micro tourism and hospitality accommodation enterprises in Cape Coast, Ghana. The researcher observed that home-stay owners were very much concerned about the amount of energy they consumed hence entreated customers to abide by energy conservation rules. It is evident that the rate of adoption of the EE technologies has picked up reasonably well since the energy efficiency standards and labelling initiatives by the government in 2005 (Tamakloe, 2022) but other scholars like Opoku et al. (2019) are concerned that 85 percent of air-condition (AC) and refrigerator users in Ghana often purchase the lowest (1 star) and next lower (2-3 stars) EE rated categories of air-conditioners which save less energy compared to higher-rated ones.

2.4.2 The productivity impacts of different electricity types and energy efficiency technologies

2.4.2.1 Different electricity types and firm productivity

This section focusses on empirical studies that investigated the productive impacts of different electricity types used by firms. Specifically, the impacts of the characteristics of these different electricity types including their per unit of output costs and their reliability in terms of hours of availability or outages, are considered in the empirical review.

The energy-growth nexus has been extensively researched for decades. The consumption of energy, represented by different fuels, have been found to be pro-growth. Aqeel and Butt (2001), for instance, found electricity consumption to promote economic growth in Pakistan, Yuan et al. (2008) discovered positive short- and long-run relationships between output and energy use in China. Tang et al. (2016) argued that energy, together with foreign direct investment (FDI) and capital stock positively influence economic growth in Vietnam while Hassan et al. (2022) found a positive impact of electric power consumption on economic growth in the long- and short-run in Finland and Portugal, and in the long-run in France.

In the African region, Twerefou et al. (2018) explored the causal relationship between total energy consumption, electricity consumption and petroleum consumption on one hand and economic growth on the other hand for 17 West African countries. They found electricity and petroleum consumption to impact growth positively in the long run. At a micro level, Pueyo et al. (2020) explored energy use and enterprise performance in Ghana with a gender lens that had long been overlooked in the energy and development literature. After sampling 400 microenterprises for a firm-level survey coupled with in-depth interviews, key informant interviews and focus group discussion, the researchers found a positive correlation between the use of electricity and business profit, regardless of the owner's gender.

Focusing on the specific characteristics of the energy systems consumed by business enterprises, Garrone et al. (2019) argued that businesses and households in most developing countries that are connected to the grid system experience frequent black-outs and brown-outs. In a pooled country study by Blimpo and Cosgrove-Davies (2019) more than half of connected businesses and households in countries like Ghana, Burundi, Guinea, Liberia, Nigeria, and Zimbabwe reportedly received electricity from the national grid less than 50 percent of the time as of 2014. Some of these characteristics can be anti-growth.

Abdisa (2018) explored the effects of the frequent, yet prolonged power outages experienced in Ethiopia on businesses and the entire industrial sector that is very reliant on the hydro-powered national grid. Accordingly, the overall estimated marginal cost of power outages on firms in Ethiopia is $1,625 translating into an overall increase in the total cost of firms by $76,830 (a 15% increment) from 2011 to 2015 due to power outage. This cost outlays led to decreased productivity which is more pronounced for small firms because they face stiffer financial challenges when it comes to adapting to the power outages. Adenikinju (2003) and Moyo (2012) observed similar results in Nigeria where about 76% of manufacturing firms lost 9 percent of their sales to power outages. Adenikinju (2003) noted that firms in Nigeria spend 20-30 percent of their initial investment capital to fix power supply issues owing to the unreliability of the grid electricity.

Cole et al. (2018) examined the impact of power outages on the total sales of 2775 manufacturing firms in 14 non-island SSA countries. It is evident from the results that frequent power outages significantly reduced firm sales and the greatest impact is felt by firms without back-up generators. They concluded that if average hourly outages could be reduced to 73 percent, sales of an average firm in SSA could increase by 85 percent. These results confirm the findings of an earlier study by Eberhard et al. (2011) that total sales of African firms are 4.9 percent lower than they would actually be if electricity supplies were reliable. And if advanced power interruption notices are given out to firms, outage costs could be reduced by 20-33 percent (Diboma & Tatietse, 2013).

Specifically in Ghana, Abeberese et al. (2021) explored the impact of electricity outages on the productivity of small and medium-sized manufacturing firms using exogenous variation in electricity rationing-induced outages. Their analysis revealed an estimated 10 percent productivity decrease because of power outages between 2012 and 2016 and they recommended eliminating outages which could lead to an increase in firm productivity. The long-run effects of power outages on businesses were predicted by Fried and Lagakos (2020) to be many times larger. They found the rationing of grid electricity and the possibility of self-generated electricity at higher cost to cause lower firm productivity in the developing world by creating idle resources, depressing the scale of incumbent firms, and reducing entry of new firms. These revelations were the results of a dynamic macroeconomic model the researchers built to study the long-run general equilibrium effects of power outages on firm productivity in developing countries.

During periods of power supply challenges, outages, and power rationing among users, firms react in varied ways depending on resource capacities. After studying the behaviour of 23,000 energy-intensive Chinese firms from 1999 to 2004, Fisher-Vanden et al. (2015) found that firms substituted materials for energy during the power shortages in the early 2000s in China which enabled them to avoid substantial productivity losses. Other firms may invest in alternative power sources. Owusu et al. (2022) argued that investing in alternative source of electricity, predominantly diesel/petrol powered generators, significantly reduce the profit of businesses in Accra after they sampled and studied 50 owner-managers of micro and small enterprises. As such, even though investment in back-up generators to provide power during outages keeps the business running, it does not come without its own cost issues. Using an incomplete back-up methodology on a cross-sectional data of 7353 firms in 12 African countries, Oseni (2012) found out that self-electricity generation burdens firms with costs ranging between $0.46 and $1.25 per kWh. The researcher used Nigeria to explain the gravity of the cost structure and noted that net outage cost, after adjusting for cost-reflective tariff, incurred by an average firm in Nigeria could hire and pay the annual salaries of 2 more workers at the 2012 minimum wage.

Oseni & Pollitt (2015) demonstrated that unmitigated outage losses for firms that engaged in self-power generation were between $2.01 and $23.92 compared to $1.54 - $ 32.46 for firms without back-up generators. The intriguing part of their findings is that firms that engage in self-power generation would have incurred an additional 1-183 percent outage losses if they had decided not to invest in back-up generators. In an earlier study, Foster and Steinbuks (2009) demonstrated that when other factors are controlled, a firm in SSA owning a generator decreases losses from power cut-offs by about 1 percent of the firm's total sales. These findings agree with Scott et al. (2014) and Cissokho and Seck (2013) that outage-induced investment in generators, with higher cost of electricity, by firms does not necessarily lead to higher cost of production partly due to the small proportion of electricity costs in firms' total costs and also good management practices during power insecurities.

2.4.2.2 Energy efficiency practices and firm productivity

As already established in sub-Section 2.4.1.4, firms are investing in energy efficiency technologies due to electricity insecurities and price increases. But the rate of adoption is slow in developing regions like the Caribbean (Millar & Russell, 2011), South America (Sehnem et al., 2016) and SSA (Ackah, 2017; Lee et al., 2019). Sy (2016) explored the impact of sustainability practices on the performance of 5 multinational firms operating in Cebu's export processing zone in Philippines. The thesis investigated the impacts of economic, environmental, ethical, governance, and social sustainability practices and found environmentally oriented sustainability practices like recycling, reduction of resource consumption, re-use of materials, and energy conservation to improve the companies' overall performance and reputation even though additional investment expenses are incurred initially. Similarly, Sehnem et al. (2016) found that the adoption of such sustainable practices as described by Sy (2016), improve product quality, public image, management, and growth of 300 industrial enterprises sampled in Southern Brazil. They concluded that more innovations are needed in energy usage, products, and organizational dimensions for maximum productivity.

Past research findings from Ghana suggest a low adoption of energy efficiency technologies, particularly the industrial (machinery) efficiency. Apeaning and Thollander (2013) for instance, discovered an energy efficiency gap in the Tema industrial area because of the low implementation of energy efficiency measures by the industries. To identify how industrial efficiency and other factors may have impacted short- and long-run domestic electricity demand in Ghana, Adom et al. (2012) used an ARDL Bounds cointegration approach on a 1975-2005 time series data. The researchers found industry efficiency to drive electricity down but not as much as income, while output and demographic features drive it upwards. This result is contrary to what Ackah (2017) found after studying small- and medium-scale enterprises (SMEs) in Ghana. According to Ackah (2017), about 72% of the SMEs argue that reduction in energy consumption among SMEs in Ghana, particularly in rural areas, was attributed to blackouts and not efficiency. Ackah (2017), nonetheless, concluded from the study that energy consumption has not been efficient at firm level just like the work of Apeaning and Thollander

(2013), and that, output has not been significantly impacted by energy efficiency. Various policies were recommended to enhance energy efficiency at firm/industry level such as the imposition of penalty on special load tariff (SLT) customers when their power factor was below 90% (Lee et al., 2019).

2.4.2.3 Predictors of firms' environmental performance

In this sub-section, the researcher reviews various literature sources on the factors that influence how companies manage and mitigate their environmental impacts. These predictors range from regulatory frameworks, market pressure, to internal management practices and technological innovations.

In some countries, governments implement regulations that mandate firms to adopt environmentally friendly practices. Porter and van der Linde argue that stricter environmental regulations often lead to higher environmental performance because firms will seek to comply and avoid penalties (Porter & van der Linde, 1995). The reverse was observed by Anukwonke (2015) and Kaggwa et al. (2009) among many sub-Saharan African countries. According to the researchers, the lack of stringent environmental regulations and weak enforcement mechanisms have often resulted in poor environmental performance in SSA.

Corporate structure and governance have been found to influence firms' environmental performance. Sharma (2000) for instance, found that a strong governance structure, including the presence of independent directors and environmental committee, are associated with improved environmental performance. Visser (2006) argues that the structure of a firm may result in active engagement in corporate social responsibilities (CSRs) which foster good environmental performance. The researcher added further that the extent and impact of CSRs vary widely across different countries in SSA.

Technological innovations have strong associations with environmental performance. According to (Hart, 1995), the adoption of green technologies and investment in research and development are critical in enhancing a firm's environmental performance. Kakulu (2008) further argues that firms which have access to advanced green technologies like renewables and energy efficiency technologies increase their ability to improve their environmental ratings. According to the researcher, the opposite is true and often compounded by financial constraints.

Economic factors equally, have been proven to determine firms' environmental performance. King and Lenox (2001) argue that larger firms with more resources tend to have better environmental performances due to their ability to invest in sustainable practices. In support, Ofori et al. (2014) concluded that economic conditions including firm size and capital, or financial resources significantly influence the environmental practices of firms in Ghana. Market and consumer expectations sometimes encourage firms to engage in good environmental practices (Bansal & Roth, 2000).

2.5 Review of theories on firms' decision and choice making related to energy and productivity

Three theories are reviewed in this section that are regarded relevant to explain firms' decision and choice making behaviours, along with firms' performances that are linked to energy systems. The three theories explain the behaviour of firms in a developing context like Ghana regarding investment decisions. However, they underpinned different components of the subject under investigation, hence there was no need for comparison among the theories.

2.5.1 Theory of decision-making: The Bounded rationality and Satisficing

Decision making is the beating heart of any formal organization (Simon, 1947). Although there are no universally agreed classifications, some scholars like Ahmed and Omotunde (2012), Briggs (2014), Hausman and McPherson (2016), and Małecka (2019) are convinced that most theories of decision making can be classified under one of normative and descriptive theories with few positioned in the middle where they are understood to possess characteristics of both in their applications. The consensus is that normative decision theory prescribes how decision makers ought to behave and make choices whereas descriptive decision theory explains how they behave in reality (Małecka, 2019; Turpin & Marais, 2004). The review focuses on the theory that could practically explain the real decision-making behaviour of an organization which Barnard (1968) defines as a coordinated system of activities or forces of more than two people. In this sense, descriptive decision theories that explain how decision makers (of an organization in a developing country like Ghana) take investment decisions among different choices are brought into focus.

The organization is said to provide positions of responsibilities (executive positions) where those who man these positions exercise power, authority, and influence over others, and they take actions having one eye on the situation (problem), and the other eye on the short- and long-term effects of this decision (Vargas-Hernández & Ortega, 2018). Economists believe the firm like the household is a rational entity and, therefore, makes rational decisions regarding alternative choices of production, distribution, and consumption. Unsurprisingly, the pioneering theories of decision making in economics and psychology were entrenched in the complete or perfect rationality model (Simon, 1978). By this, the decision maker who is a rational individual or manager is perceived to make decisions under certainty where they have complete information regarding the available alternatives, the consequences of implementing each alternative, have an organised set of preferences for these consequences, and the capability to compare consequences and to determine which is preferred (Kreitner & Kinicki, 2001; Simon, 1978). In practice, there are far more uncertainties beyond the comprehension of the decision maker. In making a choice, there are only a few alternatives that come to mind as opposed to the availability of all possible alternatives suggested by the rationality theory. Complete rationality is limited (bounded) by the lack of knowledge. In practical terms, organization performance may be limited by resourcefulness, decision making process may be bounded by the speed of mental process and individuals may be bounded by their values, goals, trainings, and experience (Simon, 1978; Vargas-Hernández & Ortega, 2018).

The bounded rationality theory was, therefore, proposed by Herbert Simon as a more fitting theory to explain cognitive decision making by individuals and complex systems. This forms the basis on which organizational behaviour theories are anchored (Simon, 1955). Simon's main thesis and contribution to the economics of the organizations is that human behaviour is intentionally rational, but in a limited way (Simon, 1947). Organizational behaviour is, therefore, synonymous with the theory of intentional and bounded rationality. In the decision-making process, the organization cannot obtain the maximum result/outcome because it is impossible to verify all possible alternatives in the first place. So as individuals and organizations struggle for rationality, they are restricted within the limits of their knowledge. The choices they make can be subjectively viewed as rational within a bounded set of factors that correspond to a closed system of variables (Vargas-Hernández & Ortega, 2018). This implies that decisions can be taken at any point in time without necessarily worrying about possible implications of knowledge biases since it is almost impossible for the decision makers to have complete knowledge about all the alternatives and their implications. Some of the bounded conditions that affect the desires and opportunities of the decision maker according to Vargas-Hernández & Ortega (2018), Simon (1978), and Simon (2000) include bounded mental capacity of the decision maker; knowledge of an acceptable set of actions; approximate and heterogeneous knowledge of the consequences; evolutionary and unsettled preferences; temporary and cost limitation that affect the decision, and search for a satisfactory result rather than the best result.

Developed with the theory of bounded rationality is the theory of satisficing (Simon, 1947). A crucial assumption in the theory of the firm is that the firm owner or entrepreneur strives to maximise his/her profit. According to (Vargas-Hernández & Ortega, 2018), this assumption may not always be the case in reality because of the following reasons: the entrepreneur may not care to maximise his/her return but may simply want to earn a return that he/she regards as satisfactory; given that equity owners and the active managers of organizations are separate and distinct people hence the managers may not often be motivated to maximise profit; where there is imperfect competition among firms, maximizing profit is an ambiguous goal because an optimal action for one firm may depend on the actions of the other firms.Therefore, firm must not always be expected to be set up to maximise profit. Rather, the attainment of a certain level of profit, holding a certain share of the market, or a certain level of sales might be the real goals for several enterprises that they may deem practically attainable. Firms will, therefore, try to "satisfice" rather than to "maximise" (Vargas-Hernández & Ortega, 2018, p. 263) because in most cases, the individuals placed in decision-making positions in the firm (i.e., the managers) practically lack the capacity to maximise (Simon, 1947).

The present study is anchored on the bounded rationality and satisficing decision-making theories because they better explain the decision-making dynamics of enterprises in a developing country like Ghana where there are imperfect information and inadequate resources needed to access relevant market information. Additionally, firms in this kind of developing settings engage in the production of, and services of similar characteristics hence most enterprises do not aim to maximise profits but often seek to survive and keep certain share of customers in the market (Bosma & Kelly, 2018; Herrington & Kelley, 2012). The selection of these theories is also justified because as Conlisk (1999) suggested, there is abundance empirical evidence of the application of these theories that prove themselves.

2.5.2 Rogers' Diffusion of Innovation Theory

The Diffusion of Innovation Theory was first developed by Rogers (1995) in communication science to 'explain how an idea or product gains momentum and spreads through a specific social system over time' (p. 15). The theory, thus, emphasises the way innovations are taken up in a population. In Rogers' view, four factors combine to facilitate the spread of new ideas among a population; the innovation itself, communication channels, time, and the nature of the social system into which the innovation is being introduced.

According to Rogers (1995), the first factor, innovation, is an "idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p.11). Hahn and Schoch further highlight that the acceptance or adoption of an innovation is significantly influenced by innovation characteristics and adopters' perception (Hahn & Schoch, 1997). Generally, the innovation diffusion theory proposes five attributes (Figure 4) of innovations that stimulate the adoption or rejection of an innovation or new technology (Brown, 1971, 1981; Rogers, 1995): the relative advantage in terms of economic and social prestige over the existing practice or technology; the compatibility of the innovation with the adopters' existing values, culture, past experiences and needs (Brown, 1981; Rogers, 1995); the perceived difficulty of learning to use and understand the innovative technology (complexity); the triability of the technology which represents less uncertainty to the potential adopters (Rogers, 1995; Sonnenwald et al., 2001); and the observability of the technology which is the degree to which the results of an innovative technology are easily seen and understood to build confidence in a potential adopter (Rogers, 1995; Sonnenwald et al., 2001).

The second factor is communication channels. These are the means through which messages travel from one individual to another. Rogers (1995), observes that mass media channels are often the most effective and efficient means to inform an audience of potential adopters about the existence of an innovation. Another effective channel for transmitting information about an innovative technology is face-to-face communication (Coleman et al., 1957; Howard, 1969).

Time is the third factor that plays a major role in defining both the pace at which the adoption of the technology is occurring, and the positions individuals occupy during the progress of adoption (Rogers, 1995). Five adopter categories have been proposed by Rogers based on the rate of time of adoption as shown in Figure 2.8:

- Innovators: They are venturesome types, daring, risk-takers, enjoy being at the cutting edge and with access to substantial financial resources.
- Early adopters: They use the information provided by innovators' implementation and confirmation of the innovation to make their own adoption decisions.
- Early majority: They interact frequently with their peers, but hardly hold positions of opinion leadership in a system. The early majority needs solutions with minimum discontinuity, hence, deliberate for some time before completely accepting a new idea.
- Late majority: They are influenced by networks' peer pressure. They exercise lots of restraint in the face of any new technology, doubt its value, and do not adopt it until most people in the social system have adopted it.

- The laggards: They are either very traditional or isolated in the social system. If traditional, they are suspicious of innovations and often interact with other traditionalists. If isolated, their lack of social interaction reduces their awareness of an innovation's demonstrated benefits.

A: Bell-shaped curve showing categories of individuals innovativeness and percnetages within each category

B: S-shaped curve representing rate of adoption of an innovation over time

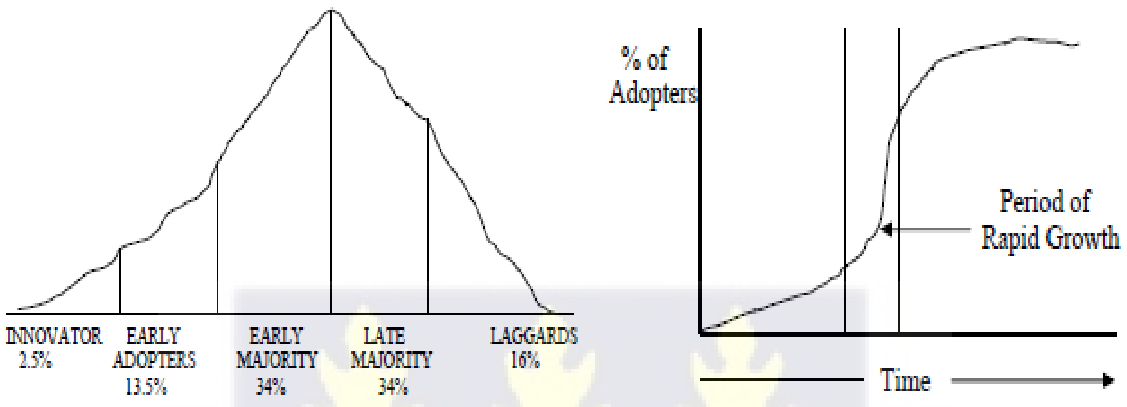

Figure 2.8: Time dimensions of different categories of adopters of an innovation

Source: Adapted from Rogers (1995)

The fourth and last element in Rogers' Diffusion of Innovation Theory is the social system. The social system, which constitutes individuals, informal groups, organisations and/or subsystem, has boundary within which innovation diffuses because the structure of the system, the system's norms, the roles of opinion leaders and change agents all have an influence on the adoption of the new idea/technology.

An examination of the rate and extent of the adoption of new energy systems such as, renewables and energy efficiency technologies, among firms in the Greater Accra Region of Ghana was discussed within the context of Rogers' Diffusion of Innovation Theory. Specifically, the first factor (the characteristics of the innovation itself), the time factor and the fourth factor (social systems) of the theory were instrumental in explaining the pace of adoption, the positions of the individual firms along the time dimension of the technology diffusion progress, and lastly, the reasons or factors determining the pace of adoption of the new energy systems amongst the firms.

2.5.3 Energy and productivity: Quality adjusted multi-factor productivity theory

The resource-productivity measure proposed by Gollop and Swinand (1998) assesses how production impacts the environment. It reflects the contributions of energy or resources to total production in a partial way. Energy or resources are, therefore, considered as inputs in the production function that partially determines output.

The multi-factor, also known as the total-factor productivity principle expands on the partial productivity measure of the contributions of labour, capital, and resources/energy (Abbott, 2018). The multi-factor productivity theory originates from the marginalists economic tradition. The main tenet of the theory is that a combination of different inputs determines production (Abbott, 2018). The proponents of the theory were, however, quick to add that though production is a result of the combinations of different inputs, the contribution of each input can be determined distinctly from other inputs (another important tenet of the theory). The multi-factor productivity theory further argues that all factors of production will be paid that value which it adds to production (Clark, 1908). The most widely used framework of the multi-factor productivity is the KLEMS which is understood as the two primary factors of production, capital (K), labour (L), and three intermediate inputs energy (E), materials (M) and services (S). The KLEMS is the basis of more recent and modern productivity accounting for economies and enterprises (Elkomy et al., 2020).

After Solow (1957) introduced technical change in the Cobb Douglas production function to explain labour productivity, the empirical results were deemed unsatisfactory and left a lot to be explained (Elkomy et al., 2020). What many scientists agree on though is that different types of labour, capital and energy could have different contributions to output. Researchers have, therefore, made adjustment to Solow's framework by adding more detailed descriptions of labour and capital. This adjustment often takes the form of higher qualities of labour and capital as suggested by Barnett et al. (2014), Franklin (2018, 2019), and Goodridge et al. (2018). For instance, high quality labour that adds most value to the firm is presumably paid highest. Also adjusted capital that guarantees high level of capital services should attract more rent compared to those with lower services (OECD, 2009).

Useful energy is trusted to deliver quality adjusted capital and labour services (Ayres & Voudouris, 2014; Warr et al., 2008). Useful energy is portrayed as the portion of the theoretical maximum energy available that performs a useful service (Brockway et al., 2019; Miller et al., 2016). Energy goes through different transformation or conversion steps (OECD, 2001). Coal for instance, could be turned into electricity which is distributed to households as final energy. This final energy, electricity, powers various appliances through the provision of an energy service like lighting or cooling. These energy services (or useful energy) are believed to enhance the contributions of capital and labour inputs to total production (Finn, 2000; Keen et al., 2019). Keen et al. (2019) represented the absolute dependency of the capital (K) and labour (L) factors of production on energy (E) in the production function (Y) as

$$Y = f[L(E), K(E)] \qquad (1)$$

Equation (1) implies that if energy is zero, there will not be production because energy is required for any level of productivity from capital and labour.

Mair (2019), McCloskey (2010), and Malm (2016) argue that culture shifts with capitalism drives energy use, particularly, fossil fuel to affect labour productivity and growth. This view was also corroborated by Allen (2009) and Parthasarathi (2011) who emphasised how fossil fuel usage boosts labour productivity growth through the relative costs of labour and coal as evident in the pre-industrial England. Meanwhile, Daly describes physical capital as merely a “matter that is capable of trapping energy and channeling it to human purposes” (Daly, 1968, p. 397). If this is true, then capital productivity will often be expected to be impacted by energy supply of how specifically energy is used (Elkomy et al., 2020). With this understanding, (Finn, 2000) defined capital utilization (U) to rely on energy as

$$U = \frac{E}{K} \quad \ldots\ldots (2)$$

Introducing this capital utilization in a standard production function gives the functional form;

$$Y = f(L, KU) = f\left(L, K\left(\frac{E}{K}\right)\right) \quad \ldots\ldots (3)$$

Equation (3) supports the theorization of most energy scientists that energy and capital are quantity complements. This means that an increase in the use of energy increases the productivity of capital hence the productivity of a given capital stock depends on the use of energy. This quantity complementarity can be explained in terms of the energy conversion chain (the transformation steps) and the useful energy. If capital needs energy to be able to produce goods and services, then capital productivity is improved by ensuring that every step of the energy transformation/conversion is more efficient because this frees up more energy that can be directed by capital into the production process. Ensuring this efficient conversion process will mean using more efficient and cleaner forms of energy like electricity instead of coal (Brockway et al., 2019). This ultimately leads to the maximization of the portion of energy accessed by capital and used to perform economically valuable work. On the contrary, decrease in energy quality and energy efficiency reduces capital productivity because more energy will be wasted (Fagnart & Germain, 2016). This ultimately leads to a decreased output.

In this thesis, the theory is selected among other theories of the firm and production because of the particular emphasis placed on the role of energy in the production function which highlights the prime focus of the present study. This is, therefore, important in explaining how useful energy services, particularly in terms of their costs and reliability, mediate capital and labour, and can also independently affect the performance of firms in a developing country like Ghana.

2.6 The firm, the choices, and the performances framework

This study is operationalised by the conceptual framework; the firm, the choices, and the performances, as illustrated in Figure 2.9. The framework was developed based on the theories reviewed in the preceding sub-section. The owner/manager of the Ghanaian firm is first of all faced with the need to take decision reagrding investments required by the business. According to Simon (1947)'s theories of bounded rationality and satisficing, the decision maker (firm owner/manager) makes rational decisions subject to bounded conditions that surround him/her. In settling on a decision, the firm owner may have limited mental capacity to make the best decision, may not have full knowledge of the actions he/she has taken and the consequences of the actions, may not have the complete cost structure of the actions taken, and may not have complete knowledge of alternative actions. These limitations ultimately affect the choices that a typical Ghanaian firm owner would make. For instance, when firms use old and energy inefficient machines and equipment because of a lack of resources to replace or upgrade their systems, they end up paying more for electricity, while the reverse is true for firms that have the resources and knowledge to deploy more energy efficient machinery systems.

Investment decisions often lead to the making of choices in terms of adopting new ideas or technologies. The adoptability of these decision outcomes (new ideas or technologies) depends on the innovation itself, the communication channels, social system, and the time as Rogers

(1995) expounded in his Diffusion of Innovation Theory. Understanding the fundamental reasons behind the choices that firms in the Greater Accra Region of Ghana make, particularly in terms of energy systems preferred and the alternatives overlooked, are qualitatively explored in the study. Finally, these choices regarding the critical inputs according to the quality adjusted multi-factor productivity theory affect the performances of the firm. How the required level of capital investment, the size of labour, research and development (R&D), and energy systems affect the financial and environmental performances of the firms are quantitatively explored in the study.

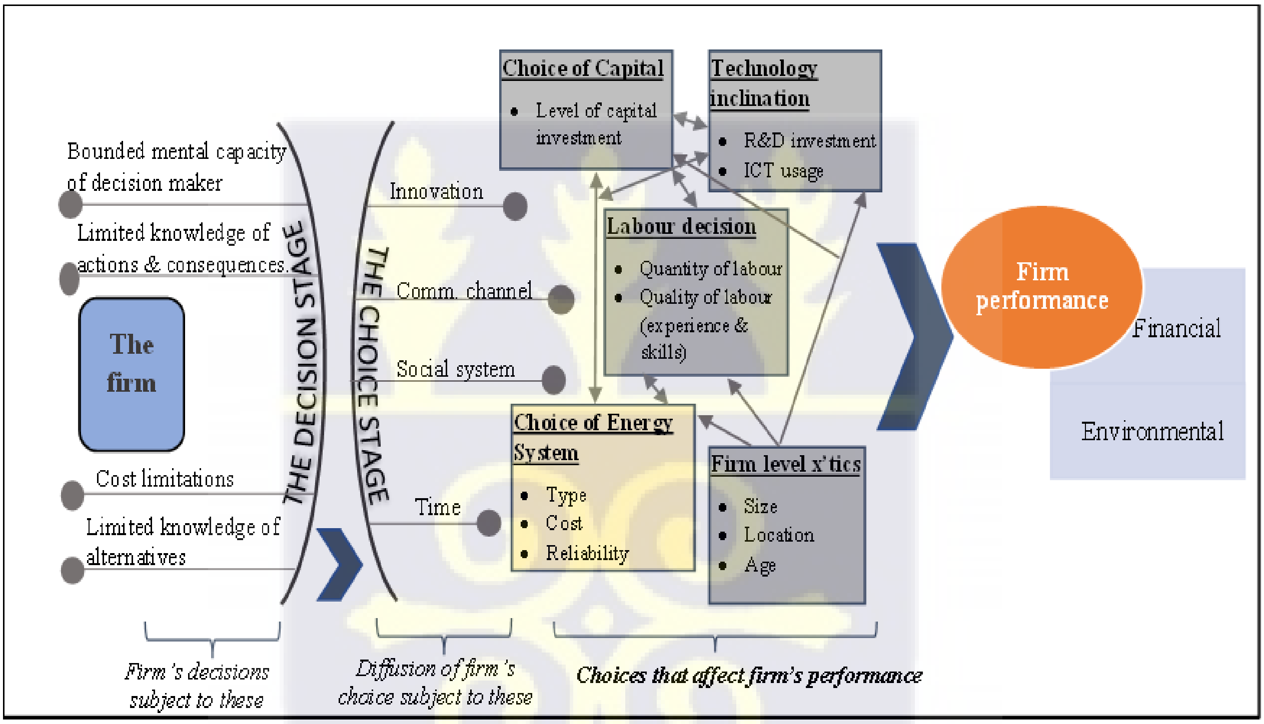

Figure 2.9: The firm, the choices, and the performances framework

Source: Author's construct

The financial performance of firms can be adversely affected by poor energy services like blackouts, power fluctuation, and high power-production costs. The environmental rating or performance of firms can also be enhanced when the right energy efficiency technologies and renewables are utilised that consume less energy, emit less and have less impact on the climate and the environment. The adoption of these technologies goes in tandem with increasing R&D and IT investments carried out by the firms which in the end can enhance the environmental rating of the firms.

2.7 Conclusion

Different energy systems are used by firms in the developed and developing worlds. Whiles least costs and reliability play key roles in firms utilizing grid electricity in the developed regions, least costs and the ease of access to grid electricity are the main reasons firms in developing countries like Ghana regard grid electricity as their primary electricity source. Despite the popularity of grid electricity, the reviewed literature sources also suggest negative impacts of certain characteristics of the grid system such as hours of blackouts and the need for back-up alternatives that attract more investment cost to the firms.

Self-power generation from diesel/petrol generators are common in developing countries when the primary source becomes unreliable, and the initial cost outlay of alternative sources like renewables is a huge barrier to their adoption compared to developed countries where firms are investing more in renewables due to favorable policy instruments, public reputations, and environmental concerns. Key government programmes like the CFL replacement programme in 2007, the Energy Efficiency Standards and Labelling Regulations in 2010 and the subsequent Refrigerator Rebate and Exchange Scheme in 2012 championed by the Energy Commission led to significant adoption of efficient lighting and refrigeration in Ghana.

In conclusion, not many of the reviewed literature sources have explored issues beyond costs and finance for the low adoption of alternative sources like renewables in developing countries. The present study seeks to fill this gap by exploring the fundamental reasons behind firms' preferences for certain electricity sources, and the reasons other alternatives are less preferred.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter describes and justifies the methodological designs and approaches that the thesis adopted to achieve the set objectives of the study. It details the rationale behind the number of subjects (sample) used, how the subjects were studied (design), and the data collection and analysis. The chapter is structured as follows: The philosophical assumptions that underpin the choice of methods used to collect, analyse, and present the data are first described. This is followed by a discussion of the research design; the study site, data sources and collection process, sampling procedure, methods of analysis, descriptions and justification of selected variable and conclusion.

3.2 Philosophical Underpinnings

As explained under the conceptual framework in the preceding chapter, firms often than not make bounded rational decisions because they are limited in various ways. For instance, resource availability, geographical location, information asymmetry, knowledge of the existence of alternative actions, and the knowledge of the consequences of actions may force firms to act differently depending on how they are exposed to these factors. It is, therefore, imperative to understand from the perspectives of firm managers or owners in the Greater Accra Region of Ghana why they invest in certain energy systems and not others. Ontologically, understanding the standpoints of Ghanaian firm managers is important because their experiences which make up their realities would certainly be different from those of other firms located in other geographical regions with different business environment.

Epistemologically, the researcher deemed it appropriate to minimise the "distance" (Guba & Lincoln, 1988, p. 94) between himself and the participants in order to know as much about the participants as possible. To successfully obtain these different viewpoints of the firm managers or owners in the Greater Accra Region of Ghana, selected participants were engaged through conversational personal interviews, some of which were done over multiple visits to the participants at places they considered to be most comfortable. Methodologically, a two-prong approach was adopted to understand the different reasons behind energy systems preferred by firms in the Greater Accra Region of Ghana and the implications of their decisions: Firstly, a bottom-up approach was adopted where the inquiry was driven by the lived experiences of the participants regarding their decisions on different energy systems subject to available resources. This was intended to produce detailed knowledge of the subject matter with deeper understanding of firms' energy choices. Secondly, the study enlisted a representative sample of participants to provide a wider perspective on the subject matter of the study, allowing for statistical inferences and generalization for the entire population.

Generally, the research was driven by pragmatic philosophy. The study identified and applied the most appropriate design and methodology to help understand the multiple realities of firm managers and/or owners in the Greater Accra Region regarding energy systems decisions and their implications. The goal of the study was that the findings could positively influence policy formulations regarding sustainable energy systems for firms in Ghana. No one methodological system was deemed sufficient to comprehensively explore the choices and effects of firms' energy systems. A combination of approaches that provided the best chance of achieving the goal of the study was considered appropriate. This philosophy informed and provided justification for the research design of the study.

3.3 The Research Design

The study favours a mixed research design based on the underlying philosophical underpinnings described in the preceding section. The chosen design is in line with Patton's "paradigm of choice" (Patton, 1990, p. 12) which accepts methodological appropriateness over methodological orthodoxy. The period before the 1990s was regarded as the qualitative-quantitative paradigm wars era (Patton, 1990) because both designs were seen as two opposing paradigms, each with core scholars who consistently followed the respective principles to the latter and would deny the possibility of mixing the paradigms. Quantitative researchers decide what to study, ask specific and narrow questions, collect quantifiable data from a relatively large number of participants, analyse these numbers using statistical methods and tools, and often conduct the inquiry in an unbiased and objective manner (Creswell, 2015). Qualitative researchers on the other hand rely on the realities of participants, ask deep and thought-provoking questions, collect data consisting largely of texts from participants, describe and analyse these texts for themes, and conduct the inquiry in a relatively subjective manner (Creswell, 2015). From the 1990s to the present times, researchers originally belonging to the ideologies of both paradigms have begun to see the relevance of integration. The conjoining of the two traditions was believed to have been initiated and fueled by the increasing complexity of societal problems which require both deeper and broader inquiry and understanding to be able to provide sustainable solutions (Denscombe, 2008; Johnson & Onwuegbuzie, 2016; Tashakkori & Teddlie, 2003).

A mixed research design entails collecting, analysing, and combining both quantitative and qualitative research methods in a single study to understand a research problem (Creswell, 2015; Molina-Azorin, 2016). The design originated in the social sciences, expanded into the medical sciences, and has recently been developed and refined to be used in a wider research field, helping to provide solution to complex societal problems (Creswell & Clark, 2017). The mixed methods design is preferred in this study for the purposes of triangulation, complementarity, and development (Creswell & Clark, 2007; Greene et al., 2016). The mixed methods design affords the researcher the possibility of combining different methods to better provide holistic answers to the complex research questions than approaching the study solely with either of the two research traditional approaches. Such understanding arises when findings from one approach complements findings from other approaches to ensure reliability of the findings or provides the researcher with the necessary information required to develop the other approach. The combined methods, therefore, add value and contribute significantly to understanding of the energy landscape of businesses in a developing country like Ghana.

The term “mixed” is not just used for the name’s sake. At some point, the different approaches must be mixed or integrated. This is the point of integration (Schoonenboom & Johnson, 2017), also known as the point of interface by Morse and Niehaus (2009) and Guest (2013). This is basically where quantitative and qualitative components are brought together. It is a key decision, if not the most important decision, in a mixed methods design. Teddlie and Tashakkori (2009) suggest four different stages where mixing is possible: the conceptualization stage; the methodological (data analysis) stage; analytical (data analysis) stage; and inferential stage. In this study, both qualitative and quantitative components were mixed-up, albeit at different levels, in all the stages suggested by Teddlie and Tashakkori (2009).

The study adopted the Explanatory Sequential Design proposed by Creswell and Clark (2017) where the researcher in the first phase collected and analysed the quantitative data, followed by the collection and analysis of the qualitative data in the second phase. When it comes to the weights placed on the designs, the study adopted the deductive-sequential design proposed by Morse and Niehaus (2009) where the core component is quantitative (denoted as **QUAN**), and the supplementary component is qualitative (denoted as **qual**). The explanatory sequential design is represented in Figure 3.1.

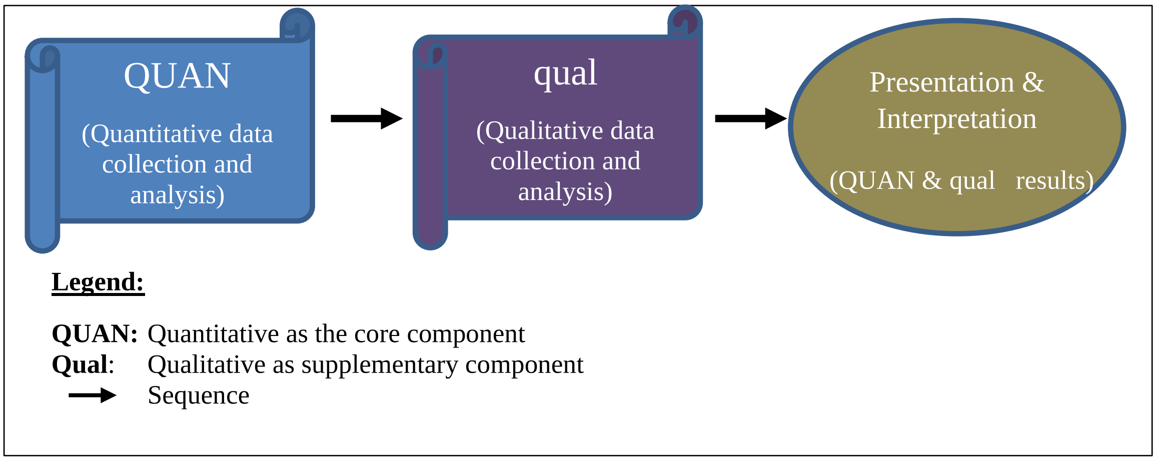

Figure 3.1: The adopted explanatory sequential mixed methods design

Source: Author's construct

The two approaches were integrated at the data collection, data analysis, and representation stages to ensure complementarity. At the data collection stage, the quantitative survey was carried out first and the data provided a pool of targeted respondents out of which some participants were drawn for the qualitative survey. Additionally, preliminary analysis of the quantitative data informed the development of the interview guide for the in-depth and key informant interviews. Though each objective is analysed with a dominant approach, the secondary approach provided complementary supports during the interpretation and discussion stage of the findings. For instance, the qualitative data provided underlying reasons to some quantitative findings in Objectives Two (2) and Three (3) which are predominantly quantitative in structure.

3.4 The Study Site

Greater Accra Region was purposively selected as the broad geographical site of the study. The coastal region, located in the south-central part of the country, is one of the sixteen administrative regions of Ghana. The capital city Accra is the main international gateway into the country and the most popular destination for many young people in Ghana and neighboring countries. Though the region is one of the smallest in terms of land size, it has the highest population density, reportedly about 1,681 people per square kilometer as of 2021 from about 1,236 per square kilometer in 2010 (GSS, 2021; GSS, 2013) suggesting that many people are drawn to the region for various reasons, chief among them, economic opportunities. Accra and Tema are the most populous, economically active, industrialised, and most developed cities in the region. Figure 3.2 shows the Greater Accra Region with spatial distribution of establishments among its districts as of 2016.

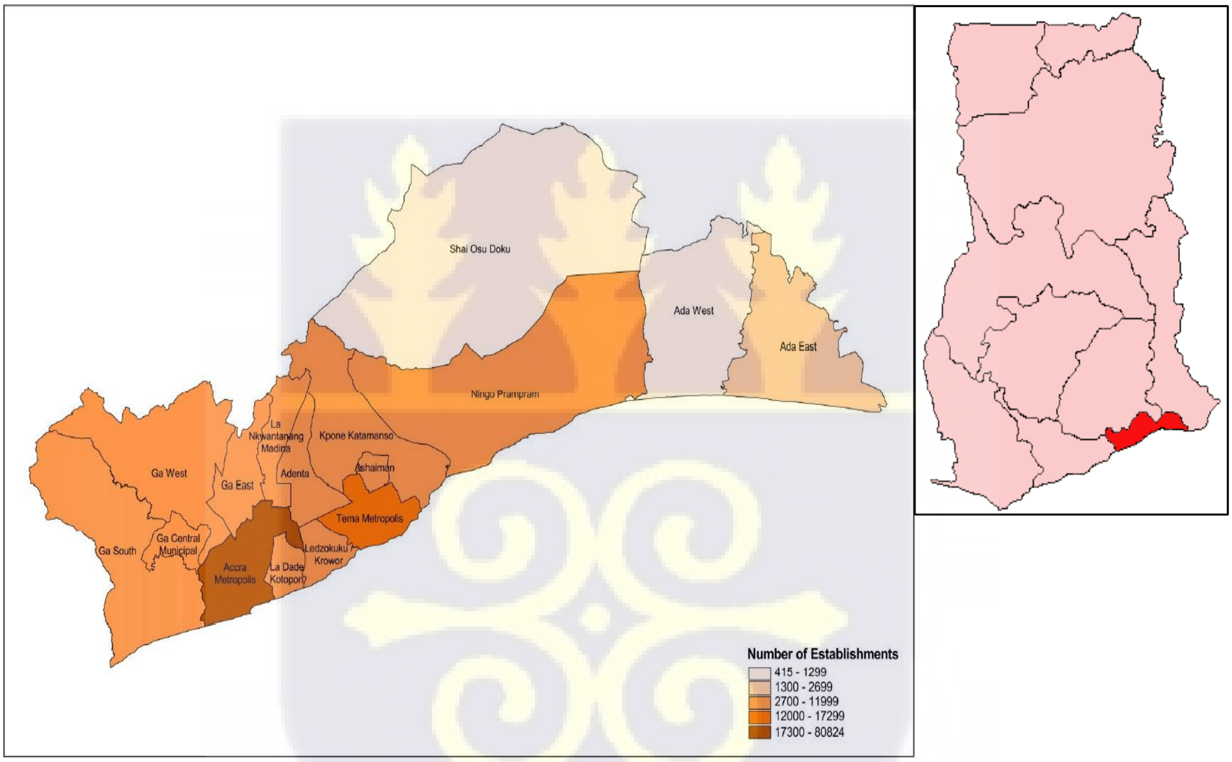

Figure 3.2: The map of Greater Accra Region with spatial distribution of establishments among its 16 administrative districts as of 2016

Source: GSS (2016)

The business climate of the region makes an interesting site to study. According to the latest business establishment survey carried out in 2014, the region housed the most business establishments in the country. Nearly 28 percent of all the 638,234 business establishments in the country operated in the Greater Accra Region as of 2014 (GSS, 2015). Unsurprisingly, the region has the largest number of large-sized, medium-sized, small-sized, and micro-sized establishments in the country. Any sampling technique used would ensure adequate representation of all the different sizes of establishments in the region.

The Greater Accra Region is also the most exposed positively and negatively when it comes to power issues. By virtue of its gateway status, the region is favoured to receive the most key resources and developmental projects. There are more opportunities to access and use modern energy systems like the RETs in the Greater Accra Region than other regions because policy and regulatory authorities, as well as other relevant institutions that oversee the development of such technologies are more prevalent in the region. However, the region also faces numerous challenges with the grid-power supply system. During the 2012-2016 power crises period and even beyond, all electricity demand sectors in the Greater Accra Region had to cope with a hard-to-swallow power load-shedding that increased the costs of doing business in the region. The effects of the crises were felt hardest in the region because of the high population density. These energy and business dynamics of the region also informed the researcher’s decision to select it as a study site.

3.5 Data Requirement, Sources and Collection Process

The study relied on primary data that were collected via an industrial survey, in-depth interviews (IDIs), and key-informant interviews (KIIs) from participants in the study site for the analytical chapters. The decision to use primary data stems from the unavailability of current and comprehensive secondary data that captures all the relevant information and variables required to answer the research questions of this study. The researcher has no knowledge of the existence of any such data that could be accessed easily for the purposes of this study. However, some existing data sets and instruments that captured information on relevant variables were examined to enrich the data collection instruments for this study. These data sets and instruments afforded the researcher the opportunity to spot gaps that needed to be filled since they were not captured in these data sets. The data sets examined were SAMSET Household, Commercial, and Institutional dataset[8]; and the GLSS 7 dataset[9]. The instruments of related projects like the GRIDWATCH project[10] were also reviewed to inform the development of the data collection instruments for this study. Finally, an extensive body of literature was reviewed, constituting the complementary secondary sources of information used in the thesis.

3.5.1 Quantitative data needs: type, instrument, and procedures

Quantitative data was needed to establish the inferential association of the dependent and independent variables of the study. The researcher employed a retrospective data collection approach where information on events that have taken place in the past were gathered in the present time (Butz, 1981; Buxton, 2021; Weinger et al., 2003). All survey data are recall data according to Butz (1981). It becomes retrospective when the reference period for the recall is considered too long (Butz, 1981). It is a useful approach to understand past actions/activities around certain events in order to predict present and future behaviours (Buxton, 2021; Weinger et al., 2003). Specifically, the researcher asked firms about their investments, expenditures, incomes, and other operations from 2015 to 2021.

[8] Data set was collected by ISSER, University in 2014 under the Supporting Sub Sahara African Municipalities with Sustainable Energy Transition (SAMSET) project. Available at https://samsetproject.net/
[9] Data set was collected by the Ghana Statistical Service in 2017
[10] The GRIDWATCH project was led by the University of California, Berkeley from 2019 to 2021, and the data collection phases were led by ISSER. https://www.energyeconomicgrowth.org/node/191

Among other limitations, researchers are most concerned that the inaccuracies of retrospective data increase the farther back in time the questions try to reach. To limit these recall biases and inaccuracies, the current study used a 2-year interval period, that is, 2015, 2017, 2019, 2021 which requires a 4-year data recall instead of a 7-year recalls if information was required for every year from 2015 to 2021. In many respects, retrospective data has been likened to panel data because they all describe characteristics of an entity (individual, firm, or country) over a period of time (Butz, 1981; Buxton, 2021). The data that was primarily collected for this study was, therefore, treated as a panel data where records on the operations of firms in the Greater Accra Region of Ghana were gathered for 2015, 2017, 2019, and 2021 periods. The researcher chose 2015 as the base year to capture the behavoir of firms during the recent power crises period 2012-2016.

Table 3.1: The quantitative data collection activities

Activity	**Time duration**
Development of draft questionnaire (Paper version)	1 week
Review of questionnaire by supervisory team	1 month
Finalised the paper version of the questionnaire	2 days
Developing Computer Assisted Personal Interview (CAPI) version of the instrument	1 week
Obtaining ethical clearance from the Ethics Committee for the Humanities, University of Ghana for both QUAN and qual surveys	1 month
Recruitment and training of enumerators	3 days
Piloting of questionnaire instrument	1 day
Field work	10 days
Monitoring of field activities	5 days
Data cleaning and management	1 week
Obtaining field reports from enumerators	2 days

Source: Author's tabulation

The pre-field activities and other on-field activities as far as the quantitative data collection is concerned are summarised in Table 3.1. The study relied on structured questionnaire as the quantitative data collection instrument that was developed while having the thesis aim and objectives in mind. The questionnaire is appended to the thesis in Appendix D.

The researcher then proceeded to develop a computer assisted personal interview (CAPI) version of the questionnaire. This was intended to eliminate errors from the enumerators during the enumeration exercise, particularly with the observation of skip patterns, and from data entry personnel if paper version was used. The CAPI system also ensured that the researcher could monitor the data collection exercise remotely by observing how much data was being submitted by the enumerators while on the field, how much was left to do, the quality of the data and corrections or updates of the CAPI system that needed to be done even when the enumerators were still in the field.

Before the field activities could commence, the researcher had to obtain ethical clearance from the Ethics Committee for the Humanities, University of Ghana to ensure all the ethical guidelines were duly met (Appendix E). Ten (10) enumerators were recruited and trained for the fieldwork. It was a one-day training that sought to equip the enumerators with sufficient knowledge and understanding of the project, its objectives, the tasks of the enumerators, and how to use the CAPI system. The usability of the instrument was assessed in a pilot survey where each trained enumerator undertook one survey and reported back to the researcher how effective the CAPI system was. The fieldwork itself took 10 days to be completed and data management commenced immediately after the fieldwork ended.

3.5.2 Qualitative data needs: type, instrument, and procedures

The qualitative data was gathered using key informant interview (KII) and in-depth interview (IDI) designs for two separate categories of participants. The KIIs design was applied to participants in the policy space while the IDIs design was applied to representatives from the business establishments who were identified in the quantitative data. Based on the sequential data collection design adopted for the study, the qualitative data collection only commenced after the quantitative data collection was completed and preliminary analysis of the data was carried out. This sequential procedure was instrumental because it informed the development of the KII and IDI guides, and also allowed relevant questions to be captured after the initial quantitative analysis. The systematic roll-out of the qualitative activities are presented in Table 3.2.

Table 3.2: The qualitative data collection activities

Activity	Time duration
Development of draft KII and IDI guides	2 days
Review of the guides by supervisory team	2 weeks
Finalization of the guides	1 days
Identification and profiling of targeted participants drawn out from quantitative data	1 day
Field work	6 weeks
Transcription of audio data into text data	5 days
Data cleaning and management	1 week

Source: Author's construct

Before the researcher embarked on the qualitative fieldwork, an interview guide was developed by the researcher, reviewed, and approved by the supervisory team, as well as the Ethics Committee for the Humanities, University of Ghana. The researcher carried out the KIIs and IDIs himself within a period of 6 weeks but the transcription of the audio data into text data was done by a professional group under the supervision of the researcher. The transcribed data was reviewed and cross-checked with the audio data for consistency and minimised omission errors.

3.6 Sampling procedure and selection of respondents

The study primarily investigates the financial and environmental performances of selected business establishments in the Greater Accra Region of Ghana considering their decisions on energy systems and other factors of production they used from 2015 to 2021. The businesses of all sizes per GSS's classifications, were, therefore, the targeted subjects for the study. In other words, large-, medium-, small-, and micro-sized firms in the Greater Accra Region of Ghana represented the targeted population of firms for the study. An appropriate sample of these businesses was, therefore, required from these total populations. It was imperative that a scientific approach was used to sample the businesses out of the population such that inferences made from the sample would be reflective of the entire population. Since the focal points are organizations or entities, they could only be represented by people who took decisions and have knowledge about the organizations' activities. The sampling unit of the study is, therefore, business establishments in the Greater Accra Region represented by individuals. The sampling methods and sample sizes per the research designs are discussed in the sub-sections.

3.6.1 Sampling for the quantitative design

The quantitative research component of the mixed methods design used a three-stage sampling approach as described below and depicted in Figure 3.3:

Stage One: The initial stage of the sampling process involved the selection of the broad geographical area where the samples would be drawn from. As described in the preceding section (see Section 3.4), Greater Accra Region was selected as the broad geographical study site because it is the region most associated with the good, the bad, and the ugly in terms of its structural, administrative, and business opportunities as well as the power crisis that it frequently faces.

Stage Two: In the second stage, clustered and purposive sampling methods were used. In the Greater Accra Region, there are sixteen (16) local government districts. These represented clusters. As of 2015, about 177,152 business establishments were recorded in the Greater Accra Region, distributed across these sixteen (16) clustered districts. Notably three of the 16 districts, the Accra Metropolis, Tema Metropolis, and Ga South Municipal alone host about 62% of these business establishments. The researcher, therefore, settled on sampling business establishments from these three districts.

Stage Three: At this stage, the study used stratified and purposive sampling methods. The business establishments in Ghana, the Greater Accra Region and the three clustered districts (Accra Metropolis, Tema Metropolis and Ga South Municipal) are often classified as large-sized, medium-sized, small-sized, and micro-sized based on the number of employees. These classifications represent the strata in each cluster (district). The researcher reasonably expected variations in business behaviours across the different strata hence sought to have representations from all the strata in the sample. However, the study is interested in business establishments that use any source of electricity in their production activities hence purposive sampling method was used to select the required sample.

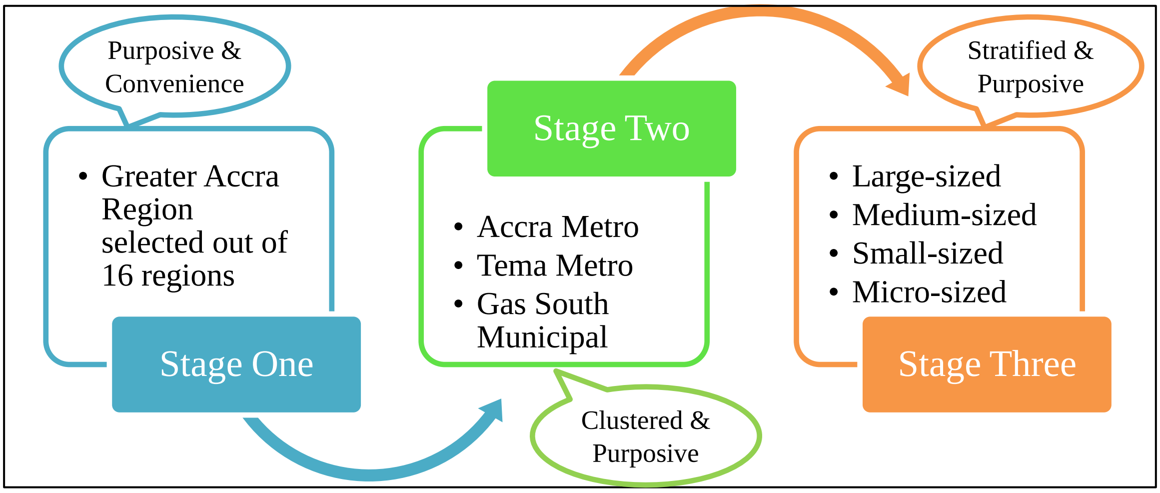

Figure 3.3: The three-stage sampling approach used by the study

Source: *Author's construct*

With clarity on the sampling methods, the study adopted the approach of Smith (2013) to determine the required sample size for the quantitative component of the mixed methods design. Described below is the sample frame for the computation of the sample size:

The population size (pop): This is the total number of business establishments that the sample is expected to represent. According to the Economic Census data collected by the Ghana Statistical Services in 2014 during the Integrated Business Establishment Survey (IBES), the population of business establishments in the industry and services sectors in the Greater Accra Region was 176,815 as of 2014 (Table 3.3). The researcher excluded the agricultural sector businesses because they are usually not energy intensive activities in the region, apart from a few poultry farms that depend on lights.

Table 3.3: Total business establishments in the industry and services sectors in the Greater Accra Region as of 2015

Sector	**Total establishments in the Greater Accra Region**				
	Total	Micro	Small	Medium	Large
Industry	27,302	21,457	4,929	597	319
Services	149,513	120,606	24,187	3,833	887
Total	**176,815**				

Source: GSS (2015)

Margin of error (Confidence interval - CI): This determines how much higher or lower than the population mean the researcher is willing to allow the sample mean to fall. The researcher settled on a margin of error of 5% which has been widely used by scholars.

Confidence level (CL): This is the level of confidence the researcher has that the actual mean falls within the confidence interval. The researcher chose a confidence level of 95%.

Standard deviation (StdDev): This is how much variance is expected in the responses. In other words, it is the percentage picking a choice often expressed in decimal. Since the survey was yet to be carried out, the actual variance was unknown but 5% was used, which often guarantees sufficient sample size needed.

The sample size was determined in two stages:

Stage One: Determining the sample size (ss)

$$ss = \frac{(Z - score)^2 * StdDev(1 - StdDev)}{(CI)^2}$$

Where **Z-score** is the z value corresponding to the 95% confidence level ***(Z-score = 1.960)***; **StdDev** is the standard deviation ***(StdDev = 0.5)***; and **CI** is the confidence interval ***(CI = 0.05).*** Given these statistics, ss is computed as:

$$ss = \frac{(1.960)^2 * 0.5(1 - 0.5)}{(0.05)^2} = \frac{3.8416 * 0.25}{0.0025} = \frac{0.9604}{0.0025} = 384.16$$

Stage Two: Correction for finite population

$$new\,ss = \frac{ss}{1 + \frac{ss - 1}{pop}}$$; where **pop** is the population

$$new\,ss = \frac{384.16}{1 + \frac{(384.16 - 1)}{176815}} = \frac{384.16}{1.00216701} = 383$$

The sample size required for the study given the population of business establishments in the Greater Accra Region as of 2014 is **383**. The researcher went further to determine if this sample size was adequate to detect a minimum effect, if there is an effect, using G*Power statistical power analysis program developed by Faul et al. (2007). Details of the G*Power analysis are presented in Table 3.4.

Table 3.4: Power analysis of sample size that detects minimum effect

Input Parameters	**Proposed Effect size f^2**			
	0.04	0.06	0.08	0.1
Type I error (α) prob	0.05	0.05	0.05	0.05
Power (1-β) error prob	0.80	0.80	0.80	0.80
Number of predictors	5	5	5	5
Total sample size	**327**	**220**	**166**	**134**

NB: Based on F-test, using Linear multiple regression: Fixed model, R^2 deviation from zero statistical test; and A prior type of power analysis

Source: Author's construct

In the G*Power program, the researcher opted for an a priori type of power analysis and a linear multiple regression: fixed model, R^2 deviation from zero statistical test. These options were selected because the researcher expected to estimate a linear multiple regression model with firm performance as the dependent variables with some predictors. This statistical test also predicts F-test that describes the overall fitness of the model. The researcher assumed the probability of rejecting a true null hypothesis (type I error) to be 0.05 while the probability of detecting an effect (Power) is assumed to be 0.80, widely supported by some of the early statistical scholars such as (Cohen, 1988, 1992). The number of predictors was fixed at 5 even though it could be less or more in the actual model to be estimated.

The effect size to be detected is a crucial element in the power analysis. It is the minimum meaningful effect that is of relevance to the research. The larger the effect size, the smaller the experiment required to detect it. Such minimum effects are best determined from empirical research or pilot studies. Energy related studies in SSA show an effect range of 5% to 10% on firm output or growth in general. According to Twerefou et al. (2018) a percentage increase in electricity and petroleum consumption each increases GDP per capita by 10.7% and 5.8% respectively in the West African Region. Abeberese et al. (2021) also observed that power supply challenges costed businesses in Ghana 10% output loss annually during the 2012-2016 power crises. From Table 3.4, a total sample size of 134 is sufficient to detect a minimum effect change of 10% in firm performance. For lower minimum effects, for instance 4%, a total sample of 327 would be required to detect such an effect. Therefore, the computed sample size of **383** was more than adequate to detect as low as 4% effect change in firm performance for a unit change in the energy variables in the model.

There were reported refusal cases, but the researcher made room for replacements from the sample frame for the qualified firms that were willing and available to participate. The reported enthusiasm and willingness showed by the participants outweighed the refusal rate, hence, the enumerators over sampled to the level of 404 firms in total across the three districts and across all sizes of firms within the manufacturing and services sectors. Each of the respondents was and only selected after satisfying these four inclusion criteria: the firm uses productive energy; existed since 2015 or earlier; the respondent is part of the firm's management / decision making team; and finally, the respondent is willing to participate in the study. Because the data was retrospectively collected for the 2015, 2017, 2019, and 2021 periods as mentioned earlier, the total panel data points came to **1,616.** It is, however, not a balanced panel data as data was missing for some variables for some years. The proportions of the firm sizes according to the 2014 IBES data were micro-sized (80.3%), small-sized (16.5%), medium-sized (2.5%) and large-sized (0.68%). The sampling technique was generally guided by these 2014 IBES proportions to reflect the true distribution of firms according to their sizes in the Greater Accra Region, but not in the strict sense. For example, in the 2014 IBES, there were 84.4% service and 15.4% industries activities in the Greater Accra Region. In the study, a little more weight was given to industrial activities (27%) because of government's initiatives like the 1D1F which was intended to boost industrial activities within the period. For most part of the inferential statistics, the medium- and large-sized firms were combined because they did not have enough sample to generate sufficient degree of freedom.

3.6.2 The qualitative sampling methods and sample size

The study used purposive sampling method for the qualitative component of the mixed methods design. The selection of participants for the qualitative study was dependent on the initial exploration of the quantitative data to identify the right participants to sample, and the right questions to ask. Findings from the initial quantitative analysis, coupled with the need to have relevant stakeholders provide insightful feedback to research questions, key informants from the energy sector, and suppliers of different energy systems were enlisted. The number of key informants the researcher settled on, as indicated in Table 3.5, was influenced by the institutional appropriateness, the availability and willingness of targeted respondents.

Table 3.5: Sampled qualitative participant groups

Design	**Categories**	**Targeted institutions/ groups**	**Number of participants**
Key informant interviews (KIIs)	Policy and Regulatory bodies	Ministry of Energy, Ghana	1
		Energy Commission, Ghana	1
	Energy suppliers	Electricity Company of Ghana Ltd	1
		AB Solar Africa Ltd.	1
		Tino Solutions Ltd.	1
In-depth interviews (IDIs)	Enterprises	Large-sized firms	3
		Medium-sized firms	3
		Small/Micro-sized firms	4
Total interviews			***15***

Source: Author's construct

For the in-depth interviews, the researcher targeted 5 percent of the quantitative sample, that is, about 20 firm representatives across the three districts and firm sizes which are utilizing different energy systems. The researcher, however, applied the principle of data saturation where the qualitative data collection process was halted once no new information was being gathered and the researcher felt that the issues have been extensively exhausted by the participants already interviewed (Creswell, 2007). By this principle, the researcher carried out 10 IDIs which generated the required data needed for the qualitative analysis.

3.7 Analytical methods

The methods that are applied to analyse the quantitative and qualitative data are discussed in this section. The selected analytical methods were influenced by the design of the research, type of the data gathered and the characteristics of the dependent variables. It is important to note that the appropriateness of all methods is imperative to bring about reliability of the results, and the successful achievement of the study objectives.

The broad analytical approach adopted to achieve each objective has been detailed in Table 3.6. Objective one (1) was analysed more qualitatively to explore issues beyond cost that inform or underline firms' energy choices, interlaced with few descriptive statistics from the quantitative data.

In objectives two (2), the researcher investigated how per unit of output costs and reliability of different electricity sources as well as different energy efficiency technologies utilised by firms impact their financial performances from 2015 to 2021. Finally in objective three (3), the impacts of the per unit of output costs and reliability of different electricity sources as well as different energy efficiency technologies utilised by firms on their environmental performances from 2015 to 2021 were accessed. Objectives two (2) and three (3) were analysed with quantitative techniques.

Table 3.6: Objectives aligned with analytical designs

Obj. #	**Objective**	**Dependent variable (*form of variable*)**	**Key independent variables**	**Analytical techniques**
1	To explore the underlying factors behind the decisions of firms in the Greater Accra Region to invest, or not invest in different energy systems during the most recent power crisis and post-crisis periods (2015-2021).	The decision and choice of different energy systems	Exploring issues beyond cost	Qualitative and Quantitative (only descriptive analysis)
2	To investigate the effects of the per unit of output costs and reliability of different electricity sources as well as different energy efficiency technologies utilised by firms in the Greater Accra Region on their financial performances from 2015 to 2021.	• Financial performance of firms ***(continuous)***	• Per unit of output costs of different electricity systems • Reliability of different electricity systems • Different energy efficiency practices	Quantitative (descriptive and inferential analyses)
3	To examine the impact of the per unit of output costs and reliability of different electricity sources as well as different energy efficiency technologies utilised by firms their environmental performances from 2015 to 2021.	• Environmental performance of firms ***(continuous& categorical)***	• Per unit of output costs of different electricity systems • Reliability of different electricity systems • Different energy efficiency practices • IT and R&D investments	Quantitative (descriptive and inferential analyses)

Source: Author's construct

3.7.1 Quantitative analytical methods

3.7.1.1 Estimation methodology: Panel fixed-effects

As established in the preceding sections, the historical data collected on business establishments located in Accra Metro, Tema Metro, and Ga South Municipality in the Greater Accra Region for the 2015, 2017, 2019, and 2021 was treated as a panel data. The behaviours of 404 firms were historically gathered across a four-time period. Panel data methods were applied to this data for the analysis of Objectives Two and Three.

For the regression models of financial performance (FP) and environmental performance (EP) as the dependent variables measured in continuous forms, panel fixed-effects (FE) methods were applied to analyse their determinants. The justification of choosing FE over other methods like that random-effects (RE) and pooled OLS are found in the following underlying assumptions according to Greene (2012):

- *Correlation between the entity's error term and independent variables:* Each entity (firm) has some observable or unobservable time-invariant characteristics that may or may not bias the predictor (independent) or outcome (dependent) variables. Example of such characteristics are business practice, location, gender and race of business owner or manager, and beliefs, values, and preferences of business owner or manager. Fixed-effects models (FEM) remove the effects of these time-invariant characteristics of the entities (firms) such that only the net effects of the predictors on the outcome variable are assessed.
- *The time-invariant characteristics are unique to the entity (firm) and should not correlate with other entity characteristics:* Each entity (firm) is uniquely different hence the entity's error term and the constant (which captures individual firms' characteristics) should not be correlated with the others.

Given a general regression model of the form:

$$y_{it} = x_{it}'\beta + z_i'\alpha + \varepsilon_{it} = x_{it}'\beta + c_i + \varepsilon_{it} \qquad (4)$$

y_{it} is the outcome (dependent) variables. There are K regressors in x_{it}, not including a constant term. The heterogeneity or individual effect is $z_i'\alpha$ where z_i contains a constant term and set of individual or group-specific characteristics which may be unobserved. β is the coefficient for the predictors and ε_{it} is the error terms. $'i'and't'$ represent the entities and time.

The goal of the analysis is consistent and efficient estimation of the partial effects represented as

$$\beta = \partial E[y_{it} \mid x_{it}] / \partial x_{it} \qquad (5)$$

The possibility of Equation (5) depends on the assumptions about the unobserved effects (Greene, 2012). If z_i in Equation (4) is observed for all the entities and contains only a constant term, then ordinary least squares provide consistent and efficient estimates of the common α and the slope vector β. In this instance Pooled Ordinary Least Square (Pooled-OLS) methods can apply (Greene, 2012).

If the unobserved characteristics or variables z_i in Equation (4) are uncorrelated with the included predictor variables thereby violating the above assumptions, the mean independence takes the form:

$$E[c_i \mid x_{i1}, x_{i2}, \ldots,] = h(x_{i1}, x_{i2}, \ldots,) = h(X_i) \qquad (6)$$

In this case, the unobserved variables $h(X_i)$ must be included in the model as predictors to avoid the problem of variable exclusion. This is the assumption that underlies the adoption of random-effects model. The key challenge of using the RE model is that the model is likely to suffer exclusion problem because the researcher may not be able to specify all the required unobserved characteristics that are uncorrelated with the predictor variables.

If the z_i in Equation (4) is unobserved but correlated with x_{it}, then the mean independence will take the form:

$$E[c_i \mid x_{i1}, x_{i2}, \ldots,] = \alpha \qquad (7)$$

In this case, the least squares estimator of the slope vector β is biased and inconsistent hence the impacts of the time-invariant unobserved variables need to be controlled to have the fixed-effects model (FEM) as

$$y_{it} = x_{it}'\beta + \alpha_i + \varepsilon_{it} \tag{8}$$

Where $\alpha_i = z_i'\alpha$ embodies all the observable effects and specifies an estimable conditional mean. This FEM takes α_i to be a group-specific constant term in the regression model.

According to Stock and Watson (2008), if these unobserved characteristics do not change over time, then any changes in the outcome (dependent) variable must be due to influences other than these fixed characteristics. The sum of this group-specific term α_i and the stochastic error term ε_{it} is a constant that can be represented as v_{it}. For a FEM, the explanatory variables may be correlated with this constant term such that $\text{cov}(v_{it}, x_{it}) \neq 0$ hence the Ordinary Least Square (OLS) techniques cannot be used. Dougherty (2011) also argues that if the sampling method used in a study is not random, fixed-effects is more suitable as illustrated in Figure 3.4. Before the estimations were carried out, each empirical model was first tested using the Hausman test (Greene, 2012) to ascertain if the models indeed satisfied the fixed-effects assumptions before the results were presented. The Houseman test results are shown in Appendix A.

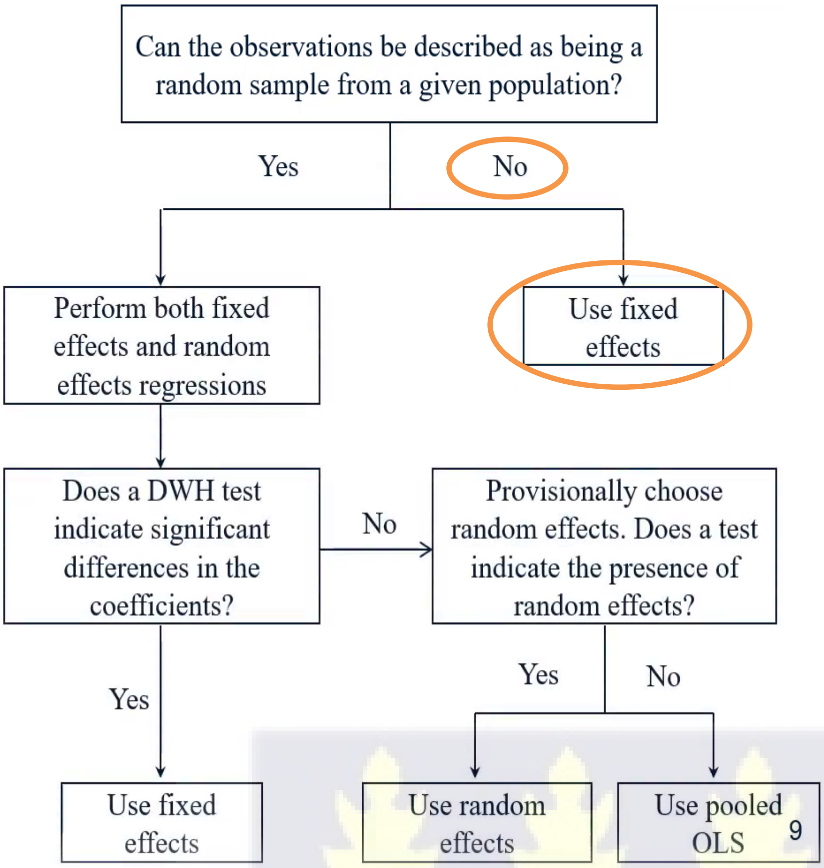

Figure 3.4: Conditions under which fixed or random effects are appropriate

Source: Dougherty (2011, p.421)

3.7.1.2 Theoretical and empirical models

Following from Equation (1) based on the Quality Adjusted Multi-factor Productivity Theory, the general theoretical and a Cobb-Douglas production function is expressed as

$$y_{it} = f(x_{it}) = f[A_{it}, K_{it}, L_{it}, E_{it}, Z_{it}] = A_{it}(K_{it}E_{it})^{\alpha_1}(L_{it}E_{it})^{\alpha_2}(Z_{it})^{\alpha_3} \qquad (9)$$

Where y_{it} are the outcome(dependent) variables, A_{it} is the technological change introduced by (Solow, 1957), K_{it} is the capital input, L_{it} is the labour input, E_{it} is the energy services, and Z_{it} is the vector of other material and service inputs explained in the KLEMS multi-factor productivity theory, and $\alpha_i, i = 1,2,3$ are the substitution parameters to the respective inputs.

By applying natural logarithm to Equation (9), a simple constant elasticity of substitution production function is derived involving linear terms like scale parameters, elasticity of substitution parameters and input-share parameters, making it relatively easier to estimate and interpret than a second-order transcendental logarithm (translog) production function which often involves complex cross-product terms. For this study, the predictor variables of interest are per unit of output cost and reliability of grid electricity, per unit of output cost and usage of generator-produced electricity, and energy efficiency technologies used. Other input variables, also serving as control variables include size of the firm, capital resource of the firm, research and development (R&D) investment, and internet (IT) investment of the firm.

The fixed-effects regression functions of financial performance (FP) of the firms in the Greater Accra Region are presented in Equations (10) and (11). The difference between the two (2) equations is that Equation (10) included a composite index of energy efficiency technology (EET) while Equation (11) explored how different energy efficiency technologies are associated with the dependent variable, FP. In estimating Equation (11), the different energy efficiency technologies were first combined in one model, and then treated separately in different models to assess their associations with the dependent variable.

$$\begin{aligned} FP_{it} = {} & \phi_0 + \phi_1 GRID\_C_{it} + \phi_2 GRID\_\mathrm{R}_{it} + \phi_3 GEN\_C_{it} + \phi_4 CAP_{it} + \phi_5 SIZE_{it} + \phi_6 IT_{it} + \phi_7 R\&D_{it} \\ & + \phi_8 COVID_{it} + \phi_9 NEWPRODUCT_{it} + \phi_{10} MKT_{it} + \phi_{11} BUSTRUCTURE_{it} + \phi_{12} EET_{it} + \varepsilon_{it} \end{aligned} \tag{10}$$

$$\begin{aligned} FP_{it} = {} & \Lambda_0 + \Lambda_1 EE\_AC_{it} + \Lambda_2 EE\_LIGHT_{it} + \Lambda_3 EE\_MACHINERY_{it} + \Lambda_4 EE\_REFRIG_{it} + \Lambda_5 GRID\_C_{it} \\ & + \Lambda_6 GRID\_R_{it} + \Lambda_7 GEN\_C_{it} + \Lambda_8 CAP_{it} + \Lambda_9 SIZE_{it} + \Lambda_{10} IT_{it} + \Lambda_{11} R\&D_{it} + \Lambda_{12} COVID \\ & + \Lambda_{13} NEWPRODUCT_{it} + \Lambda_{14} MKT_{it} + \Lambda_{15} BUSTRUCTURE +_{it} + \varepsilon_{it} \end{aligned} \tag{11}$$

Where,

FP_{it} is Financial Performance
$GRID\_C_{it}$ is grid electricity system cost per unit of output
$GRID\_R_{it}$ is reliability of grid electricity system
GEN_C_{it} is generator electricity cost per unit of output
EET_{it} is the level of energy efficiency technologies practiced by the firms
EE_AC_{it} is level of energy efficient air conditioning systems used
EE_LIGHT_{it} is level of energy efficient lighting systems used
$EE\_MACHINERY_{it}$ is level of energy efficient machinery systems used
EE_REFRIG_{it} is level of energy efficient refrigeration systems used
$SIZE_{it}$ is quantity of labour employed
CAP_{it} is capital resource
$R\&D_{it}$ is R & D investment
IT_{it} is IT investment
$COVID_{it}$ is dummy for Covid − 19 years
$NEWPRODUCT_{it}$ is new product introduced
MKT_{it} is market where products / services are sold / marketed
$BUSTRUCTURE_{it}$ is structure of the business

ϕ_0, Λ_0 are constant terms with embedded time − invariant x'tics of regressors
$\phi_j, \Lambda_j \quad j = 1, ..., m$ are parameter coefficients

For each of Equation (10) and (11), six (6) different sub-models were estimated to explore the effects of the predictor variables on the financial performance for different samples of the firms in the Greater Accra Region. These samples included the full sample (*t=2015, 2017, 2019, 2021*); power crisis era (*t=2015, 2017)*; post-crisis era (*t=2019, 2021)*; micro-sized firms; small-sized firms; and medium-large sized firms. The medium- and large-sized firms were combined in one sample because of the small number of firms in these sample categories.

The fixed-effects environmental performance functions of the firms in the Greater Accra Region of Ghana are presented in Equations (12) and (13). Like Equations (10) and (11), a composite index of EET was included in Equation (12) while different technologies of EET are explored in Equation (13). Again, for each of Equation (12) and (13) six (6) sub-models for the different types of samples as described above were estimated to explore the effects of the predictor variables on the environmental performance.

$$EP_{it} = \gamma_0 + \gamma_1 GRID\_R_{it} + \gamma_2 USEGEN_{it} + \gamma_3 CAP_{it} + \gamma_4 SIZE_{it} + \gamma_5 IT_{it} + \gamma_6 R\&D_{it} + \gamma_7 COVID_{it} + \gamma_8 NEWPRODUCT_{it} + +\gamma_9 MKT_{it} + \gamma_{10} BUSTRUCTURE_{it} + \gamma_{11} EET_{it} + \varepsilon_{it} \quad (12)$$

$$EP_{it} = \theta_0 + \theta_1 EE\_AC_{it} + \theta_2 EE\_LIGHT_{it} + \theta_3 EE\_MACHINERY_{it} + \theta_4 EE\_REFRIG_{it} + \theta_5 GRID\_R_{it} + \theta_6 USEGEN_{it} + \theta_7 CAP_{it} + \theta_8 SIZE_{it} + \theta_9 IT_{it} + \theta_{10} R\&D_{it} + \theta_{11} COVID_{it} + \theta_{12} NEWPRODUCT_{it} + \theta_{13} MKT_{it} + \theta_{14} BUSTRUCTURE_{it} + \varepsilon_{it} \quad (13)$$

Where,

EP_{it} *is Environmental Performance*
$USEGEN_{it}$ *is availability of generator to use*
All other variables in the models are already defined

γ_0, θ_0 *are constant terms with embedded time − invariant x'tics of regressors*
$\gamma_j, \theta_j \quad j = 1,...,m$ *are parameter coefficients*

It has already been mentioned that monthly profit was used to represent financial performance in Equations (10) and (11) as robustness and reliability checks on the total monthly revenue originally used to represent financial performance. To double the robustness and reliability checks, stochastic production frontier models introduced by Aigner et al. (1977) and Meeusen & van Den Broeck (1977) were estimated to assess the effects and efficiency of the factors of production on firm output, in this case the financial performance from 2015 to 2021. The stochastic frontier approach is a parametric method preferred over a non-parametric data envelopment approach because the stochastic frontier approach acknowledges the fact that random shocks beyond the control of the firms can affect output which aligns with the bounded rationality theorization of Ghanaian firms. The general form of the stochastic production frontier function is:

$$y_{it} = \beta_o + \sum_{j=1}^{k} \beta_j x_{jit} + v_{it} - su_{it} \quad (14)$$

The frontier function experts that the dependent variable and independent variables are on the natural logarithm scale hence $y_{it} = \ln(y_{it})$ and $x_{jit} = \ln(x_{jit})$. The disturbance term of Equation (11) has two components; the non-negative inefficient term, and the symmetric idiosyncratic error term (v_{it}). The frontier function can fit a time-invariant model, where the inefficiency term is assumed to have a truncated normal distribution, or a time-variant decay model, where the inefficiency term is modeled as a truncated-normal random variable multiplied by a function of time.

The stochastics production frontier models estimated in this study fit the time-invariant system, where the inefficiency effects are modeled as $u_{it} = u_i$, $u_i \overset{iid}{\sim} N^+(\mu, \delta_u^2), v_{it} \overset{iid}{\sim} N(0, \delta_v^2)$, u_i and v_{it} are distributed independently of each other and the covariates in the models. *Gamma* is the estimate of $\gamma = \delta_u^2 / \delta_S^2$ and *sigma2* is the estimate of $\delta_S^2 = \delta_u^2 + \delta_v^2$. *Gamma* ($\gamma$) is between 0 and 1, and the optimization is parameterised in terms of the logit of γ which is reported as *(lgtgamma)* in the estimated results. Also, *(mu)* is the estimate of u, and *(lnsigma2)* is the parameterised estimate of δ_S^2.

Based on the theoretical function in Equation (14), the empirical model for the stochastic production frontier function can be expressed as:

$$
\begin{aligned}
FP_{it} &= \omega_0 + \omega_1 GRID\_C_{it} + \omega_2 GRID\_R_{it} + \omega_3 GEN\_C_{it} + \omega_4 CAP_{it} + \omega_5 SIZE_{it} \\
&\quad + \omega_6 IT_{it} + \omega_7 R\&D_{it} + \omega_8 EET_{it} + \varepsilon_{it}
\end{aligned}
\tag{15}
$$

Where, all the variables are in natural logarithm forms, ω_0 is the constant term, $\omega_i, i = 1, 2, ..8$ are the coefficients that can be interpreted as percentage changes, and ε_{it} are the disturbance term.

3.7.1.3 Variable description and measurement

The inclusion of variables in the four (4) models discussed in the preceding sub-section is informed by the reviewed theories and empirical literature. Brief descriptions and measurement indicators of the included variables are described below, and summarized in Table 3.7.

Financial performance (FP): FP is one of the dependent variables, measured in continuous form, for which the study investigates the predictors. The study primarily used average monthly total revenue of firms (before tax and other deductions) as a measure of the firms' financial performance. A natural logarithm was taken of the average monthly revenue after adding a factor of one (1) across board to take care of zero data points. This transformation was necessary to normalise the variable, minimise the impacts of outliers, ensure linear relationship with the predictors, and to get the parameter estimates as partial elasticities. A similar transformation mechanism is applied to the firms' monthly profit (revenue less costs) which is secondarily used as a proxy for financial performance for robustness checks.

Environmental performance (EP): EP is the other dependent variable measured as a continuous index. An index was generated out of the following environmental policies/actions implemented by the firms: recycling or use of recycles materials; re-use of materials; reducing material usage; degradable packaging materials; eco-friendly products; controlled pollution for production process; renewable energy mix; wastewater treatment; sustainable solid and e-waste management; and less paper, more electronic operation system applications. The levels of application of the environmental policies/actions (as qualitatively reported by the firm representatives) are used as weights to determine the differentiated levels of environmental policies/actions applications by the firms.

Grid electricity system cost per unit of output (GRID_C): GRID_C was measured in continuous form. It is the operational cost of the national grid system that was used to produce one unit of output by the firms. *GRID_C* was computed by dividing the total costs of operating the national grid electricity (which include the monthly bills, maintenance costs and other accessories like costs of multiple phase installations) by the total monthly output value of the firm. Natural logarithm was applied to the total values for the same reasons cited for FP. From literature, GRID_C is expected to be negatively associated with FP and EP.

Reliability of the grid electricity system (GRID_R): GRID_R was measured as a continuous variable. It is the total hours of blackout (power outages) experienced by the firms within a month generated from the frequency of power outages and duration of a typical outage within a typical week. According to the reviewed literature sources GRID_R is expected to have reducing effects on FP and EP.

Generator electricity system cost per unit of output (GEN_C): GEN_C was measured in continuous form. It is the operational cost of the generator system that was used to produce one unit of output by the firms. *GEN_C* was computed by dividing the total costs of operating the generator (which include fuel purchase and maintenance costs) by the total monthly output value of the firm. Natural logarithm was applied to the total values for the same reasons cited for FP. Just like GRIC_C, GEN_C is expected to be negatively associated with FP and EP.

Generator usage (USEGEN): USEGEN is a dummy variable for the availability and use of generators. For businesses where generators were readily available and used, USEGEN was assigned '1' and where generators were unavailable, USEGEN was assigned '0'. The direction of USEGEN is inconclusive in the existing literature. USEGEN is expected to be negatively associated with EP but with FP it can have positive or negative effect depending on the level of usage. USEGEN is not time-invariant because some firms that used generators in the power-crisis period discontinued it in the post-crisis period while some that did not use it the crisis period used it in the post-crisis period. This shows some level of variance.

Level of energy efficiency technologies used by the firms (EET): EET is the level of energy efficiency technologies practiced or used by the firms. These technologies include energy efficient lighting (EE_LIGHT), energy efficient machinery systems (EE_MACHINERY), energy efficient refrigerator systems (EE_REFRIG), and energy efficient air-conditioning systems (EE_AC). After the firm representatives reported the energy efficient technologies that they applied, they were also asked to indicate the level (in percentage terms) of the lighting, machinery, refrigeration, and space cooling systems of the firms that use the energy efficiency technologies. These percentages were, therefore, qualitatively perceived by the firm representatives and not based on any technical measurement approach. An index (EET) was created from EE_LIGHT, EE_MACHINERY, EE_REFRIG, and EE_AC using simple average score. The individual energy efficiency technologies and the aggregated index (EET) were used in different models. They are all expected to be positively associated with FP and EP.

Market where firms sell their products/services (MKT): MKT is measured as a dummy variable where 1 is assigned to outside the district market and 0 is assigned to the district market. It shows the market coverage of the firms, whether they are confined to the district or not. Firms with wider market coverage are expected to have increased FP. According to different literature sources, wider markets pushes firms to be more innovative to meet the increasing demand which expectedly increases their environmental ratings.

Size of the firm (SIZE): SIZE is the size of the firm measured as a continuous variable. It is the quantity or the number of labour employed by the firm. Natural logarithm was applied to the total values for the same reasons cited for FP. According to the literature sources, SIZE is expected to be positively associated with FP.

Table 3.7: Summary of variable descriptions and measurement issues in the quantitative component

Variable Type	**Variable**	**Variable form**	**Measurement**
Dependent variables	FP	Continuous (natural log)	Average monthly total revenue is used as a proxy.
	EP	Continuous (index)	A simple average-index was created from the levels of recycling or use of recycles materials; re-use of materials; reducing material usage; degradable packaging materials; eco-friendly products; controlled pollution for production process; renewable energy mix; wastewater treatment; sustainable solid and e-waste management; and less paper, more electronic operation system applications. The levels of these components (in percentages), were qualitatively obtained from the firm representatives (respondents)
Independent variables (key predictors)	GRID_C	Continuous (natural log)	Monthly cost of national grid electricity per unit of output produced. This was measured by dividing total monthly grid electricity cost by total value of output of the firms. This was transformed into a natural logarithm form in the models.
	GRID_R	Continuous	It is the total blackout hours experienced within a month by the firm.
	GEN_C	Continuous (natural log)	Monthly cost of generator electricity per unit of output produced. This was measured by dividing the total monthly generator electricity cost by total value of output of the firms. This was transformed into a natural logarithm form in the models.
	USEGEN	Categorical	Measured as 1=low, 2=medium, and 3=high generator reliability from availability/accessibility and quality of electricity from generators within a typical month.
	EETs	Continuous	They are measured from qualitatively inquired levels of usage, expressed in percentages, assigned to various energy efficiency technologies used by the businesses. The technologies used are energy efficient lighting systems (EE_LIGHT), energy efficient machinery (EE_MACHINERY), energy efficient refrigeration systems (EE_REFRIG), and energy efficient air-conditioning systems (EE_AC).

Source: Author's construct based on Field Survey, 2022

Variable Type	Variable	Variable form	Measurement
Independent variables (controls)	R&D	Continuous (natural log)	Monthly total R&D investment.
	IT	Continuous (natural log)	Monthly internet service expenditure.
	SIZE	Continuous (natural log)	The number of employees engaged by the firm.
	CAP	Continuous (natural log)	The value of all capital assets owned by the firm represents its capital resources.
	MKT	Categorical	Measured as a dummy variable, 1 for within the district, 2 for outside the district, MKT captures the market coverage of the businesses.
	COVID	Categorical	A dummy variable of COVID-19 years. 1 is assigned to COVID-19 years and 0 assigned to the years prior.
	NEWPRODUCT	Categorical	In terms of measurement, 1 is assigned to businesses that indicated to have introduced new products/services and 2 assigned to businesses that have not.
	BUSTRUCTURE	Categorical	Firms that are structured as sole proprietorships are assigned 2 and 1 assigned if it is otherwise. The otherwise category combines corporation and partnership firms.

Source: Author's construct from Field Survey, 2022

Capital resources of the firm (CAP): CAP is measured as a continuous variable. It is the value of the capital assets owned by the firm ranging from building assets, production equipment, closing stocks, furniture, and all other assets used by the firm for productive purposes. Natural logarithm was applied to the total values for the same reasons cited for FP. All production theories expect CAP to be positively associated with FP and CAP is also essential to all innovations and new investments that are expected to positively impact the firms' EP.

Research and development investment (R&D): R&D is the total monthly investment or expenditure on research and development. It is measured as a continuous variable. Natural logarithm was applied to the total values for the same reasons cited for FP. R&D is expected to have positive effects on both FP and EP of the firms.

Information technology application (IT): IT is the monthly expenditure on internet services used by the firm. It is measured as a continuous variable. Natural logarithm was applied to the total values for the same reasons cited for FP. Just like R&D, investment in IT is expected to improve the firms' FP as well as their environmental performances.

Years of COVID-19 (COVID): COVID is a dummy variable created for the years COVID-19 pandemic was declared to be present in Ghana. 1 is assigned to those years and 0 is assigned to the years prior to the COVID years. The negative impact of the COVID-19 pandemic cannot be overstated. For the period that the pandemic was in full swing, FP of the firms is expected to be lower.

Introduction of new products/services (NEWPRODUCT): NEWPRODUCT asserts the level of innovativeness, product differentiation and product newness of the firms. It is measured as a dummy variable where 1 is assigned to firms that have introduced new products/services in the past year and 0 assigned to businesses that have not. Firms that often introduce new products or services suggest their increased investment in R&D, IT and CAP, hence, expected to have increasing effects on FP and EP.

Structure of the business (BUSTRUCTURE): BUSTRUCTURE is a dummy variable of the business structure of the firm. Sole proprietorship businesses are assigned 1 while other structures combined (corporations and partnerships) are assigned 0.

3.7.1.4 Endogeneity problem

One of the conditions of a causal-effect relationship between a dependent variable (y) and a predictor variable (x) is that no other causes should eliminate the relation between x and y (Holland, 1986). In other words, changes in x produce changes in y holding all other things equal. The problem of endogeneity arises if *x* depends on some unmodeled causes that also influence other variables in the model such that *x* becomes correlated with the error term (Antonakis et al., 2014). The sources of this problem include omitted variables, errors in the measurement of the predictor variables, and simultaneity (Wooldridge, 2012).

Assuming the “true" model to be estimated is:

$$y_{it} = \alpha + \beta x_{it} + \phi z_{it} + \varepsilon_{it} \qquad (16)$$

But z_{it} is omitted from the regression, perhaps because there was no way to measure it, then the model that is estimated is:

$$y_{it} = \alpha + \beta x_{it} + \mu_{it} \qquad (17)$$

Where $\mu_{it} = \phi z_{it} + \varepsilon_{it}$, thus, the omitted variable z_{it} term is absorbed into the error term. If the correlation of *x* and *z* is not zero (0) and *z* independently affects *y*, the *x* is correlated with the error term μ_{it}. Hence *x* is not exogenous for α and β since *y* depends also on z and ϕ. Given the consequence of omitting a variable, it is always best to stay safe by including a variable when one is doubtful of its inclusion (Cameron & Trivedi, 2005). The models in Equations (10), (11), (12), and (13) included a lot of possible variables to minimise the problem of omitted variables.

With the measurement error, supposed that instead of observing *x* in Equation (16), what was observed is $x^*_{it} = x_{it} + v_{it}$. The Equation (17) becomes:

$$\begin{aligned} y_{it} &= \alpha + \beta(x^*_{it} - v_{it}) + \mu_{it} \\ y_{it} &= \alpha + \beta x^*_{it} + \mu_{it} - \beta v_{it} \qquad (18) \\ y_{it} &= \alpha + \beta x^*_{it} + \sigma_{it}\ , \ where\ \sigma_{it} = \mu_{it} - \beta v_{it} \end{aligned}$$

Since both x^*_{it} and σ_{it} depend on v_{it}, they are correlated.

The problem of endogeneity could also arises from simultaneous relationships where the dependent variable in one equation becomes a determining factor in other equations (Wooldridge, 2012). In the financial performance model presented in Equation (10), the capital value of the firms (CAP), the employee size (SIZE), internet expenditure (IT), R&D expenditure, and the level of energy efficiency technology adoption (EET) are suspected to be endogenous because they could all be simultaneously determined by total revenue (FP) of the firms. The Durbin-Wu-Hausman Endogeneity Test results (see Appendix B) confirmed these suspicions.

It was difficult to find consistent instruments in the quantitative survey data that correlate with the endogenous variables but uncorrelated with the error term. As Rossi (2014) pointed out, sometimes, the 'cure' to the problem (in this case using instrumental variables) can be worse than the disease if poor IVs are used. Additionally, lagged versions of the endogenous variables could not be generated to be used as instruments because the panel data was not collected annually. For these reasons, suitable IVs were not available to be used hence, the researcher only acknowledged the presence of endogeneity in the models and did not focus entirely on establishing causal effects relationships but to reveal the associations between the dependent and independent variables.

3.7.2 Qualitative analytical methods

The qualitative component of the mixed methods was analysed within the case study approach described by (Creswell, 2015). With this approach, the thesis explored a bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection and reported a case description and case-based themes (Creswell, 2015). In this study, the issues or concerns being explored were the reasons for the adoption or non-adoption of different energy systems, and the cases to illustrate these issues were businesses in the Greater Accra Region of Ghana within a bounded system, that is, a developing context. Though some scholars like Stake (2005) view case study research not as a methodology but a choice of what is to be studied, others like Creswell (2015), Denzin and Lincoln (2005), Merriam (1998), and Yin (2003) view it as a strategy of inquiry, a methodology, or a comprehensive research strategy. The current study adopted the two schools of thought, viewing the approach as a choice of what to study and a method of inquiry. As a method, the qualitative study adopted a collective case study approach where the inquirer selected multiple case studies to illustrate the issues or concerns identified (Creswell, 2015).

Thematic content analytical method was employed to illustrate and interpret the qualitative data (issues) collected on the cases. The analysis focused on key issues or what Creswell (2007) termed as “analysis of themes” (p. 75) not for the purpose of generalizing beyond the cases, but for understanding the complexity of the issues concerning the cases. The thesis identified issues within each case and then looked for common themes that transcended the cases as suggested by Yin (2003). To identify these themes, the researcher employed multiple coding techniques described by Saldana (2013). At the initial first cycle coding stage where huge chunks of the qualitative data were reduced to simple code s, the researcher employed descriptive coding --which summarises in a word or short phrase, the basic topic of a passage--, in vivo coding --also known as verbatim coding, it is a word or short phrase from the actual language found in the data--, and holistic coding --attempts to grasp basic themes or issues in the data by absorbing them as a whole instead of analyzing them line by line-- methods. These first coding methods were preferred because they overlap in their application, relate to how best to answer the qualitative research questions, and the researcher found them easy to perform to understand the complexity of the identified issues.

At the second cycle coding stage, the thesis classified, categorised, prioritise, integrated, synthesised, and conceptualised the data coded through first cycle coding methods. Pattern coding method was used at this stage where the codes identified emerging themes or explanations from the first cycle codes and grouped these summaries into smaller number of sets, themes, or constructs as suggested by Miles and Huberman (1994). After the themes were developed the researcher chronologically presented, interpreted, and represented the voices of the participants as cases. Table 3.8 presents a guide for the first and second cycle codes used for the discussion of the qualitative component of the study. The second cycle codes were separate themes developed from the first cycle block codes.

Table 3.8: Codebook for the first and second cycle codes

Main research questions	First Cycle Codes	Second Cycle Codes
• What factors underlie the firms' choice for different energy systems? • Why are some alternative systems like RETs less preferred to others?	Factors accounting for the use of grid-energy system	Related themes developed based on the reasons why firms use grid-energy system
	Factors accounting for the use of generator system	Related themes developed based on the reasons why firms use generator system
	Factors influencing the adoption of RETs in Ghana	Related themes developed based on the reasons why firms use RETs
	Benefits of investing in RETs	Related themes developed based on the reported benefits of investing in RETs
	Factors accounting for the non-adoption of RETs	Related themes developed based on the reasons why firms do not use RETs

Source: Author's construct based on Field Survey, 2022

3.8 Conclusion

Businesses in Ghana, like any other developing country experience different realities with regards to their business culture, practices, and investments. In terms of investment decisions regarding key inputs like energy systems, their choices may be dependent on their environment, resource availability, awareness and access to relevant information and technologies. To understand the different realities of businesses in the Greater Accra Region of Ghana regarding the choice of energy systems for their production needs, the researcher adopted a mixed research method that allowed for both an in-depth and a wider inquiry into the lived experiences of the businesses.

Having settled on Greater Accra (G/A) Region due to its business centeredness, and three districts from the region that housed about 62% of all businesses, the researcher sampled 404 firms for the quantitative design and 15 participants involving key informants and firm representatives for the qualitative design. The enterprise survey was designed to collect historical data for 2015 and 2017 representing the power crisis era, and 2019 and 2021 representing the post-crisis era. The purpose of designing the survey along these eras was to assess how businesses behaved in the two eras in terms of their choices regarding different energy systems, the underpinning factors, and how their performances are relatively impacted. Viewed as a panel data, the researcher used the Fixed-Effect regression methods to model the quantitative relationships between financial and environmental performances of the firms on the left-hand side, and the per unit cost and reliability of different electricity types, different energy efficient technologies, as well as other variables as determined by the reviewed theories, on the right-hand side. The qualitative component was analysed using thematic analytical techniques within a case study approach to understand the complexity of energy decisions concerning businesses in the Greater Accra Region of Ghana.

CHAPTER FOUR

UNDERPINNING FACTORS OF ENERGY SYSTEMS CHOICES BY FIRMS IN THE GREATER ACCRA REGION OF GHANA

4.1 Introduction

This chapter sets out to understand the complexity of the energy systems utilised by businesses in the Greater Accra Region of Ghana. The discussion is focused on unearthing the types of energy systems used by the firms during the electricity crisis and post-crisis eras and why each utilised energy system was preferred according to the standpoints of respondents in the study - policy makers, electricity suppliers, and firms. The view of these participants in the study on the energy systems that are often not utilised, and the underpinning reasons are also discussed in the chapter. The chapter finally ends with a conclusion.

4.2 Profile of the study participants

A total of fifteen (15) participants were involved in the study. These include 2 key informants from policy and legislative institutions, 3 key informants from fuel supplier institutions and 10 firm representatives. As already pointed out in Chapter 3, the data gathering phase reached a saturation point after 13-14 participants were interviewed. At this point, no new information was coming through hence the researcher decided to settle on 15 participants for the qualitative design. For the sake of identification and confidentiality, the researcher assigned identifiers, a combination of letters and numbers, to the participants rather than their real names. Other key characteristics like the sex, institution, participant category and the positions held in the institutions/organization were also provided (see Table 4.1).

The energy sector is a heavily male dominated sector as reflected in the number of males who participated in the study. It must be reiterated that the firm representatives were drawn from the respondents of the quantitative survey. Additionally, these were the participants who were willing to participate after numerous calls were made in search of potential participants. The researcher could not get any female key informants as he was consistently directed to the male officials who were regarded as the best informants when the institutions were identified and contacted. There were two (2) female firm representatives that participated in the in-depth interviews. The skewness of the gender dominance towards males in the productive energy sector corroborates the findings of Pueyo et al. (2020) that productive energy like electricity is consumed more by male-owned enterprises, underlined by the gendered division of labour, lower value of women's work and limited access to start-up capital.

Different sizes of firms were sampled for the study and all the participants hold key executive positions in their respective institutions. The study, therefore, achieved its target of involving knowledgeable participants who take part in decision making for their institutions at different levels. It is, therefore, presumed that they have a wealth of information to share on the choice of energy systems used by firms and the underlying reasons.

Table 4.1: Profile of respondents in the qualitative study

Identification	Gender	Institution	Participant category	Designate/Position
Policy / Regulatory Officer (PRO_1)	Male	Energy Commission, Ghana	Policy / Regulatory (Key informant interview -KII)	Principal Programme Officer, Renewable Energy
PRO_2	Male	Ministry of Energy, Ghana	Policy / Regulatory (KII)	Asst. Programme Officer, Power Directorate
Fuel Supplier (FS_1)	Male	Electricity Company of Ghana Ltd.	Fuel Supplier (KII)	District Manager of ECG
FS_2	Male	AB Solar Africa Ltd.	Fuel Supplier (KII)	Chief Executive Officer (CEO)
FS_3	Male	Tino Solutions Ltd.	Fuel Supplier (KII)	Founder
Firm Representative (FR_1)	Female	Cleaning Solutions Ltd. in Tema Metropolis	Large-sized manufacturing firm	Human Resource Director
FR_2	Male	Salt mining company in Ga South Municipality	Medium-sized manufacturing firm	Senior Officer
FR_3	Male	Good Blocks Production Company Ltd in Ga South Munic.	Small-sized manufacturing firm	CEO
FR_4	Male	Phlox Graphics in Tema Metropolis	Small-sized services firm	CEO
FR_5	Male	J&J Interior Design & Décor in Accra Metropolis	Medium-sized services firm	Senior Officer
FR_6	Female	Thy Grace Beauty Saloon in Accra Metropolis	Micro-sized Services firm	Manageress
FR_7	Male	Blue Gate Guest House in Tema Metropolis	Small-sized services firm	Manager
FR_8	Male	Smart Graphic Design company in Accra Metropolis	Micro-sized services firm	CEO
FR_9	Male	Winners Auto Shop in Ga South Municipality	RET user. Small-sized services firm	Senior Officer
FR_10	Male	Ederick Limited – Whirlpool in Accra Metropolis	RET user. Large-sized services firm	Senior Officer

Source: Author's construct based on Field Survey, 2022

4.3 Energy systems used by firms in the Greater Accra Region of Ghana

4.3.1 The energy systems used during the 2012-2016 power crisis period

Ghana went through a serious power crisis period between 2012 and 2016, but not for the first time in her history. As pointed out in Chapter Two (2) of this study, many factors accounted for the shortage in the supply of electric power to the demand sectors, chief amongst them being the insufficient inflow of water into the Akosombo, Kpong and Bui Dams attributed to climate change. In recent history, similar power crises have been recorded in 2007, 1998, and 1984. But the 2012-2016 power crisis was described as most devastating (Adusah-Poku et al., 2022) and impactful (Danso-Wiredu et al., 2016; Ruiter, 2016). A Principal Programme Officer at the Energy Commission recalled the 2012-2016 power crisis period as:

> *"…a particularly challenging period for everyone having to deal with frequent power outages but the most impacts were felt by businesses, especially small-sized ones who had limited alternatives" [PRO_1, 2022].*

His description of the situation aligns perfectly with all the firm representatives that participated in this study. According to the CEO of a small-sized services firm in Tema Metropolis:

> *"We really suffered. For instance, anytime they took the light we had to temporarily shut down. If we knew the light was not going to come back on for that day, the day would have ended for us. We nearly went out of business"* [FR_4, 2022].

The dire nature of the impacts described by the participants are in synch with Abeberese et al. (2021)'s findings that revealed a 10 percent loss in firms' output during the 2012-2016 power crisis period. The quantitative data revealed that firms in the Greater Accra Region of Ghana practiced electricity fuel stacking during the power crisis period. This involved two (2) major sources, the grid and generator sources, and a third source, RETs, which was not very popular amongst the firms. Considering the entire period of the study, all the firms used grid-electricity, 21.5% used generator electricity and less than 1% used RET electricity (Table 4.2).

Table 4.2: Electricity sources used by firms vis-à-vis the eras

Electricity source	Size classification of firms				Era		Total
	Micro	Small	Medium	Large	2015-2017	2019-2021	
Grid-electricity	1275 (100)	300 (100)	17 (100)	12 (100)	802 (100)	802 (100)	1604 (100)
Generator-electricity	201 (15.76)	124 (41.33)	9 (52.94)	11 (91.67)	196 (24.44)	149 (18.58)	345 (21.51)
Renewables-electricity	10 (0.78)	2 (0.67)	0 (0.0)	0 (0.0)	6 (0.75)	6 (0.75)	12 (0.75)
Cases	***1275***	***300***	***17***	***12***	***802***	***802***	***1604***
Chi2 (Pr)	***144.84 (Pr=0.000)***				***8.24 (Pr=0.041)***		

Source: Field Survey, 2022

Findings from the qualitative component of the study support the quantitative data that firms of all sizes rely heavily on grid electricity. The officer from the Energy Commission noted that:

> "*Before the power crisis in 2012, we all depended heavily on VRA (Volta River Authority) electricity, both people and businesses. So, whether crisis or no crisis, people have always had the national grid-electricity"* [PRO_1, 2022].

This view was re-echoed by the fuel suppliers, confirming the heavy reliance on the national grid-electricity. A District Manager of ECG who oversees operations in one of the ECG districts in the Greater Accra Region expressed that:

> "*All businesses who require power for their business operations use the national grid electricity for the operations and for lighting. Even those who do not use it in their operations directly, use it for lighting purposes or refrigeration for small businesses for instances, for cooling their drinks and water. It has been like that, before the 2012-2016 power crisis, during and even after"* [FS_1, 2022].

A supplier of solar systems described the national grid-electricity as "*integral*" to businesses in Ghana. He explained the grid-electricity usage during the crisis era as follows:

"During the dumsor (the power crisis), businesses suffered because the grid power was integral to their existence and very few of them had alternatives …" [FS_2, 2022].

Electricity from diesel/petrol-powered generators was also used significantly in Ghana during the power crisis era. As reported in Table 4.2, more firms used generators during the crisis period (2015-2017) compared to the post-crisis period. Additionally, more percentages of generator usage were recorded for medium and large-sized firms. One of the participants of the qualitative study noted:

"During the dumsor (the power crisis) some firms often turned to generators as their next alternative, for some, their only alternative but for many too, there was no such alternative aside the primary source (which is the grid-electricity)" [FS_2, 2022].

This view was generally held by the respondents in the qualitative study, and it is in synch with the quantitative findings results and findings from other empirical studies like Abeberese et al. (2021), Blimpo and Cosgrove-Davies (2019, and Oseni and Pollitt (2015) who found firms in developing countries like Ghana and Nigeria to depend on own power generation during power shortages. A senior officer of a salt mining company in Ga South municipality added to the argument by noting that:

"We use power a lot for our activities. So, during the load shedding (power crisis) of 2012-2016 period, we used the plant (industrial generator) a lot. For us here, the plant was a major source aside the ECG power, even now" [FR_2, 2022].

Out of the 10 firms sampled for the qualitative study, 6, represented by FR_1, FR_2, FR_3, FR_5, FR_7, and FR_10 reported to have used generators aside their main power source during the 2012-2016 power crisis. The extent of usage, however, differed based on the size and activity level of the firm as well as the operation cost of the generators. According to the manager of a guest house in Tema Metropolis:

"We put on the generator if we had lots of guests. If we had less than 5 guests before they took the light, we could not put it (the generator) on because of the costs" [FR_7, 2022].

On the contrary, some firms could not do without using the generator system. The senior officer of a large-sized services firm in Accra Metropolis noted that:

> *"The plant was always ready to start work when the need came because of the nature of the business. Items needed to be showcased. We could not afford to be without power for long during the crisis period. The cost of not using it was going to be more than the cost of using it. In that sense I can say we had no choice but to use it"* [FR_10, 2022].

Only three (3) firms from the quantitative sample reported to have used electricity from renewable sources during the crisis period (Table 4.2). The usage of energy efficiency technologies on the other hand was popular among the firms during the power crisis period. The CEO of a micro-sized services firm in Accra Metropolis recalled that:

> *"We practiced energy efficiency in this firm during the dumsor (the power crisis) era particularly with lighting. You know, when they did the general replacement of the old lights with these energy bulbs, it became part of our culture. You won't even get the old ones to buy in the market now, so you have no option of inefficient light bulbs"* [FR_ 8, 2022].

Clearly, efficient lighting technologies dominated the EET landscape amongst the firms during the power crisis period and this aligns with previous studies like Adom (2019), Agyeiwaah (2019), and Gouws et al. (2012). The CEO of the micro-sized services firm continued:

> *"We solely used the energy efficient bulbs. We know there are other technologies like efficient fridges and air-conditioners, but we don't have them"* [FR_ 8, 2022].

A senior officer of a large-sized services firm, however, argued that they went beyond efficient lighting systems. According to her:

> *"We applied energy efficiency technologies in our overall processes, lighting, and cooling systems. We have new machines that consume less energy, we have the EC energy recommended bulbs, and we also have the starred air-conditioners in our structures"* [FR_1, 2022].

4.3.2 The energy systems used in the post-power crisis period

The energy landscape of the firms had not changed significantly from what was observed during the crisis era. Coupled with the evidence in Table 4.2, the firm representatives also noted that they are running on the same energy systems as they did during the *dumsor* era, except that some of the systems have been upgraded. A senior officer of a medium-sized services firm in Accra Metropolis said:

> *"Before the 2012-2016 crisis, we always had some intermittent blackouts. These things are not going away any time soon"* [FR_5, 2022].
>
> He continued and asked me (the researcher).
>
> *"Are we not still have power issues? So, for us, we have been using the same electricity systems before the 2012-2016 crisis, during the crisis, and we continue to rely on them, that is, the grid electricity supported by generators"* [FR_5, 2022].

Similarly, the same energy efficiency technologies are applied in the period after the 2012-2016 power crisis, only intensified by some establishments. A senior officer of an auto shop in Ga South municipality stated that:

> *"We started using these types of bulbs (energy efficient bulbs) since 2012". They have even brought new ones into the market like the LED ones. We use them all. We mix them. But we also use new air-conditioners that have the stars. The stars mean they are efficient right?"* [FR_9, 2022].

This was reiterated by the manager of the guest house who said:

> *"We continue to use efficient light bulbs. I don't know how it helped us during the dumsor (power crisis in 2012-2016) but it is helping us now save some cost. The same applies to the air-conditioners that we have recently replaced with the yellow labelled ones (efficient)"* [FR_7, 2022].

4.4 Business establishments and grid electricity

This section focuses on the grid-electricity system used by the business establishments. Most importantly, the section attempts to understand why the firms use this system from the quantitative and qualitative data perspectives, and for what end-uses.

4.4.1 Factors accounting for the use of grid-electricity

The grid-electricity is the most used electricity system as established in sub-section 4.3. The reasons given for the high dependency on this system according to the quantitative data are presented in Table 4.3. Accordingly, the firms have reportedly chosen to invest in national grid electricity system because they prefer it as the primary power source. This is common among all sizes of business establishments. The reasons for this overwhelming preference can be deduced from the other factors reported in Table 4.3. Electricity from the national grid is considered to be readily available and easily accessible (Table 4.3). The medium- and large-sized firms have reported such reasons than the smaller firms. Few firms (less than 30%) invested in the grid system because they thought it was cheap. This electricity source is understandably used for all end-uses, from lighting, space colling, to machine operations. According to Table 4.4, 99 percent of the firms use grid power for lighting, 75 percent use it to operate their equipment, and 60 percent use it for space cooling. The observed differences among the size classified firms are statistically significant but not for the crisis periods classifications according to the chi-square statistics (Tables 4.3 and 4.4).

Table 4.3: Why firms chose to invest in grid electricity vis-à-vis firm size and power crisis eras

Reasons	Size classification of firms				Era		Total
	Micro	Small	Medium	Large	2015-2017	2019-2021	
It is a cheaper source	332 (26.04)	77 (25.67)	0 (0.0)	4 (33.33)	212 (26.43)	201 (25.75)	413 (25.75)
It is environmentally friendly	212 (16.63)	43 (14.33)	0 (0.0)	0 (0.0)	128 (15.96)	127 (15.84)	255 (15.90)
It is easily accessible	567 (44.47)	123 (41.0)	4 (23.53)	9 (75.0)	355 (44.26)	348 (43.39)	703 (43.83)
It is readily available	603 (47.29)	138 (46.0)	9 (52.94)	8 (66.67)	365 (45.51)	393 (49.0)	758 (47.26)
It is preferred as main electricity source	1159 (90.90)	283 (94.33)	13 (76.47)	7 (58.33)	729 (90.90)	733 (91.40)	1462 (91.15)
To complement my primary source	5 (0.39)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.37)	2 (0.25)	5 (0.31)
As a back-up to primary source	6 (0.47)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.50)	2 (0.25)	6 (0.37)
Because primary source is unreliable	4 (0.31)	1 (0.33)	0 (0.0)	0 (0.0)	5 (0.62)	0 (0.0)	5 (0.31)
Encouraged by policy instrument	13 (1.02)	3 (1.0)	0 (0.0)	0 (0.0)	8 (1.0)	8 (1.0)	16 (1.0)
Forced by policy instrument	4 (0.31)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.25)	2 (0.25)	4 (0.25)
Cases	***1275***	***300***	***17***	***12***	***802***	***802***	***1604***
Chi2 (Pr)	***640.67 (Pr=0.000)***				***22.33 (Pr=0.938)***		

Source: Field Survey, 2022 *NB: Colum percent of cases in parenthesis*

Table 4.4: End uses of grid electricity by firm size and power crisis eras

End uses	Size classification of firms				Era		Total
	Micro	Small	Medium	Large	2015-2017	2019-2021	
Lighting	1270 (99.61)	296 (98.67)	17 (100)	12 (100)	797 (99.38)	798 (99.50)	1595 (99.44)
Cooking and/or boiling water	52 (4.08)	22 (7.33)	9 (52.94)	3 (25.0)	42 (5.24)	44 (5.49)	86 (5.36)
Space cooling or heating	737 (57.8)	203 (67.67)	13 (76.47)	12 (100)	480 (59.85)	485 (60.47)	965 (60.16)
Operating equipment	899 (70.51)	274 (91.33)	17 (100)	12 (100)	595 (74.19)	607 (75.69)	1202 (74.94)
Cases	***1275***	***300***	***17***	***12***	***802***	***802***	***1604***
Chi2 (Pr)	***231.66 (Pr=0.000)***				***1.75 (Pr=0.988)***		

Source: Field Survey, 2022 *NB: Colum percent of cases in parenthesis*

To further understand the core reasons why firms in the Greater Accra Region regard the national grid electricity as a go-to or main system when they think of electricity, participants of the qualitative study provided deeper insights to amplify the reasons stated in Table 4.3. The views of the respondents from the policy and regulatory institutions, as well as the fuel suppliers on why firms opted for the grid-electricity as the first and main electricity source are captured in the following themes, and represented pictorially in Figure 4.1.

4.4.1.1 Solid, secured, and a guaranteed system

The grid system is viewed as a secured and guaranteed source of power to the end-users. This security purportedly allows for uninterrupted production which enhances firms' growth and expansion. Compared to other electricity sources, the grid system is believed to provide this kind of security to the enterprises. According to a senior officer at the Energy Commission of Ghana:

> *"People and for that matter companies opt for the national energy system (grid-electricity) because of security and the guaranteed supply of energy. Even during the time of dumsor where power was rationed in the country, when it (the grid power) gets to where a particular factory has been sited, and it is time for them to have power, I mean it is a solid power where there is no interruption, until maybe a ration will take it away from them. So, I will say because of security and guaranteed supply of the national system, that is why people always go for it"* [PRO_1, 2022].

The security of the grid system has been found in the literature to encourage its usage. Baurzhan and Jenkins (2016) and Fried and Lagakos (2020), for example, observed that firms depended on the grid system for a large part of their activities because it was regarded as a guaranteed system. Some policy measures have also favored the preference for the national grid electricity. The senior officer at the Energy Commission added:

> *"Government policies have also worked against other electricity sources like renewables. That favors the national grid, doesn't it? Even though in the past 2 years or so, the government has increased the renewable share in the grid system, it is still dominated by thermal plants. There is a government subsidy on the national grid, so it cushions the consumers a little bit. That works against individuals and companies who*

may want to invest in other systems. You know the cost aspect is very important. If the national grid appears cheaper, why will they go for the other more costly alternatives. There are other benefits of alternative systems like the renewables that people do not consider" [PRO_1, 2022].

The senior officer's observation aligns with that of other reviewed studies. Kemausuor and Ackom (2017) and Kumi (2017) argued that the national grid has seen a remarkable infrastructural growth over the years in Ghana, sometimes enforced by the power supply challenges the country has experienced. The only other energy sub-sector that has seen a similar growth is the petroleum sub-sector, according to the researchers.

4.4.1.2 Convenient, reliable, and safe

Although expressed in a different form, but connoting the same understanding, the District Manager for one of the ECG districts in the Greater Accra Region is of the view that businesses are more inclined to use the national grid due to its reliability and safety characteristics. According to him:

"I am sure they (businesses) go for the national grid as number one because first of all, they need a certain quantum of energy, and it should be reliable, and the national grid is very capable of supplying all the requirements of our enterprises. The national grid is also very safe. I mean you are assured that once you are getting power from ECG, it will be able to power your equipment and not destroy them. It is also very reliable even though we somehow have power outages, but the reliability is there" [FS_1, 2022].

In another explanation, the Founder of Tino Solutions Limited, a renewable system supplier noted that:

"*The national grid has been the go-to system for many companies for many years because it provides conveniency. You get power conveniently. You know, people don't like to suffer or hustle. People will prefer to pay say, 500 cedis every month for power rather than pay GHS 500 times 10 now as initial cost for another source to be enjoyed free after 10 years. People want it the easy way, simple"* [FS_3, 2022].

4.4.1.3 Simply available

Easy accessibility has also played a huge part in companies or firms investing in the national grid as their primary electricity source. The Assistant Programme officer at the Power Directorate of the Ministry of Energy had this to say when asked why firms go for the grid-electricity:

> "*It is definitely access. For most of these firms, where they are situated, access to the national grid electricity is relatively easy. Even on a national level, you can see that access to electricity (the national grid) is quite high. That is the main drive for them (the firms) moving to the power grid"* [PRO_2, 2022].

Affirmatively, the founder of Tino Solutions Limited sums it up beautifully as:

> *"You know in our country, financing new technologies is a big issue and because other alternative power sources require significant finance, they (businesses) simply go with what is available, that is, the national grid"* [FS_3, 2022].

The firms have slightly different perspectives on why they have the national grid as their go-to system. The firms differ on the claims of FS_1 that the national grid is a very reliable source. Several of them hold the common view that the national grid is not so reliable as claimed but there are no better alternatives. One of the firm representatives exclaimed:

> "It *(the national grid system) is not reliable at all. Now is better than few years ago but even now we do get dumsor here and there. We have had to repair or completely replaced faulty items caused by unreliable supple from the national grid. Last 2 months, we had low current. When it came back, the voltage was so high that one of our computer systems got damaged"* [FR_5, 2022].

The views of the firm representatives align with the findings of Blimpo and Cosgrove-Davies (2019), Eberhard et al. (2011), Fried and Lagakos (2020), and Scott et al. (2014) that the grid system is highly unreliable yet overly subscribed because of its infrastructure and the ease of access which makes it the most viable option.

4.4.1.4 The monopoly power of the grid system

Despite the reliability concerns, the national grid is the main power source for nearly all firms in the Greater Accra Region of Ghana. To a senior officer of a medium-sized manufacturing firm in the Gas South Municipality, the dominance of the national grid has been unbreakable because of the lack of a realistic competition in the power supply market in Ghana. He exclaimed:

> *"Just take a critical look at the power market. All the major stakeholders from different suppliers are with the national grid. So where is the competition for the grid? There is one but perhaps very uncompetitive in terms of cost, I mean the generators. The national grid flexes a muscle that cannot be competed with. So as enterprises who require huge power and rely on constant supply, we have no real choices but to go to the national grid"* [FR_2, 2022].

The CEO of a small-sized services firm expressed the same sentiment about the lack of real options for business establishments. According to him:

> *"The power grid is enjoying monopoly here in Ghana, yes, monopoly power. There is no other major supplier of power in Ghana aside the VRA-ECG power. I mean power supplier at a competitive cost, none, there is none. There are only supplies at the individual levels which we all know cannot compete with the grid system. There are other markets like the solar that are not fully developed in Ghana, so the national grid appears unrivaled. So, if you take our situation, it is like in the case of no real alternatives, bad is good because the grid is just bad at times, but we cannot do without it"* [FR_4, 2022].

These assertions are not different from what other scholars have found. Bawakyillenuo (2012) for instance, observed that rural folks would rather wait for the national grid to get to them naturally than sign up for an off-grid alternative electricity source. That is how much the grid system is preferred. Other studies like Deutschmann et al. (2021) and Gunatilake et al. (2012) argue that the grid system remains first-choice power source for most businesses in developing countries despite the increasing willingness-to-pay for reliable alternative sources.

4.4.1.5 Just there for all to access

Because of the huge presence of the national grid as enshrined in the monopoly power of the grid as mentioned above, many of the firms regard the national grid to be just there for all to access. This according to them makes firms rely heavily on the national grid system for their power needs. The manager of a small-sized services firm in the hospitality industry in the Tema Metropolis noted that:

> *"ECG power (the national grid) is available for everyone. Anybody or any business can just go and access it once you have the connection fee or meter fee or whatever you need to do to get it, they are just there. I am sure when this guest house was being built, the power to get was not a headache at all, like where would they get power from? No no. It was already there. So, they would rather think of how much do we need to go get power? So yes, the ECG power is available, so businesses go to them first"* [FR_7, 2022].

In another expression, the CEO of a graphic design services firm reiterated the availability of the grid system as a go-to factor. He noted that:

> *"We all go to the national grid for power simply because it has been there for long, and it will continue to be there in the future. It has that track record, so you know you don't wake up one day and the grid is not there. Whether raining or sunny, it is there and when you want it you can get it"* [FR_8, 2022].

4.4.1.6 The grid is cheap

Other firms also believe that the grid system is just unbeatable when it comes to the cost of electricity. This is a major factor that causes firms to invest and use the grid system at the expense of other systems. According to the manageress of a beauty shop in the Accra Metropolis:

"Sometimes when the ECG is not there, like when they do light off, we can't use other power sources. It is because those sources like generators can be expensive. The ECG is cheap comparatively. That is why for us we depend on it so much" [FR_6, 2022].

In agreement, a senior officer of medium-sized services firm also in the Accra Metropolis noted:

"*Other power sources are expensive. You are looking at the huge initial cost for solar and regular maintenance cost as well. For generators, the cost of operation is always high given the rising fuel prices in this country. But with the grid, even though it is not so cheap like that, it is better than the alternatives. So, we think of the grid first, before trying to support with others"* [FR_5, 2022].

These views align with the findings of Preuninger (2014), Bardazzi et al. (2015), and Solnørdal and Foss (2018) that firms in both developed and developing countries always consider the relatively cheaper cost of the national grid in their energy decisions.

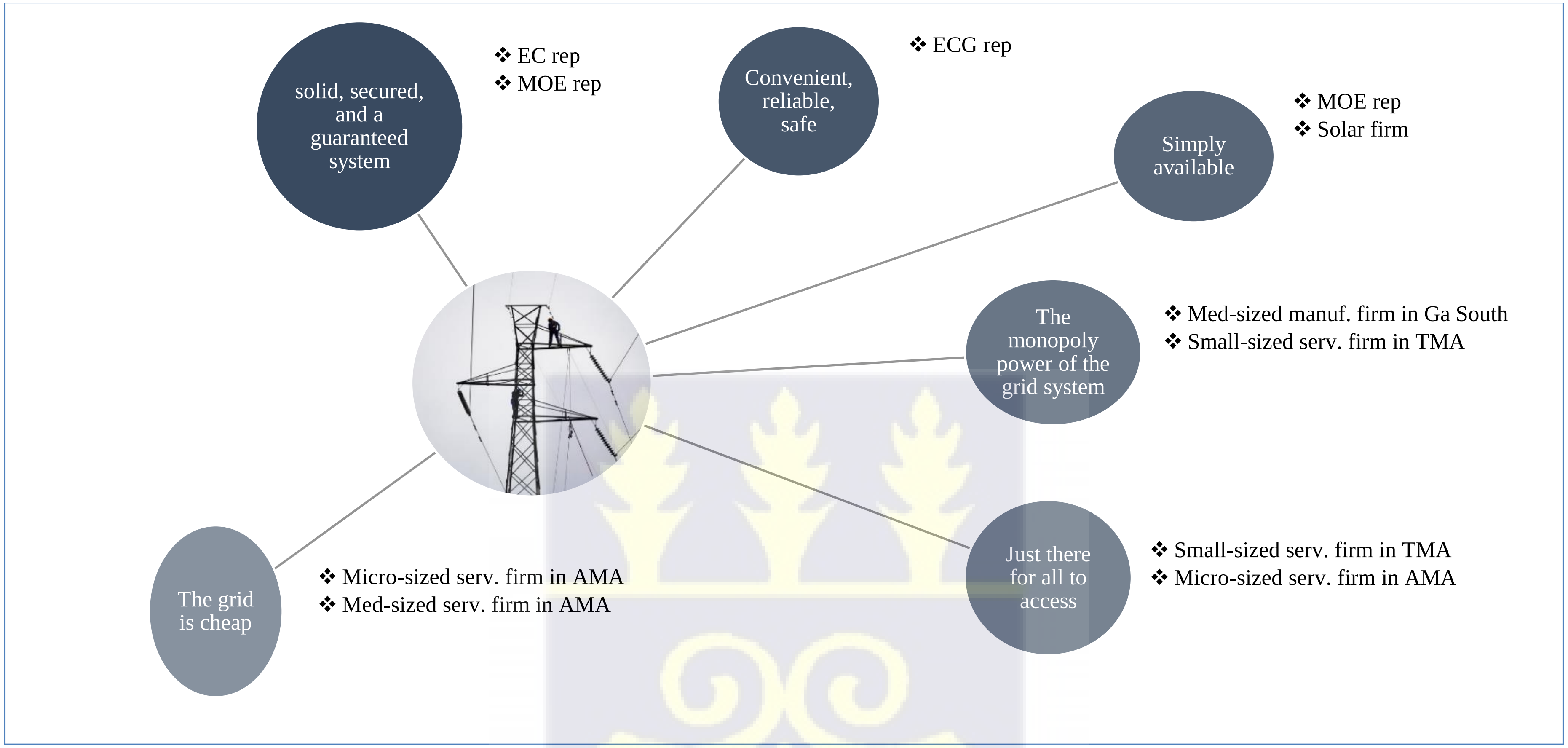

Figure 4.1: Diagrammatic representation of the reasons why businesses use grid electricity

Source: Author's Construct based on Field Survey, 2022

4.5 Business establishments and generator-electricity system

This section focuses on the generator systems used by businesses in the Greater Accra Region of Ghana. The findings from the quantitative survey and qualitative interviews have provided insight into what the electricity generated from diesel/petrol generators is used for and why they are often used. About 22 percent of the firms sampled in the quantitative study reportedly used diesel/petrol-powered generators (Table 4.2). They are used for pretty much everything just like the electricity from the national grid. About 97 percent of these firms used the generators for lighting purposes, 72 percent for space cooling, and 90 percent used it to operate their equipment or machines (Table 4.5). The similarity with the grid electricity in terms of the end-uses is not surprising because both sources often use the same connectivity systems of the enterprises. In most cases, when the generators are switched on, they power everything like the grid electricity.

Table 4.5: End uses of self-generated electricity by firm size and era

End uses	Size classification of firms				Era		Total
	Micro	Small	Medium	Large	2015-2017	2019-2021	
Lighting	191 (95.02)	123 (99.19)	9 (100)	11 (100)	189 (96.43)	145 (97.32)	334 (96.81)
Cooking and/or boiling water	5 (2.45)	5 (4.03)	9 (100)	3 (27.27)	11 (5.61)	11 (7.38)	22 (6.38)
Space cooling or heating	123 (61.19)	107 (86.29)	9 (100)	11 (100)	132 (67.35)	118 (79.19)	250 (72.46)
Operating equipment	168 (83.58)	122 (98.39	9 (100)	11 (100)	178 (90.82)	132 (88.59)	310 (89.86)
Cases	***201***	***124***	***9***	***11***	***196***	***149***	***345***
Chi2 (Pr)	***263.51 (Pr=0.000)***				***8.28 (Pr=0.218)***		

Source: Field Survey, 2022 *NB: Colum percent of cases in parenthesis*

According to the generator users in the quantitative survey, the generators serve as back-up power sources to their primary source because they found the primary source (which has been reported as the national grid system) to be highly unreliable (Table 4.6). Some of the establishments also invested in generators to complement their primary source of electricity.

Table 4.6: Why firms chose to invest in generators vis-à-vis firm size and power crisis eras

Reasons	Size classification of firms				Era		Total
	Micro	Small	Medium	Large	2015-2017	2019-2021	
It is a cheaper source	7 (3.48)	0 (0.0)	0 (0.0)	0 (0.0)	5 (2.55)	2 (1.34)	7 (2.03)
It is environmentally friendly	4 (1.99)	0 (0.0)	0 (0.0)	0 (0.0)	3 (1.53)	1 (0.67)	4 (1.16)
It is easily accessible	12 (5.97)	6 (4.84)	0 (0.0)	4 (36.36)	13 (6.63)	9 (6.04)	22 (6.38)
It is readily available	21 (10.45)	25 (20.16)	0 (0.0)	4 (36.36)	28 (14.29)	22 (14.77)	50 (14.49)
It is preferred as main electricity source	9 (4.48)	0 (0.0)	0 (0.0)	0 (0.0)	4 (2.04)	5 (3.36)	9 (2.61)
To complement my primary source	46 (22.89)	22 (17.74)	0 (0.0)	0 (0.0)	38 (19.39)	30 (20.13)	68 (19.71)
As a back-up to primary source	133 (66.17)	103 (83.06)	9 (100)	7 (63.64)	135 (68.88)	117 (78.52)	252 (73.04)
Because primary source is unreliable	115 (57.21)	66 (53.23)	5 (55.56)	3 (27.27)	115 (58.67)	74 (49.66)	189 (54.78)
Encouraged by policy instrument	3 (1.49)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.51)	2 (1.34)	3 (0.87)
Cases	***201***	***124***	***9***	***11***	***196***	***149***	***345***
Chi2 (Pr)	***176.88 (Pr=0.000)***				***29.79 (Pr=0.374)***		

Source: Field Survey, 2022 *NB: Colum percent of cases in parenthesis*

4.5.1 Factors accounting for the use of generator-electricity systems

The following themes were extracted from the views of the respondents in the qualitative study as the factors that encouraged businesses in the Greater Accra Region to invest in generators.

4.5.1.1 Ability to afford

The first push factor that encouraged some firms to invest in generators is affordability. This has been reported by some of the respondents in the qualitative study. According to the senior officer of a salt mining fim in Ga South Municipality:

> *"We are a faily big company that produces substanive tonnes of salt on daily basis. We are able to afford the plant which we use when ECG (grid power) is not there because we make enough to sustain its operations"* [FR_2, 2022].

In suport, a senior officer of a large-sized manufacturing firm in the Tema Metropolis noted that:

> *"The company can afford an industrial plant because it makes enough revenue to cover its purchase and maintenance costs"* [FR_1, 2022].

Affordability is a major push factor when it comes to investment in generators. The views of the respondents align with the findings of Foster and Steinbuks (2009, Fried and Lagakos (2020), and Oseni and Pollitt (2015) who argued that large firms demand more total energy and are better able to cope with electricity supply challenges because they have the affordability power. The opposite is true for much smaller firms who are unable to afford the generators because of the initial and operation costs. The representative of the beauty shop in the Accra Metropolis was very clear when she stressed on her ealier submission that:

> *"As I have already told you, we can't afford the generator. First it is too expnsive to buy, the kind that can power what we do here, when I checked the price last, it is expensive. Second, fuel is also expensive now so we can't be fueling it everytime. You know business is not always good, sometimes good, other times bad so it cannot sustain generator usage"* [FR_6, 2022].

Affirmatively, the CEO of a micro-sized services firm also in the Accra Metropolis clarrified:

> *"We are a small firm, we can't afford a generator now"* [FR_8, 2022].

These imply that firms that are not using the generators are deterred by initial and operation costs. Even when they desire to use it, affordability plays a major role in their inability to use it.

4.5.1.2 Cannot afford not to use a generator

Some firms use the generators because they simply cannot afford not to use them. This goes hand-in-hand with the profitabillity and affordability potential of the firms as suggested by

Fried and Lagakos (2020). The senior officer of a large-sized services firm in the Accra Metropolis affirmed that:

> *"We have showrooms that we display our appliances to the public and they must be functioning. We can't let someone walk in to the showroom and you don't have the appliances working because there is no power, they won't take you serious. So, we are always ready to turn on the generator if the main power goes off. In fact it is an automated system so the generator comes on automatically when the grid goes off"* [FR_10, 2022].

The CEO of a cement black factory in Ga South also noted that:

> "*There is competition in our market (cement block manufacturing market) so if you relax a little you will lose your customers to your competitors. Production must continue even if there is no ECG (grid power). So the generator kicks in when that is the case"* [FR_3, 2022].

Finally, the senior officer of the Cleaning Solutions Ltd. company in the Tema Metropolis justified their generator usage as:

> *"The market is waiting. People are waiting for your goods. You can't sit down just because you have no grid power. Production must continue with or without grid power"* [FR_1, 2022].

These voices relate to the findings of Alby et al. (2012) and Oseni and Pollitt (2015) who concluded that some firms in developing countries can't afford not to have power even for a short period of time due to the potential losses that might bring.

4.5.1.3 Quickest way to generate own electricity

Compared to the other sources of generating own electric power,the diesl/petrol powered generators are regarded as the quickest mean to get power with less stress and less capital comparatively. The senior officer at the Reneable Energy Directorate of the Energy Commission of Ghana made this very clear when he said:

"*The availability and easy accessibility of generators are crucial, you know. Once there is money you can buy generator today, you install it, tommorrow you are producing power for youself unlike the renewable soucres whereby one will actually have to put in a lot of capital investment to have it established to produce power for you that is not 100% …..so people in our usual business as usual lifestyly who want to have things done will go for thermal/diesel generation, that is the quickest way of getting power supply*" [PRO_1, 2022].

4.5.1.4 Unreliability of the grid power source

Another important reason that has been widely opined by the respondents as causing firms to invest in generators is the unreliability of the primary power source, which in this case is the grid power. All the firms that use generators hold the view that they would not have to invest in them if the grid system was reliable. Even players in the policy space alluded to this fact. The Principal Programme Officer at the Renewable Directorate of the Energy Commission noted that:

"The generator is a support mechanism. We saw the rise in its usage particularly during the power crisis period when power was rationed. Lots of businesses invested in this system to support the main power which is the national grid. So even now, people only use the generators when the grid power is unavailable. I must say that the national grid has improved significantly. Now we even have excess supply. The power outages we have here and there are due to technical issues and not so much of crisis issues. But yes, generators are used when the national grid fails" [PRO_1, 2022].

The Assistant Programme Officer at the Power Directorate of the Ministry of Energy added that:

"*During times that the national grid is unavailable, businesses and some individual households turned to their personal diesel or petrol generators. We have had issues in the past with supply from the grid, but thankfully that is behind us. During those times, people could not rely solely on the grid so some who could afford plants or generators did, so that they could remain in business"* [PRO_1, 2022].

All the firms that use generators cited the unreliability of their main power source as the main driver. The Cleaning Solutions Ltd. company in the Tema Metropolis uses a plant because:

> "*We could not rely on the national grid at certain times, so we have to get a plant to generate power for our operations whenever there is dumsor (power outage from the grid)"* [FR_1, 2022].

Another large-sized services firm in Accra Metropolis invested in a plant because:

> *"It is important to have a back-up power facility to supplement the grid electricity. The grid in the past has been unreliable and from time to time, we do get those unannounced power outages, so the plant is there to provide power in times of those outages*" [FR_10, 2022].

Even smaller firms that participated in the study expressed similar views regarding their usage of generators. The senior officer of the medium-sized J&J Interior Design & Décor firm in the Accra Metropolis noted that:

> *"The enterprise had no choice but to install a generator because at some point the light outs were unbearable. You come to work and no power to work with. The workers would be there and be waiting for power to work. We had other subsidiary offices and same things were happening at those places too. We had to plan and budget for generators"* [FR_5, 2022].

The manager of a small-sized guest house in the Tema Metropolis added that:

> "*In this country if you really want to do business, you have to get a back-up power source because you cannot rely on the grid always"* [FR_7, 2022].

These reasons expressed by the respondents, which have been pictorially presented in Figure 4.2, agree with the findings of previous studies regarding the usage of generators in developing countries. Abeberese et al. (2021), Alby et al. (2012), Danso-Wiredu et al. (2016); and Fried and Lagakos (2020) are few of the studies that documented serial power supply challenges in developing countries like Ghana and Nigeria and consequently forced most firms into investing in generators to complement the grid systems.

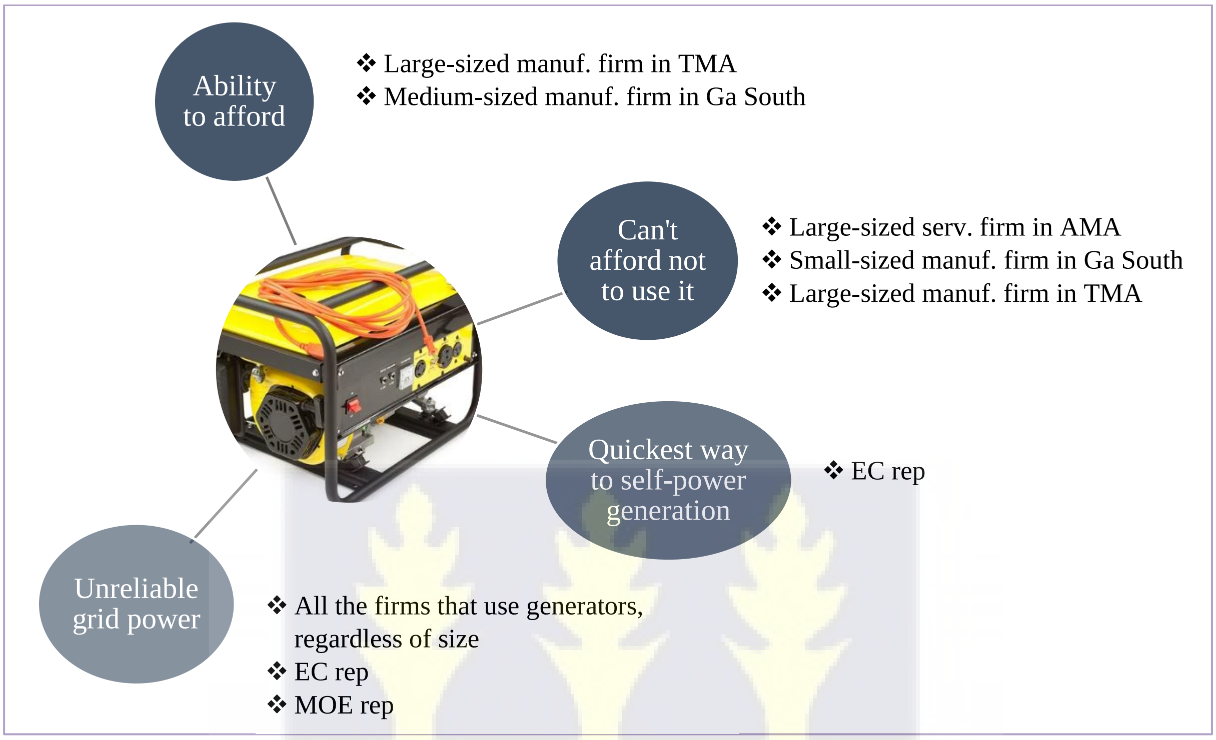

Figure 4.2: Diagrammatic representation of the reasons why businesses use generator-electricity systems

Source: Author's construct based on Field Survey, 2022

4.6 Business establishments and renewable energy technologies

In this section, the focus is turned to electricity from RETs such as solar and wind, capable of generating electricity for industrial or commercial use. The benefit of using RETs were explored, together with the factors that accounted for the non-usage of RETs according to the respondents in the qualitative interviews. The latter views have been summarised in Figure 4.3. The section also gathered some expert views on government's initiatives that have promoted or discouraged the adoption of RETs in Ghana.

4.6.1 Benefits of investing in RETs according to the respondents

Investing in RETs has many benefits documented in the energy literature (Kuamoah, 2020; Mukoro et al., 2022; Njoh et al., 2019). Some of the participants of the qualitative study shed light on the potential benefits of investing in RETs which, according to the quantitative data, very few firms are benefiting from.

4.6.1.1 Reliable power supply

It is evident from Table 4.2 that the adoption rate for RETs amongst firms in the Greater Accra Region is very low. Only 3 out of the 404 firms sampled for the quantitative firm survey were using RETs. 2 out of the 3 firms were using solar photovoltaic technologies and 1 was using wind technology. The technologies reportedly serve lighting, space cooling and equipment operation purposes in the firms and they were installed as hybrid systems together with the grid to function concurrently.

One of the reported benefits of RETs to the businesses is the guarantee of a reliable supply of electricity at a cheaper cost than other alternatives. According to the Principal Programme Officer at the Renewable Energy Directorate of the Energy Commission:

> *"The cost of renewable system is coming down very well. In that sense, the cost is competitive to the traditional grid and generator systems. I personally feel that if you a company or institution or industry and wants to have a reliable energy supply, going for renewable systems is very good only if you can have a hybrid support system because sometimes the storage systems are not adequate"* [PRO_1, 2022].

This implies that firms tend to benefit from reliable electricity supply if they invest in renewable system, although they will need other support systems depending on their operation times and activities. This observation aligns with the findings of Kipkoech et al. (2022) that renewable energies are able to guarantee food security because of reliable supply of electricity.

The CEO of a solar supplier firm also observed that:

> *"There are also those who are investing in renewables for reliability or availability of power. People are building smart homes, people have critical data, people have systems that must not go off for any reasons, and for these people they think that yes, getting reliable and available power from renewables is the answer*" [FS_3, 2022].

A senior officer at the Ministry of Energy however cautioned that maximizing the RETs depends on familiarity with the system, and how to operate it. He argued that:

> "*For people who are not very much aware of solar systems, they complain about reliability. But it all depends on the nature of the business operation. So, for companies that operate during the day, they are able to take advantage of the solar system without much of a problem like the ones that run 24/7*" [PRO_2, 2022].

4.6.1.2 Cost saving on electricity

The firms that use the RETs are said to have benefited financially from the cost-saving potential of these technologies. The officer from the Ministry of Energy observed that:

> "*Currently we have not had any firm which had expressed interest in 100% renewable. They are mostly interested in diversification, a little bit of grid, a little bit of genset, and a little bit of renewables. With renewables, there are so many advantages because they don't have to buy fuel for it, their operation cost goes down very low, so it is actually a competitive advantage for them. So, for now the hybrid model makes lots of sense"* [PRO_2, 2022].

The CEO of AB Solar Africa Ltd. confirmed that companies they have supplied renewable systems to do so. According to him:

> *"Solar system is a cost saving system. The solar cuts cost so every penny they save with solar; they can invest in other equipment. So, it improves productivity, it improves cost and the general savings of the company. We monitor our every system, and we even give warranties and guaranties on the production. So, we can actually show our customers their real savings. For firms that are not using solar systems, they lose about 20% energy savings"* [FS_2, 2022].

The CEO of another solar supplier, Tino Solutions, added that:

> "*Today we have customers that are investing in renewable energy systems for various reasons. One, cost saving is paramount for a lot of customers because those who understand the mass wealth, they see that it is cheaper in the long term"* [FS_3, 2022].

In support of the cost-saving potentials pointed out by the policy makers and suppliers, the representative of one of the 3 firms that uses renewables revealed that:

> *"At our main office or head office, we have the three sources, solar, generators and the grid power. We rely more on the solar and one of the main reasons for that is to save cost"* [FR_10, 2022].

These views of the respondents regarding cost cutting benefits of RETs agree with studies like Ahenkan et al. (2021), Pueyo et al. (2016), and UNDP & EC (n.d.) who found compelling evidence of significant reduction in generational and operational costs of RETs compared to fossil fuel and grid electricity as a result of decreasing international prices of the technologies.

4.6.2 Factors accounting for the non-usage of RETs

Despite the benefits that have been expressed by the respondents, RETs remain the least used systems compared to the national grid and generator systems according to Table 4.2. The reasons for the low investment in these technologies are expounded by the participants of the qualitative component of the study below, and represented pictorially in Figure 4.3.

4.6.2.1 High upfront cost

The initial cost, also referred to as upfront cost or initial capital (by participants) needed for the installation of renewable technologies has been identified by all respondents as a major impediment to the development and adoption of RETs by firms in Ghana. According to the officer from the Energy Commission:

"The renewable energy generation has what we call the upfront financial responsibility. For example, if you want to establish a 1MW solar generation system, you need many solar panels, invertors, cost converters and other accessories that will help you generate. In the case of renewable sources, one will actually have to put in lots of capital investment to have it establish to produce power for you" [PRO_1, 2022].

The other senior officer from the Ministry of Energy also added that:

"*On the basis of interest, we have observed lots of people and businesses showing interest in the renewables, but you know that the upfront cost for the solar is usually very high which deters potential investors"* [PRO_2, 2022].

The CEO of Tino Solutions, a solar technology supplier, further stressed the financing limitations that businesses enterprises face when it comes to investing in RETs. He argues:

"*There is largely lack of financing in our country. To invest in a good solar system, it is capital intensive. For some customers, rather than taking a loan from a bank at a high interest rate to invest in renewable technology, they will rather invest in a T-bill, and be using the interest earnings to pay electricity bills be. So, I think the biggest reason why people may not be adopting is the cost"* [FS_3, 2022].

Some of the firms that participated in the study shared similar views as the key informants. A senior officer of a salt mining company in Ga South noted that:

"*Our engineers have brought up the ideas of solar technology severally during our management meetings. But the cost involved is so much. We must buy so many batteries to be able to power our systems. So, for now we are not considering it. Cost is a hindrance. Even if you need it for your house, you need between GHS 60,000 to GHS 80,000. How much more for a company like us? Maybe, in the future. For now, it's the national grid, and then the generators"* [FR_2, 2022].

Another representative of a small-sized services firm in the Tema Metropolis reported that:

"We wish we can have the finance to install solar because we are spending so much on ECG (grid power). But we don't have the finance. If we can have some banks help in financing companies like us, many people will move to use the solar" [FR_7, 2022].

Initial cost is a major factor that has often killed the interest of investing in RETs even on the drawing board. Chen et al. (2014), Mukoro et al. (2022), and Njoh et al. (2019) have found high initial cost of RETs to contribute significantly to the low adoption of the technologies in developing countries. Ahenkan et al. (2021), Halkos and Tzeremes (2014), and Kuamoah (2020) found these economic barriers to have limited the adoption and development of RETs in Ghana which echoed in the voices of the respondents in this study.

4.6.2.2 Lack of technical knowhow

A lack of adequate experts in the solar supply market has also pushed away investors who may not be willing to invest in a risky system with limited expertise. The senior officer from the Energy Commission noted that:

> "*You know, renewable energy though has been in the system for, it is getting to 20 years now or more, but the technical knowhow to set it up, and to run it, operations and management, technical knowhow is not always there. Unlike you will go and buy maybe, a diesel generator, that once it is installed and connected, even if ordinary watchman (security man) can make sure that there is diesel in it, and when it is time for them to start it, they start it and its working. But when it comes to renewable energy, especially solar or even wind supply, you need proper technical know-how. Aside from the capital investment, somebody must have fair technical knowledge of the entire setup especially when there is a need for maintenance, you can't just send anybody to go and look at it. That is one thing that is very important*" [PRO_1, 2022].

Inadequate technical experts to provide useful before-sale and after-sale services to potential customers is a big concern for many stakeholders in the RET market. Kuamoah (2020) and Njoh et al. (2019) argue that limited people with technical experience on the RETs is a major drawback that discourages adoption of the technologies in developing countries. Ahenkan et al. (2021) found that SMEs in the City of Accra are significantly hampered by inadequate after-sale technical support where issues with faulty installations and malfunctioning systems can be addressed to instill confidence in the systems. Accordingly, business players are pushing back on investing in RETs because of the insufficient technical abilities of the service providers. If there are insufficient experts, the likelihood of poor installations is high which leads to the next deterrent factor.

4.6.2.3 Lack of trust due to poor quality

Some of the respondents in the qualitative study have expressed their lack of trust in the RETs because of a host of reasons. To some of them, faith in the technology has eluded them due to the poor-quality installation or materials of the system. When asked why people or businesses are not coming out to demand their solar supply services, the CEO of AB Solar Africa Ltd. noted with surprise in his tone:

> *"That is something I cannot put a finger on. There is always an idea that our story (installing the system without an upfront cost but discounted to be paid overtime) may be too good to be true. And people don't have real trust in the solar because we have had a lot of rubbish coming into the country as well, and so inferior materials are used, and people have had a lot of bad experiences. That is the biggest challenge that we have"* [FS_2, 2022].

In responding to the same question, the Assistant Programme Officer at the Power Directorate of the Ministry of Energy said:

> *"Sometimes installation quality. We have heard a lot of complaints about our installers. How they install the systems, not done very well so within a short period of time they get problems. It is either they don't install them properly or the materials they use are not of the required quality. That together with high upfront cost have been the biggest deterrent"* [PRO_2, 2022].

In the desktop study of UNDP & EC (n.d.), lack of trust in the RETs was identified as a major impediment. The study found that many people are still not convinced about the functionality and durability of the technologies, particularly the ones that are being imported into Ghana. Kipkoech et al. (2022) went ahead to show that though the RET market has grown remarkably in Ghana in the past decades, the acceptability of the technologies is still relatively low compared to other countries and regions because of trust issues. These findings have therefore been corroborated by the views of the respondents in this study.

4.6.2.4 The solar power needs other support systems

Another factor that is working against the adoption of renewable systems in Ghana, particularly in the business space is the associated support systems that are required for the renewable systems to be well maximised. The Assistant Programme Officer at the Power Directorate of the Ministry of Energy emphatically stated that:

> *"Currently, we haven't had anyone or business that had expressed interest in 100% renewable. They (businesses) are mostly interested in diversification (hybrid system). So, a little bit of grid, a little bit of genset and a little bit of renewable. So now the hybrid model makes lots of sense"* [PRO_2, 2022].

The senior officer from the Energy Commission confirmed this by noting that the solar system may not be able to singlehandedly support all electrical loads particularly in the night. According to him:

> *"With the solar system, you need storage systems. Secondly, you need augmenting power supply that will serve as a hybrid. For example, when you generate your power from solar, during daytime when there is sunshine, you get a lot of power generated. You may have battery systems to store some of the power during the daytime. But at night if your power needs are so high, maybe the battery system may not be able to supply you with everything. So, what you end up doing is maybe having a hybrid system, maybe something from diesel generators for example. The renewable may not produce power that is 100% like the generators because at certain times of the night you might need power supply from somewhere"* [PRO_1, 2022].

He further added that:

> "T*echnically, high electricity demand activities like steel melting companies like VALCO may not depend strongly or solely on renewable systems because it depends on the*

configuration of the system. It's (renewable system) power generation is limited. But if a factory needs certain amount of power to melt iron for example, they may end up going for the national grid" [PRO_1, 2022].

4.6.2.5 Unsupportive policies

The existing policies on renewable energy development in Ghana are found to be insufficient, unsupportive, and push investors away further. With reference to some of these unsupportive policies particularly the public-led and common tariff approaches, the senior officer from the Energy Commission opinioned that:

"So, some companies have decided or have wished to have the renewable systems for power generation but the policies in the country at the moment are not supportive to that. But we are still working on that" [PRO_1, 2022].

With the same reference, the CEO of AB Solar Africa Ltd., a solar energy supplier concluded that:

"…the supportive policies are not there. The policies there don't even make any sense" [FS_2, 2022].

These assertions are supported by the findings of other studies. Kuamoah (2020) for instance argued that there is absence of clarity in the existing policies on RE development in Ghana, and that government's energy policy priorities are less aligned with RET investment. Ahenkan et al. (2021) observed that about 90 percent of the companies they interviewed in Ghana have had issues with the current policies on RETs, particularly the Net Metering system due to conflict in the operationalisation terms between the renewable companies, the power distribution companies, and the regulator.

4.6.2.6 Information on RETs not adequate

Meanwhile, misinformation, or rather lack of adequate information about how the renewable systems work or are supposed to work at local or grassroot levels have been identified to hamper the adoption of renewables in Ghana. For instance, on cost, the CEO of AB Solar Africa Ltd. observed that:

> *"The big issue you will see in Ghana is people always look at the initial cost. So, if the initial cost is high, they think the whole setup is high on cost. But they don't think long term like solar system can run easily for 20 years so if you then look at the actual cost, I don't think they get their hands on it, they have no ideas what the real cost is"* [FS_2, 2022].

The CEO of Tino Solutions Ltd. further stressed on this information asymmetry, stating that:

> "*Most of the people don't have that knowledge to even understand that if I invest in solar and it takes me 10 years to cover the cost, it is possible that after the 10 years I will then be enjoying free power after 10 years. So, somebody like that can make the argument that no its too expensive for me to invest in solar. Of course, it is not an investment that you can make your returns in a day or in a year. People look at it from a different angle and may say it is rather expensive or it makes me uncompetitive. No, it doesn't work like that"* [FS_3, 2022].

From the submissions of the fuel suppliers, there is clearly a lack of adequate information or education about the renewable systems on the ground. The CEO of a cement block production firms reported that:

> "*I am not using it because I don't know much about it. Lack of education is the reason why people like me are not going for it (renewable system)"* [FR_3, 2022].

> The manager of a small-sized services firm in the Tema Metropolis further stressed on the low awareness noting that:

> "*People are not aware of the full benefits of the solar. I know of some guest houses that are using it. But many people are not using it because they [appropriate authorities] are not educating people on it. Awareness is low"* [FR_7, 2022].

These views from the respondents in this study agree with some reviewed literature sources. Kuamoah (2020) argued that the public sector in Ghana is ill-equipped, educated, and trained on decision making regarding RETs. Hence, most people have limited knowledge about the technologies. In support, Ahenkan et al. (2021) and UNDP & EC (n.d.) observed that low public education and general awareness of RETs among stakeholders remain key impediments to the adoption and development of the technologies in Ghana.

4.6.2.7 Lack of practical examples

Another factor that is working against the adoption of renewable technologies is the inadequate evidence of the functional or working solar systems that people can see and be attracted to. People may be moved to use a technology that they see other people using and it is working (Rogers, 1995). This evidence seems to be missing amongst the Ghanaian business space. According to a senior officer of a medium-sized services firm in the Accra Metropolis:

> "*The renewable systems are still new in the system. Not many people are using it, so people don't really see how it works. Maybe as time goes on, we will see how it actually works*" [FR_5, 2022].

Finally, the CEO of a micro-sized services firm in the Accra Metropolis confessed his lack of knowledge and evidence about the renewable systems when he said:

> "*Personally, I don't know much about it (the renewables). There is not enough information going around about it and you don't see people using it*" [FR_8, 2022].

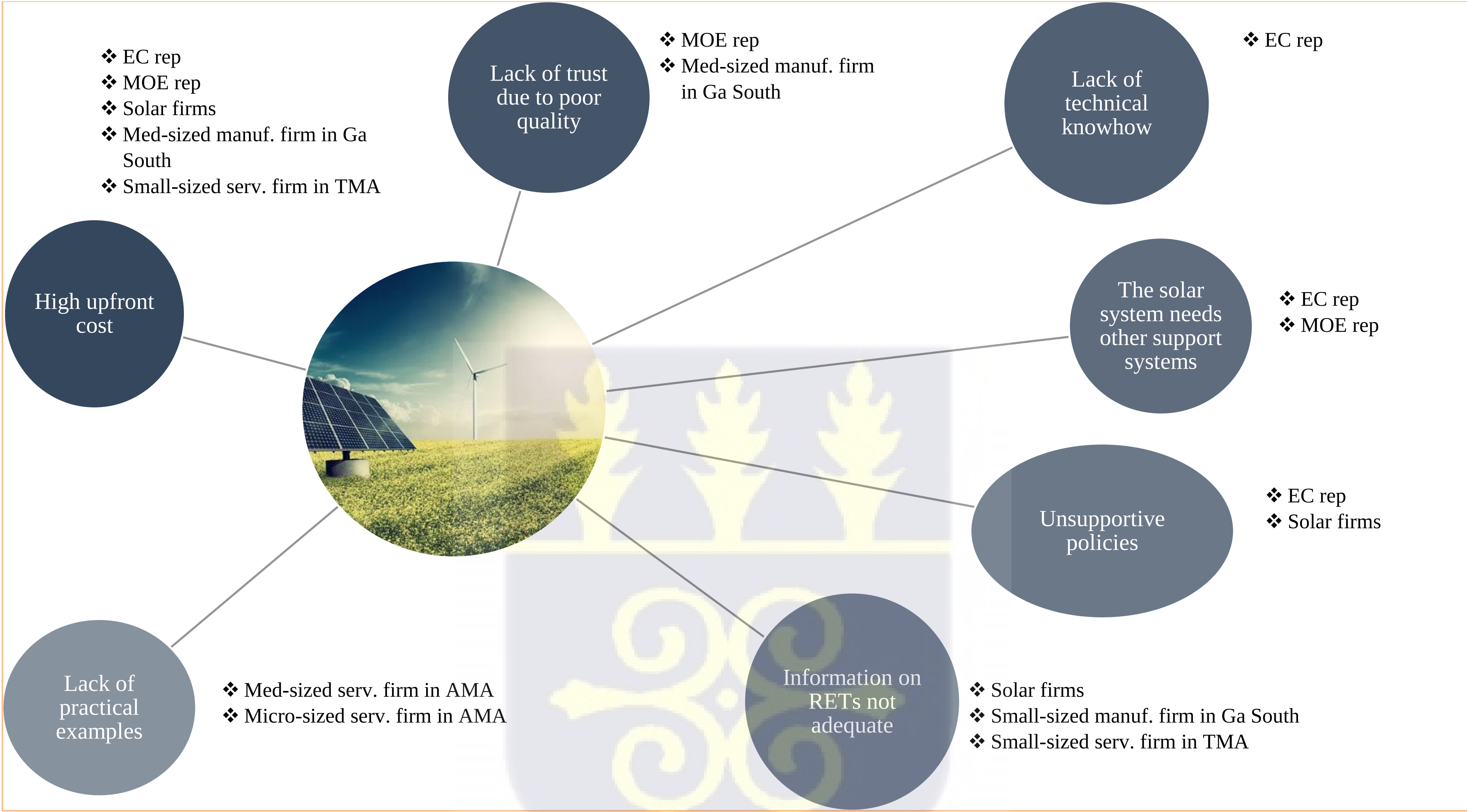

Figure 4.3: Diagrammatic representation of the factors accounting for the non-usage of renewable energy technologies

Source: Author's construct based on Field Survey, 2022

4.6.3 Government's initiatives that are either promoting or discouraging the adoption of RETs in Ghana according to the respondents in the qualitative study

4.6.3.1 Inflation

The government's inability to keep general prices constant is one of the factors reportedly working against the adoption of RETs in Ghana. Apparently, while the cost of renewables is declining in the world market, inflation has kept it high for the Ghanaian market which is discouraging its adoption. The Principal Programme Officer at the Renewable Energy Directorate of the Energy Commission explained that:

> "*You know, one thing we must understand is that the cost of renewable systems is constantly coming down. The problem in Africa, and for that matter Ghana is that the inflation affects the exchange rate which raises the import costs of these technologies and makes us feel that the cost of installing either solar system stand-alone or mini-grid systems is expensive, but at the global level, the cost of renewable system is coming down very well"* [PRO_1, 2022].

4.6.3.2 Public-led approach

Currently, there is disincentive for large-scale electricity production from RETs investors because of a temporal prohibition placed on signing of such agreements by the licensing authority, that is, the Energy Commission. According to the senior officer at the Renewable Energy Directorate at the EC:

> "*Currently in Ghana, we have a moratorium on signing of power-purchase agreement, so going into renewable systems or generating renewable energy on a large-scale is still not encouraged. But the government is doing it. There is this policy in Ghana, that is, public-led approach, that is, power generation in Ghana is led by the country*" [PRO_1, 2022].

This does not attract investors who have the intentions of large-scale electricity production from renewables.

4.6.3.3 Common tariff policy

Coupled with the public-led approach, there is another policy that discourages investors like business establishments from going all out to invest in RETs. The EC senior officer continued:

> *"…and then there is another policy that talks about common tariff system. So, if a company like Shell as an example. If Shell decides that we want to power all our filling stations in Ghana with Solar, they need license from Energy Commission to do that. Then they come and we tell them that, look you can do it, but you cannot channel excess power that you will generate to the national grid. So, it means whatever power that you generate, you must consume it and it is not encouraging enough"* [PRO_1, 2022].

4.6.3.4 Scaling-up Renewable Energy Project (SUREP)

There are other policies however, that are designed to ensure increased adoption of RETs in Ghana. There is this policy, SUREP, that is supposed to install mini-grid solar to serve island and lake-side communities where extending the national grid is not economically feasible. The Principal Programme Officer at the EC once more noted that:

> *"The government or the Ministry of Energy has gone for what we call SUREP, and the World Bank and the African Development Bank are funding that. Already there are 5 islands that have been connected to solar mini-grids and they are serving as pilots, and its being run by the Volta River Authority, and the Ministry is monitoring its feasibility. In 2020, I led a group there and we went to check the productive use of energy on the islands and other things"* [PRO_1, 2022]

4.6.3.5 Net-metering

Net-metering is another policy instrument that is being pushed to promote the adoption of RETs by individuals and businesses, though it is still at the development stage and the process is regrettably slow-paced. The EC senior officer elaborated on this policy noting that:

> "*There is this policy called net-metering. Net-metering will support an individual who produces or generates his own energy to feed into the national grid and get it back*

because ECG at the moment doesn't want to take and then pay you or anything, so they give it back to you when you need it. So, we are just working on things around that to support individuals being able to generate their own power" [PRO_1, 2022].

This policy is, thus, designed to revitalise interests of investors that might have been dampened by the common tariff policy explained above. But, it is facing its own challenges in terms of agreements with the terms of operation between the renewable service providers, distribution companies and the regulators (Ahenkan et al., 2021).

4.6.3.6 Solar subsidy programme

The Assistant Programme Officer at the Power Directorate of the Ministry of Energy did indicate that individuals and businesses have benefited in the past from a subsidised programme on solar technologies hence the ministry is trying to run a similar programme to instigate adoption. According to him:

"The interest in the adoption of solar is going higher as compared to systems like the generators in recent times. ...There are instances where people come to the ministry (MOE) to inform us that they want back-up power and they are considering the genset (generator) and solar system, so they want us to advise them in terms of reliability. So, the interest is there, the only problem is the upfront cost, so most of them request for subsidies. In the past we have had programmes like that where people benefited from it and currently, we are rolling out a similar programme" [PRO_2, 2022].

4.6.3.7 Tax exemption and the renewable energy purchase obligation regulation

Exemption from import taxes on renewable equipment is reported to be a major incentive for the development of renewable technologies in Ghana. The senior officer from the Ministry of Energy explained that:

"In terms of adoption, obviously there are tax exemptions for the importation of renewable energy technology, although the feedback we received is that the process is very cumbersome. So, for companies that are not very large or resilient, they forgo the

exemption and just pay the associated taxes. Secondly, there is the renewable energy purchase obligation for bulk consumers which is enshrined in the Renewable Energy Act. For bulk consumers we encourage them to go into non-utility scale renewable energy as a way of offsetting their dependency on the grid power. But the Energy Commission is now developing the regulations on the purchase obligations" [PRO_2, 2022].

The officer's submission suggests that not many people may be taking advantage of the tax exemptions due to the bureaucratic processes and the regulation that ensures zero-net energy for companies is still on the drawing board.

4.7 Conclusion

The findings suggest that firms chose to invest in the national grid electricity because it was largely regarded as a secured system that provided a guaranteed supply of electricity, easily accessible, cheaper, and most convenient. During periods that the national grid became unreliable because of the shortage in supply leading to rationing of the power supply, some firms turned to diesel/petrol powered generators. Though this was a more expensive alternative, it was preferred due to its readiness to provide immediate and much needed power. To some firms, they could not do without their own generators. To others, it was the only real alternative available because they didn't know much about other alternatives such as solar and wind technologies. Others were also convinced that generators produce electricity at lower cost compared to other alternatives like RETs. This is evidence of Simon (1947)'s bounded rationality theory where the decision makers intentionally make what they consider rational decisions based on the limited resources and knowledge that is available to them but are often oblivious to the consequences of their decisions.

In terms of the adoption of RETs in the Greater Accra Region of Ghana, most private individuals or businesses can be regarded as *late majorities* within Rogers' Diffusion of

Innovation Theory (Rogers, 1995). A lot of the firms are exercising restrain in the face of the new technology (renewables) because they have doubts about how it can really be helpful to them. According to the firms that participated in this study, they don't see lots of people using the technology hence they don't have much trust in it. They will only be moved to use the technology when they see lots of people using it.

CHAPTER FIVE

FINANCIAL PERFORMANCES OF FIRMS IN THE GREATER ACCRA REGION FROM 2015 TO 2021 VIS-À-VIS THE UTILISATION OF DIFFERENT ENERGY SYSTEMS

5.1 Introduction

This chapter explores the relationship between the financial performance of the firms in the Greater Accra Region and different energy systems or services from 2015 to 2021. The energy systems or services were measured in terms of the per unit of output costs of the grid- and generator electricity, hours of blackouts experienced from the grid system, and the level of energy efficiency technologies utilisation. Other determining variables like capital, labour, R&D, and IT were included as control variables in the empirical models, estimated for the full sample (2015-2021), the samples corresponding to the power crises era (2015-2017), the post-crisis era (2019-2021), the micro-sized firms, the small-sized firms, and the medium-large-sized firms. The purpose was to assess if these relationships differ significantly with different samples. The chapter proceeds by describing key characteristics of business establishments in the Greater Accra Region followed by the factors of production that enhance the ability of the firms to invest rationally. The penultimate section explores the statistical relationship between financial performance of the firms and the determinants while the last section provides summarised conclusion of the chapter.

5.2 Key characteristics of the surveyed firms in the Greater Accra Region as of 2021

Key characteristics of the firms surveyed for this study are shown in Table 5.1. The majority of the establishements surveyed (73%) were in the services sector and the remaining were into manufacturing of goods. Mirrowing the national size classification of firms according to the IBES, nearly 80% of the survey firms are micro-sized (engagging not more than 5 persons), 18.6% are small-sized (engaging 6 to 30 persons), 1.05% are medium-sized (engaging 31 to 100 persons) and 0.74% are large-sized (engaging more than 100 persons).

A little over 80% of the surveyed firms are sole proprietorship firms, 12.9% are partnerships while nearly 5% are corporations. Unsurprisingly, about 98% are private establishsments and the remaining 2% are state-owned and private-public establishements. Nearly 70% of these establishements are formally registered.

Table 5.1: Some charateristics of the sampled firms in the study as of 2021

Characteristics	Frequency	Percent
Sector of the firms		
Industry/Manufacturing	432	26.73
Services	1,184	73.27
Firm size classification		
Micro-sized	1,287	79.64
Small-sized	300	18.56
Medium-sized	17	1.05
Large-sized	12	0.74
Organizational structure of the firms		
Sole prioriet orship	1,327	82.12
Partnership	209	12.93
Corporation	80	4.95
Ownership status of the firms		
State-owned	13	0.80
Private	1,587	98.21
Private-Public Partnership	16	0.99
Business registration status of the firms		
Formally registered	1,121	69.37
Formally unregistered	495	30.63

Source: Field Survey, 2022

Predominantly, the firms marketed and sold the goods and services in the district of their location (Figure 5.1). About 73 percent of the firms noted that their primary market for their goods and services is their local district. The region (Greater Accra) represented the second largest market for the establishements. A few of the firms also sold in other regions or across the entire country (Figure 5.1).

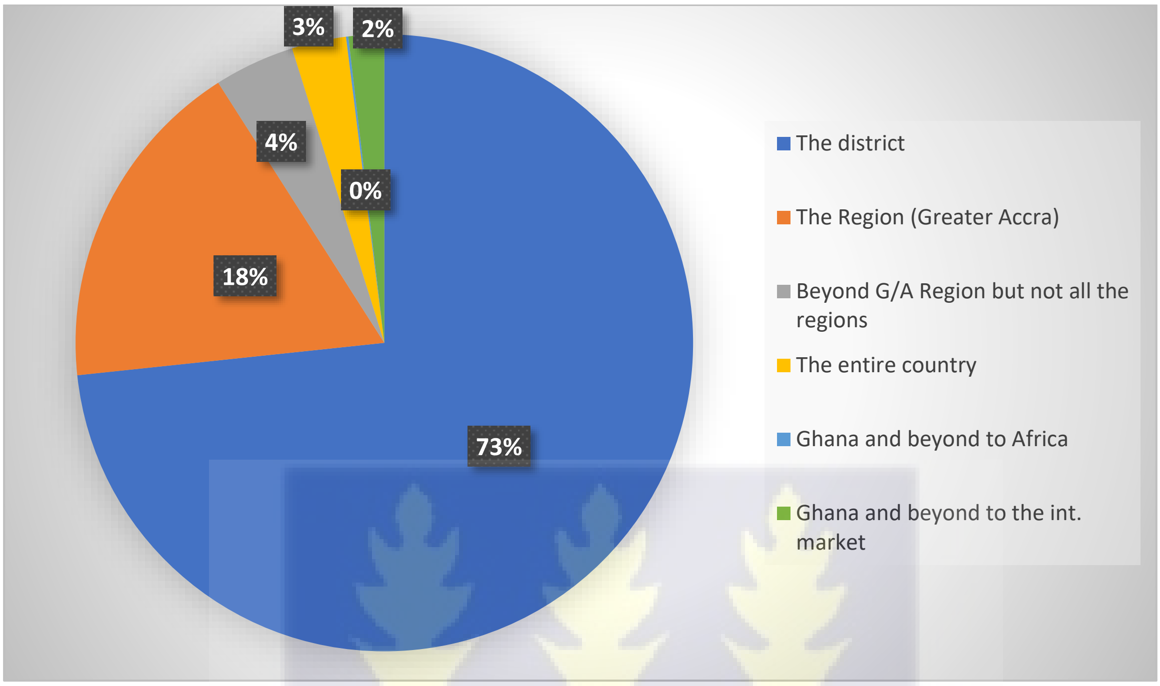

Figure 5.1: Primanry markets where businesses sell their products/services as of 2021

Source: Author's construct based on Field Survey, 2022

5.3 Capital, Labour, and Technological factors of production for firms in the G/A Region

This section examines the capital, labour, and technological factors of production available to businesses in the Greater Accra Region of Ghana that enhance their abilities to invest rationally and produce effectively.

5.3.1 Capital resource endowments of the firms

The representatives of the firms estimated the values of their vehicle fleet, land, or space owned, building structures, production plants and equipment, closing stock, all kinds of electrical appliances used in the production or servicing process, kitchen equipment, furniture and other physical assets owned by the business. The estimated values of these assets at current market price represent the firms' capital endowments. The endowment levels of the different sizes of firms are showcased in Table 5.2. Nearly 45% of micro-sized firms were GHS 10,001-50,000 capitally endowed. 21% had less than GHS 10,000 while 15% and 5% were GHS 100,001-500,000 and above GHS 500,000 endowed. For small-sized firms, the capital endowment of 35% of the firms fell within GHS 100,001-500,000 and 33% of them had estimated GHS 500,000 plus capital. Almost all medium-sized and large-sized firms had estimated capital endowment of more than GHS 500,000.

Table 5.2: Estimated value category of capital assets owned vis-à-vis firm size and era, as of 2021

Category of capital value	**Size classification of firms**				**Total**
	Micro	**Small**	**Medium**	**Large**	
10,000 and less	272 (21.13)	5 (1.67)	0 (0.00)	0 (0.00)	277 (17.14)
10,001 – 50,000	574 (44.6)	47 (15.67)	0 (0.00)	0 (0.00)	622 (38.49)
50,001 – 100,000	177 (13.75)	43 (14.33)	0 (0.00)	0 (0.00)	220 (13.61)
100,001-500,000	198 (15.13)	106 (35.33)	0 (0.00)	1 (8.33)	305 (18.81)
Above 500,000	66 (5.13)	99 (33)	17 (100)	11 (91.67)	193 (11.94)

Source: Field Survey, 2022 *NB: Colum percentages in parenthesis*

5.3.2 Labour resource endowments of the firms

In terms of labour resources of the business establishments, micro-sized firms employed 2.7 persons on average while small-sized, medium-sized, and large-sized firms averagely engaged 10, 66.8, and 670 employees respectively (Table 5.3). It must be noted that the average persons engaged by large-sized firms have been affected by the outlier firm that employed 4900 persons. The firms have also engaged more females (if outlier included).

Table 5.3: Average number of employees of the sampled firms as of 2021

Firm size	Statistics	Avg. number of employees	Avg. number of male employees
	Mean	2.7	1.6
Micro	Minimum	1	1
	Maximum	5	5
	Mean	10	6.6
Small	Minimum	6	1
	Maximum	30	30
	Mean	66.8	50.2
Medium	Minimum	35	25
	Maximum	100	100
	Mean	670.8	174.8
Large	Minimum	150	1
	Maximum	4900	400
	Mean	***9.6***	***4.3***
Total	***Minimum***	***1***	***1***
	Maximum	***4900***	***400***

Source: Field Survey, 2022

Generally, 59% of the staff engaged by the businesses are regarded as highly skilled and 56% are regarded as highly experienced. Similar characteristics of engaged staff were reported by the different size classifications of the firms (Figure 5.2). Clearly some training opportunities offered to the engaged staff by the firms has helped in their skill acquisitions. More than 30% of the firms had offered training to their staff (Figure 5.2).

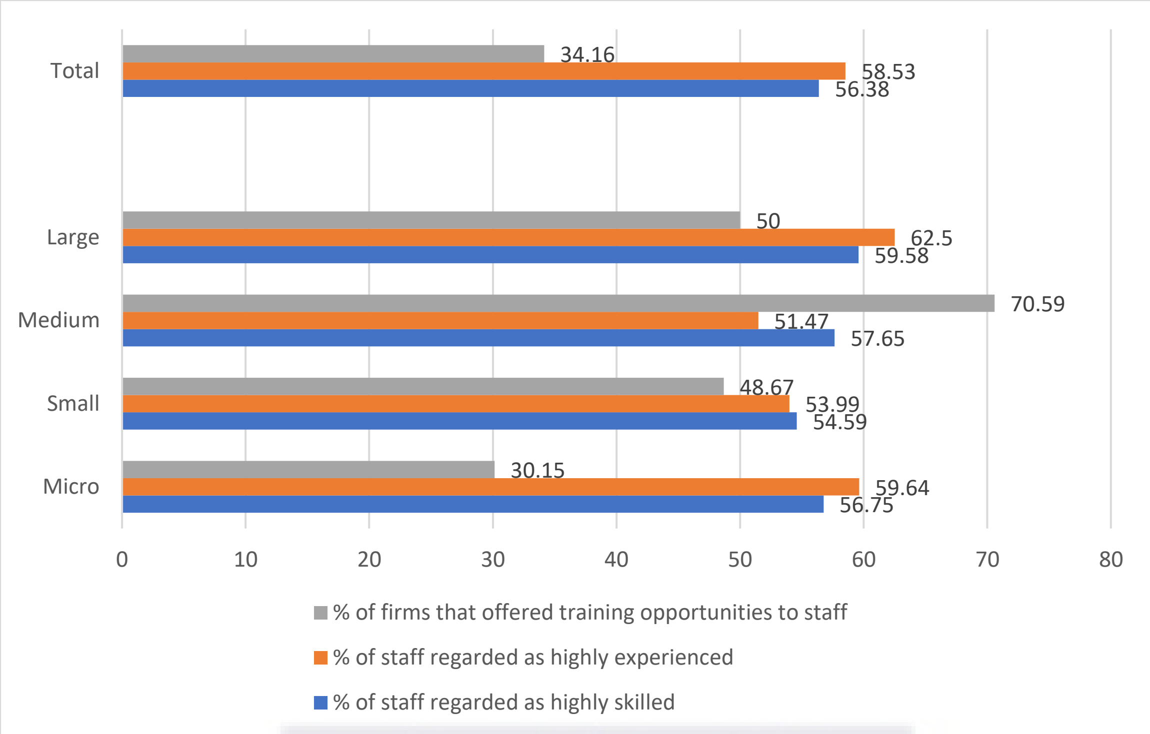

Figure 5.2: Proportion of firms that offered training opportunities to their staff and proportions of staff regarded as highly skilled and experienced as of 2021

Source: Author's construct based on Field Survey, 2022

5.3.3 Research, development, and information technology inclination of the firms

It is evident from Table 5.4 that inclination to information technologies increased with increasing size of firms. Only 17% and 26% of micro- and small-sized firms had physical or virtual IT units or desks compared to 47% and 67% of medium and large-sized firms. The observed differences across different firm sizes are significant from the chi-square statistics. Most of the firms, however, had designated IT officers and often engaged in e-transactions which show the increasing adoption of modern IT technologies.

Unsurprisingly, higher percentages of firms' productive activities were found to depend on computer systems and internet services for large- and medium-sized firms who are more likely to engage in more complex and numerous activities that require those computer and IT services than smaller firms. This also correlates with the average monthly expenditure on internet services that was incremental with the size of the firm (Table 5.5).

Table 5.4: The levels of R&D and IT investment of the sampled firms

R&D and IT Variables	Size classification of firms				Total	Pearson chi2
	Micro	Small	Medium	Large		
Physical/virtual IT unit available?						
Yes	215	77	8	8	308	
	(16.71)	(25.67)	(47.06)	(66.67)	(19.06)	39.38
No	1,072	223	9	4	1,308	Pr=0.00
	(83.29)	(74.33)	(52.94)	(33.33)	(80.94)	
IT officer available at the firm?						
Yes	134	68	8	8	218	
	(62.33)	(88.31)	(100)	(100)	(70.78)	25.48
No	81	9	0	0	90	Pr=0.00
	(37.67)	(11.69)	(0.0)	(0.0)	(29.22)	
Firm uses e-transaction?						
Yes	978	254	14	11	1,257	
	(75.99)	(84.67)	(82.35)	(91.67)	(77.78)	12.16
No	309	46	3	1	359	Pr=0.01
	(24.01)	(15.33)	(17.65)	(8.33)	(22.22)	
Did firm engage in any R&D?						
Yes	339	79	8	3	429	
	(26.34)	(26.33)	(47.06)	(25.0)	(26.55)	3.72
No	948	221	9	9	1,187	Pr=0.294
	(73.66)	(73.67)	(52.94)	(75.0)	(73.45)	

Source: Field Survey, 2022

The percentage of firms that invested in research and development was low across all size classifications of firms (Table 5.4). Less than 30% of firms across all sizes (except medium-sized firms – 47%) had reported investment in R&D over the previous years. For these firms, the average monthly R&D expenditure was about GHS 1,000 with incremental differences with respect to different firm sizes (Table 5.5). Micro- and small-sized firms which invested in R&D have mostly done so in the areas of new products/services, pricing, demand and supply, and new markets (Table 5.6). Medium- and large-sized firms have researched pricing, processes, new markets, demand, and supply issues (Table 5.6).

Table 5.5: The intensity of R&D and IT engagement of the firms

Firm size	**Statistics**	**% of firms' productive activities that depend on computer systems**	**% of firms' productive activities that depend on internet**	**Avg. monthly expenditure on internet services (GHS)**	**Avg. monthly expenditure on R&D (GHS)**
	Mean	16.33	17.12	211.29	888
Micro	Minimum	0	0	0	0
	Maximum	100	100	3,000	25,000
	Mean	30.34	30.14	480.44	1,271.6
Small	Minimum	0	0	20	0
	Maximum	100	100	7,000	12,000
	Mean	59.12	59.65	712.71	130.75
Medium	Minimum	5	5	99	99
	Maximum	90	90	3,000	200
	Mean	45	30	2,895	21,666.7
Large	Minimum	20	10	30	20,000
	Maximum	80	50	13,070	25,000
	Mean	***19.60***	***20.08***	***328.5***	***1,089.83***
Total	***Minimum***	***0***	***0***	***0***	***0***
	Maximum	***100***	***100***	***13,070***	***25,000***

Source: Field Survey, 2022

Table 5.6: Areas firms researched/developed over the 2015-2021 period

Areas	**Size classification of firms**				**Total**
	Micro	**Small**	**Medium**	**Large**	
New markets	121	23	0	3	147
	(35.7)	(29.11)	(0.00)	(100)	(34.27)
Demand & Supply	167	32	0	3	202
	(49.26)	(40.51)	(0.00)	(100)	(47.09)
Pricing	197	34	4	3	238
	(58.11)	(43.04)	(50.0)	(100)	(55.48)
New products/services	298	54	0	0	352
	(87.91)	(68.35)	(0.00)	(0.00)	(82.05)
Processes	93	36	4	0	133
	(27.43)	(45.57)	(50.0)	(0.00)	(31.0)
Supply chain	23	21	0	0	44
	(6.78)	(26.58)	(0.00)	(0.00)	(10.26)
New tech/IT	51	29	0	0	80
	(15.04)	(36.71)	(0.00)	(0.00)	(18.65)

Source: Field Survey, 2022

5.4 Electricity factor of production for firms in the G/A Region

As already discussed in Chapter Four (4), nearly all businesses in the Greater Accra Region used electricity from the national grid for various activities including lighting, machine operation, and space cooling. Nearly 22% of the business establishments used personal generators and only 3 firms indicated to be using electricity from renewable sources. Some aspects of the different electricity supply sources were regarded as obstacles to business establishments.

Despite its high dependency rate, about 60% of businesses in the Greater Accra Region were concerned about the duration, unpredictability, and the frequency of power outages with regards to the national grid electricity. These, according to the firms, were significant obstacles to their productivity over the years. Also, nearly 40% of firms in the Greater Accra Region considered the high costs of the grid-electricity to be a limiting factor. From Table 5.7, these obstacles were more pronounced during the crisis period (2015-2017) than the post-crisis period (2019-2021). It is, therefore, not surprising that more than 20% of these establishments turned to invest in generators as back-up power sources. Not that generator-electricity was cheap but because it was a necessity for some firms. As pointed out in the preceding Chapter Four, some firms could not do without the generator. For example, the CEO of a cement block manufacturing firm in Ga South noted that;

> "*...production must continue even if there is no ECG (grid power). So the generator kicks in*" [FR_3, 2022].

Table 5.7 shows that the firms that used generators considered the associated operating costs and the unpredictability of the costs as major obstacles to the firms. On average these firms spent about GHS 2,132 on monthly operation of the generators during the crisis period (2015-2017) compared to about GHS 1,082 spent on grid-electricity in the same period (Figure 5.3). Together, the average monthly expenditure on these systems used by the firms (GHS 3,247) represents 6.15% of the firms' average monthly revenue (GHS 52, 761) during the crisis era (Table 5.8). In the post-crisis era (2019-2021) the average monthly expenditure on generators declined to GHS 1,639 while that of grid-electricity increased to GHS 1,598 (Figure 5.3). Together, the average monthly expenditures of these systems in the post-crisis era (GHS 3,271) represented about 4.75% of the firms' average monthly revenue in the post-crisis era (GHS 68,882) (Table 5.8).

Table 5.7: Aspects of grid and generator electricity services that are obstacles to firms vis-à-vis crisis era

Obstacle	**Grid electricity**			**Generator-electricity**		
	Crisis era	**Post crisis era**	**Total**	**Crisis era**	**Post crisis era**	**Total**
High cost of electricity	248 (30.92)	393 (49.0)	641 (39.96)	174 (88.78)	127 (85.23)	301 (87.25)
Unpredictability of costs	87 (10.85)	116 (14.46	203 (12.66)	32 (16.33)	25 (16.78)	57 (16.52)
Hours of outages	615 (76.68)	336 (41.9)	951 (59.29)	-	-	-
Unpredictability of outages	474 (59.10)	521 (64.96)	995 (62.03)	-	-	-
Frequency of outages	433 (53.99)	193 (24.06)	626 (39.03)	-	-	-
Voltage fluctuations	239 (29.8)	160 (19.95)	399 (24.88)	-	-	-
Other	9 (1.12)	11 (1.37)	20 (1.25)	9 (4.59)	10 (6.71)	19 (5.51)
Cases	***802***	***802***	***1604***	***196***	***149***	***345***
Chi2 (Pr)	***372.12 (Pr=0.00)***			***7.48 (Pr=0.68)***		

Source: Field Survey, 2022 *NB: Colum percent of cases in parenthesis*

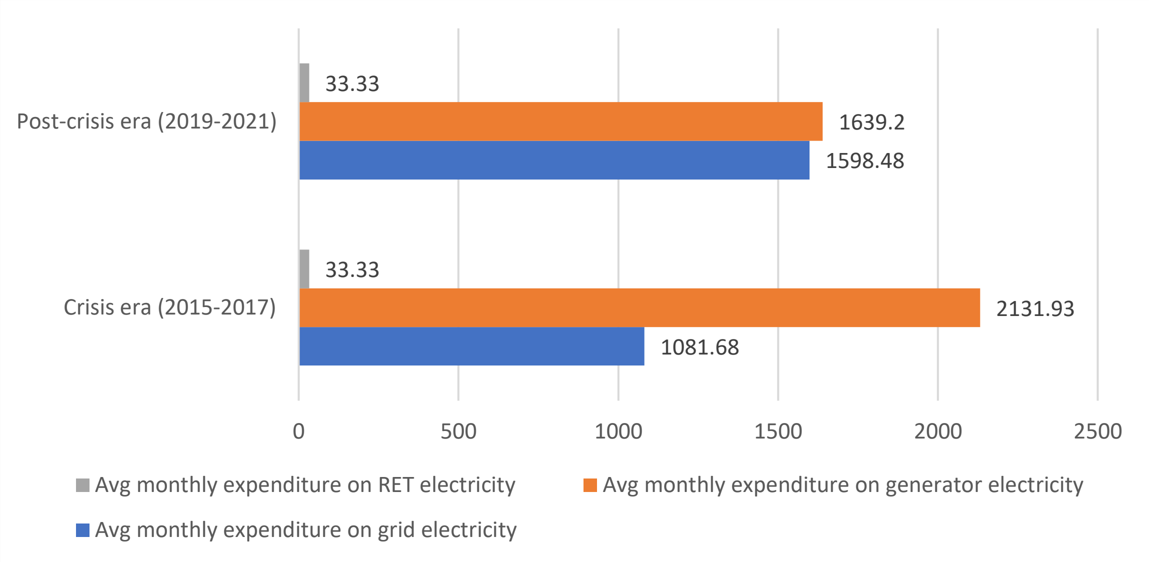

Figure 5.3: Average monthly expenditure on different electricity sources vis-à-vis crisis era

Source: Author's construct based on Field Survey, 2022

Table 5.8: Average monthly revenue of firms by size and era

Statistics	Size classification of firms				Era		Total
	Micro	Small	Medium	Large	2015-2017	2019-2021	
N	1287	300	17	12	808	808	1616
Mean	12,778.2	64,603.8	3,386,788	407,055.9	52,760.5	68,881.5	60,821
Min	0	0	99	2,000	0	0	0
Max	2,000,000	2,000,000	20,000,000	1,827,475	12,000,000	20,000,000	20,000,000

Source: Field Survey, 2022

Table 5.9 presents the average monthly cost of electricity and the costs (both grid and generator electricity) per unit of output of the sampled firms in the Greater Accra Region of Ghana. The total monthly electricity bill averaged about GHS 1,741 for the entire sample from 2015 to 2021. The larger firm-sized categories spent more on electricity than the smaller-sized firms as shown in Table 5.9. Generally, the share of the total electricity cost was about 24% of the total average monthly cost of the firms. In terms of the size categories, the shares were much higher for the large- and medium-sized firms (above 40%) compared to the small- and micro-sized firms. The grid-electricity cost per unit of output produced by the firms was about GHS 0.048

from 2015 to 2021 while the generator-electricity cost per unit of output stood at GHS 0.011 for the same period. The grid-electricity cost per unit of output was higher in the post-crisis era than the crisis era while the reverse was true for the generator-electricity cost per unit of output.

It must be mentioned that there were no explicit fuel subsidies (on gasoline, diesel, or electricity) for non-residential entities for the years that data was collected for this study. In April 2020, a 50% subsidy on electricity consumption of commercial customers was announced by the President of Ghana[11] for April, May, and June 2020 as a COVID-19 relief measure. But this subsidy was outside of the data collection period of this study. It shows that the electricity bills of the firms reflect the true costs of this fuel without any subsidies that could have been accounted for in the analysis.

Table 5.9: Average monthly electricity costs of the sampled firms in the G/A Region

Electricity cost category	**Size classification of firms**				**Era**		**Total**
	Micro	**Small**	**Medium**	**Large**	**2015-2017**	**2019-2021**	
Total electricity cost (GHS)	486.0	2,207	15,424.3	105,309.3	1,592.0	1,890.1	1,741.1
Share of total electricity cost in total cost (GHS)	0.23	0.28	0.41	0.47	0.24	0.24	0.24
Grid-electricity cost per unit of output (GHS)	0.044	0.059	0.126	0.09	0.043	0.053	0.048
Generator-electricity cost per unit of output (GHS)	0.010	0.016	0.011	0.028	0.014	0.007	0.011

Source: Field Survey, 2022

The reported decline in generator bills and the reverse in the grid-electricity costs in the post-crisis era, as evident in Figure 5.3, can be attributed to improvement in the reliability of the grid-electricity as power outages reduced significantly. This is evident in Figure 5.4 below.

[11] Government of Ghana (2020). President Akufo-Addo on updates to Ghana's enhanced response to COVID-19. Retrieved from http://www.presidency.gov.gh/index.php/briefing-room/speeches/1560-president-akufo-addo-speaks-on-updates-to-ghana-s-enhanced-response-to-covid-19.

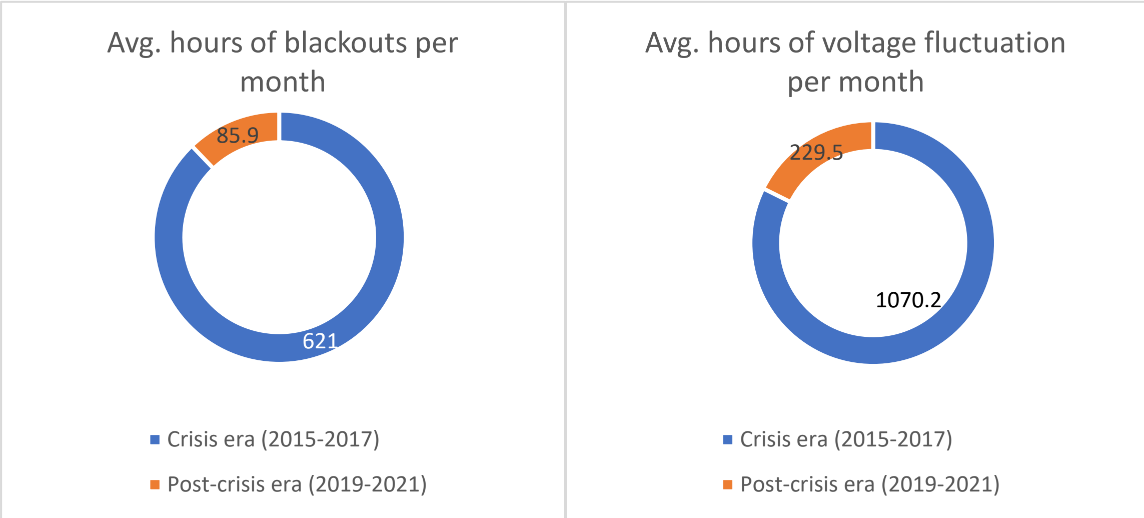

Figure 5.4: Average hours of blackouts and voltage fluctuations experienced by firms within a month

Source: Author's construct based on Field Survey, 2022

The reported average hours of blackouts per month was 621 during the power crisis era (2015-2017) compared to 85.9 during the post-crisis period (2019-2021). Similarly, the businesses reported an average of 1,070 hours of voltage fluctuation during the crisis period compared to 230 hours in the post-crisis period. During power outages and voltage fluctuations, businesses have often switched to an alternative energy source temporarily (predominantly generators), paused work until power returned, or temporarily switched to using non-electric tools, machines, or manpower. Another coping strategy often used was the installation and switching among multiple electricity phases (Figure 5.5). About 11% of the firms reported to have been using this strategy in both periods. It is not surprising to see that the higher usage frequencies of this strategy occurred during the crisis era (Figure 5.5).

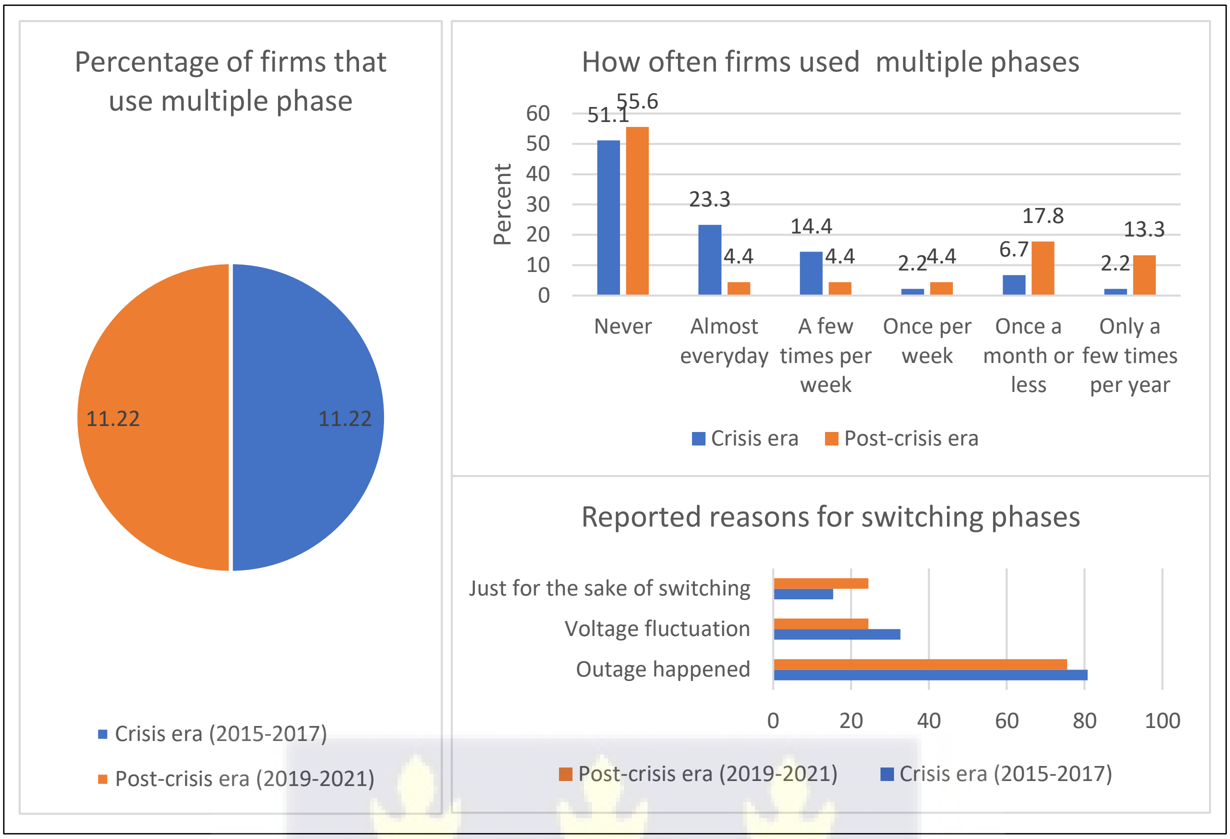

Figure 5.5: How often multiple phases on the grid-connected electricity were used and the reported reasons

Source: Author's construct based on Field Survey, 2022

5.5 The level of energy efficiency technologies usage by firms in the Greater Accra Region of Ghana

Evidence based on Chapter Four (4) shows that not many businesses in the Greater Accra Region are investing in RETs. But the sustainable energy literature have shown that as much as RETs are vital to the electricity supply mix, so are the energy efficient technologies (EETs) to the electricity demand dynamics (Gouws et al., 2012; Lins & Murdock, 2013). Not only does investment in EETs benefit the world's climatic conditions and the environment in general, but also ensures cost minimization for the businesses. Gouws et al. (2012) for instance, showed that EETs correlates with organizational success after they have surveyed 34 respondents from 10 industrial activities in South Africa.

Table 5.10 presents the energy efficient technologies (EETs) that were adopted by businesses in the Greater Accra Region of Ghana from 2015 to 2021. Generally, businesses are well inclined to using EETs, despite the disparity in the extent of usage of the different technologies. Only 11% of the sampled businesses have not adopted any EETs, meaning nearly 90% of the businesses have used at least one energy efficiency technology from 2015 to 2021 (Table 5.10). Apeaning and Thollander (2013) discovered an energy efficiency gap in the Tema industrial area. Recent studies, as well as this current study, have shown that the energy efficiency gap seems to have closed significantly between 2015 and 2021. Over 88% of the businesses in this study used energy efficient lighting systems. This technology is by far the most adopted technology by the firms in Ghana. The level of usage is similar across the different types of firms and power-crisis/post-crisis eras. This agrees with the findings of Tamakloe (2022) and Adewunmi et al. (2019) who argued that energy efficient lighting is the most practiced energy efficient action in Ghana and South Africa respectively. It is obvious that the stimulus CFL replacement programme implemented in Ghana in 2007 achieved its purpose of empowering consumers to transition to the usage of energy efficient lighting systems.

The other energy efficiency technologies have not seen that level of application by the firms. Nearly 18 percent of the firms have energy efficient machinery systems, and these firms are in the smaller-sized categories. According to them, these efficient machines are relatively new, automated, and use less energy in performing the same task as other less efficient machines. About 20 and 18 percent of the firms also used energy efficient refrigerators and air-conditioning systems. These systems, according to the firms, have the efficiency labels on them from the Energy Commission, Ghana.

Table 5.10: Energy efficient technologies used by businesses in the GA/R vis-à-vis firm types and era

EET Applications	Size classification of firms				Era		Total
	Micro	Small	Medium	Large	2015-2017	2019-2021	
Lighting	1171 (90.99)	246 (82.0)	16 (94.12)	5 (41.67)	712 (88.12)	726 (89.85)	1438 (88.99)
Machinery	241 (18.73)	49 (16.33)	0 (0.0)	0 (0.0)	137 (16.96)	153 (18.94)	290 (17.95)
Refrigeration	212 (16.47)	104 (34.67)	12 (70.59)	0 (0.0)	156 (19.31)	172 (21.29)	328 (20.30)
Air-conditioning	171 (13.29)	100 (33.33)	12 (70.59)	4 (33.33)	138 (17.1)	149 (18.44)	287 (17.76)
None	116 (9.01)	50 (16.67)	1 (5.88)	7 (58.33)	94 (11.63)	80 (9.90)	174 (10.77)
Total cases	**1287**	**300**	**17**	**12**	**808**	**808**	**1616**
Chi2 (Pr)	**346.08 (0.000)**				**3.42 (0.945)**		

Source: Field Survey, 2022 *Colum percent of cases in parenthesis*

Table 5.11 presents the perceived percentages of firms' electricity end-uses that are using energy efficient technologies. Over 88 percent of the firms had more than 80 percent of their lighting systems using energy efficient lamps while 6 percent had 61-80 percent of the lights to be efficient. When it comes to firms who have energy efficient machinery systems, about 53 percent reported that over 80 percent of their machines were energy efficient. Similarly, nearly 73 and 74 percent of the firms who use energy efficient refrigerator and A/C units reported that over 80 percent of these systems at the firms were energy efficient. These statistics suggest that for firms that are using EETs, majority have been able to convert over 80 percent of their end-uses to energy efficient systems.

Table 5.11: Perceived percentage of the firms' electricity end-uses that are using energy efficient technologies

Percent	Percentage of the firms' …			
	Lighting system using EE-lights	Machinery system using EE-Machines	Refrigerator system using EE-Fridges	A/C system using EE-AC
1 – 20	9 (0.63)	12 (4.14)	8 (2.44)	6 (2.09)
21-40	16 (1.11)	3 (1.03)	4 (1.22)	7 (2.44)
41-60	43 (2.99)	51 (17.59)	26 (7.93)	21 (7.32)
61-80	92 (6.40)	70 (24.14)	51 (15.55)	42 (14.63)
81-100	1278 (88.87)	154 (53.1)	239 (72.87)	211 (73.52)
Total	**1438 (100)**	**290 (100)**	**328 (100)**	**287 (100)**

Source: Field Survey, 2022 *Percentages in parenthesis*

5.6 The determinants of firms' financial performance in the G/A Region from 2015 to 2021

Table 5.12 presents six (6) Fixed-Effects Models (FEMs) of the financial performance of businesses in the Greater Accra Region of Ghana. Each model is a fixed-effects regression of financial performance (FP) as a dependent variable on the predictor variables (the cost per unit output and reliability of the different electricity sources, energy efficiency technologies usage, capital value and labour) and the control variables (monthly expenditure on internet services and R&D, presence of COVID-19, introduction of new products in the past year, the firms' primary market of trading, the organizational structure of the firms,). The six models (1 – 6) represent the FEMs for the entire sample, the crisis era sample (2015-2017), the post-crisis era sample (2019-2021), the micro-, small-, and medium-large-sized firms in the region. It must be mentioned that Model (6) lacks sufficient observations to produce consistent parameter estimates due to the few samples in these categories. Finally, the fixed-effects models are only settled on following the Hausman specification tests that are in favour of the FEMs (Appendix A).

Model (1) is well fitted as indicated by the F-statistics and the associated probability value which show that the independent variables jointly and significantly explain variations in the dependent variable (FP). Grid-electricity cost per unit of output was negatively associated with the financial performance of the firms. This means that if the cost per unit of output associated with using grid-electricity increases, perhaps as a result of increasing electricity tariff, financial performance reduces, and this negative association is statistically significant for all the sub-samples of the study. Though the study did not intend to dwell on the magnitude of the association, the effect was greater for the post-crisis era sample (-3.6) than the crisis era sample (-2.8), and also greater for larger firms (4.1).

Table 5.12: The Fixed-Effects Models (FEMs) of the Financial Performance of the firms regressed on grid system's characteristics and other control variables

VARIABLES	(1) Full sample	(2) Crisis era: 2015-2017	(3) Post-crisis era: 2019-2021	(4) Micro firms	(5) Small firms	(6) Med-large firms
Grid power costs per unit of output (natural log -ln-)	-3.091***	-2.794***	-3.648***	-3.119***	-3.919***	-4.098***
	(0.236)	(0.390)	(0.409)	(0.263)	(0.624)	(0.734)
Blackout hours per month (ln)	-0.034***	-0.046***	-0.050**	-0.044***	0.012	-0.034
	(0.007)	(0.011)	(0.021)	(0.008)	(0.020)	(0.038)
Generator power costs per unit of output (ln)	-0.589	-2.066**	-0.265	-0.717	-0.264	-3.727
	(0.453)	(0.823)	(1.722)	(0.474)	(1.528)	(2.804)
Firms' total capital value (ln)	0.084**	0.173**	-0.037	0.110***	-0.132	0.020
	(0.037)	(0.075)	(0.076)	(0.042)	(0.104)	(0.053)
Firm size (ln)	0.074*	-0.003	0.091	0.402***	0.682***	-0.381
	(0.043)	(0.053)	(0.129)	(0.091)	(0.240)	(0.294)
Total monthly internet service expenditure (ln)	0.051***	0.046	0.038	0.045**	0.054	0.221
	(0.017)	(0.035)	(0.037)	(0.019)	(0.043)	(0.157)
Firms' R&D expenditure (ln)	0.016	0.016	0.030*	0.034**	0.001	0.008
	(0.011)	(0.029)	(0.017)	(0.015)	(0.019)	(0.022)
Presence of COVID-19[1]						
Yes	-0.070***	-	-0.076***	-0.082***	0.036	-0.000
	(0.023)		(0.027)	(0.026)	(0.061)	(0.074)
Introduced new products[2]						
No	-0.109**	-0.033	-0.129	-0.051	-0.248**	0.041
	(0.043)	(0.078)	(0.084)	(0.047)	(0.116)	(0.149)
Firms' primary market[3]						
Outside the district	0.259***	0.112	0.204	0.206*	0.381	-
	(0.096)	(0.205)	(0.192)	(0.113)	(0.231)	
Organizational structure of the firm[4]						
Sole proprietorship	-0.213*	0.053	-0.253	-0.160	-	-
	(0.121)	(0.168)	(0.467)	(0.119)		
Level of energy efficiency technology usage (ln)	0.155	-0.095	0.699	0.008	1.071	3.563*
	(0.135)	(0.162)	(0.547)	(0.135)	(1.866)	(1.891)
Constant	7.759***	6.908***	8.896***	6.824***	8.997***	10.437***
	(0.418)	(0.846)	(1.021)	(0.451)	(1.679)	(2.022)
Observations	1,593	796	797	1,276	288	29
R-squared	0.345	0.343	0.240	0.262	0.290	0.242
F-stat (Prob > F)	24.9 (0.00)	10.2 (0.00)	10.2 (0.00)	24.4 (0.00)	6.8 (0.00)	9.7 (0.00)
Number of firm_id	399	398	399	339	95	8
Hausman Test Result	FE	FE	FE	FE	FE	FE

NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 *Ref. category: 1(No); 2(Yes); 3(In the district); 4(Otherwise)*

Source: Field Survey, 2022

With generator cost per unit of output, negative associations were observed with financial performance, but the relationship was only statistically significant for the crisis period sample. This result comes as no surprise since Table 4.2 revealed that more firms significantly used generators in the power crisis era and the negative effect of the associated cost per unit of output reverberates the findings of some past studies regarding the effects of using generators. Oseni (2012), for instance found in-house electricity generation to burden firms in 12 African countries such that outputs are significantly affected. Oseni and Pollitt (2015) also observed in 8 SSA countries that firms that engaged in self-generation experienced $2.01 - $23.92 output losses relative to firms without back-up generators.

The quality adjusted multi-factor productivity theory argues that useful energy delivers quality adjusted capital and labour services that result in increased productivity (Ayres & Voudouris, 2014; Warr et al., 2008). The reverse is true if the services delivered by the energy are not useful. Blackout is one of such services delivered by the grid system that is undesirable. According to the estimates in Table 5.12, hours of blackout experienced from the grid electricity system were associated with decreasing financial performance. Similar significant and negative associations were observed across all the sub-samples except for the small-, med-large-sized firms. These findings align with Abeberese et al. (2021) in terms of output losses due to the 2012-2016 power crisis. It was clear from Table 5.7 that blackout, together with their frequencies and unpredictability, are major obstacles to smooth business operations in the GA/R. During periods of blackout, different coping measures, some of which are counter-productive, were implemented by firms. About 38% did nothing, 22% temporarily switched to using power from alternative energy sources, preferably generators, 13% stopped working until power returned and worked less on that day, and 5% continued working but with fewer people. All these measures came at significant costs to the firms.

The effect is slightly higher in the post-crisis period compared to the crisis period, and significant for the micro-sized firms according to the results in Table 5.12. Eighty-six (86) hours of blackouts were reportedly experienced in a month on average by the firms after the crisis period (Figure 5.5). These outages negatively affect the operations of firms, particularly micro-and small-sized firms because they are mostly prone to counter-productive measures such as reducing workers or working hours. This was confirmed by the CEO of a micro-sized services firm who said that:

> "*We are a small firm, we can't afford a generator now so when power goes off, we close for the day because there is not much to do without the power"* [FR_8, 2022].

Capital has a positive relationship with the financial performance of the firms. The fixed-effects models in Table 5.12 show that when the firms' total capital value increased, their financial performance increased as well. This association was significant for the full sample and the power crisis sample at 5 percent, and the micro-sized sample at 1 percent. The result empirically explains the importance of capital in the quality adjusted multi-factor productivity theory (Abbott, 2018; Gollop & Swinand, 1998). Capital is regarded as one of the primary factors of production and if the quality of capital increases together with the capital services, productivity improves significantly (Franklin, 2018, 2019; Goodridge et al., 2018).

The number of employees, which reflects the size of the firm, is the other primary factor of production in the quality adjusted multi-factor production function. Like the capital value, the employee size had positive and significant association with the financial performance of the firms for the full sample, micro-sized and small-sized firm samples from 2015 to 2021. Abbott (2018) and Franklin (2018) observed that businesses can do almost nothing without human resources proving their importance to the firms as found in the current study. Accordingly, they organize the other factors of production. Information technology (IT) and research and development (R&D) are other factors of production that have been found to significantly enhance financial performance of firms in the GA/R of Ghana. Solow (1957) introduced technical change in the Cobb Douglass production function to explain the productivity of the factors of production, particularly, labour. Investments in research, development, and information technology have the potential of improving the productivity of labour and capital in the production function. This is supported by the empirical results in Table 5.12 which show positive and significant relationship between IT expenditure and financial performance for the full sample and micro-sized firms, and between R&D expenditure and financial performance for the post-power crisis and micro-sized firm samples. According to Tables 5.4 and 5.6, micro-sized firms have engaged in more R&D, mostly in the areas of new products or services and new pricing mechanisms. It is, therefore, not surprising to see R&D expenditure foster financial performance of micro-sized firms according to the data.

The presence of the COVID-19 virus was found to be negatively associated with financial performance of the firms in the Greater Accra Region of Ghana. The novel virus COVID-19 was declared a pandemic in 2020 by the World Health Organization (Mahase, 2020), and by April 2020, Ghana recorded her first cases of the virus (Sibiri et al., 2021). To limit the spread of the virus, the President of the Republic announced strict measures on movement of goods and people. These measures according to Aduhene and Osei-Assibey (2021) and Schotte et al. (2021) have had profound impacts on businesses. Some businesses had to lay off workers, office hours reduced drastically, physical meetings were moved onto virtual platforms with associated data and platform subscription costs, and extra costs of procuring personal protective equipment were incurred. The presence of the virus in 2021 according to the data was associated with a reduction in financial performance for the entire sample, post-power crisis sample, and for micro-sized firms.

The introduction of new products or services by the firms coupled with the primary markets where firms often sell their products or services were found to significantly influence their financial performances. For the full sample estimation represented in Model (1), the financial performance decreased for firms that did not introduce new products or services in the past year compared to firms that introduced new products or services. This association was also significant for small-sized firms in Model (5). These results further explain the importance of R&D investment since smaller firms reportedly invested more in research and development, particularly in the areas of new products or services, and pricing mechanisms. The estimated fixed-effects results also show that firms that marketed and sold their products or services outside the district in which they were located enhanced their financial performance compared to firms that only traded in their districts. This was statistically significant for the entire sample and micro-sized firms. Intuitively, firms trading outside their local district markets are guaranteed a bigger market to trade which enhances demand, product recognition, and general wellbeing of the businesses.

The legal structure of a business has the potential to influence its financial performance. According to the data analysed in Table 5.12, firms that were structured as sole proprietorships as of 2021 were worse off compared to firms that were structured differently, like partnerships and corporations. This relationship was statistically significant for the full sample in Model (1) but not so for the other samples. The relationship between energy efficiency technology usage and financial performance of the firms was estimated using a composite index form of EET as shown in Table 5.12. Though a positive relationship was largely observed, the associations were not statistically significant. The study went further to investigate the associations between financial performance and the four (4) different EETs which are presented in Table 5.13. The table presents five (5) different models of financial performance of the entire sample of firms in the Greater Accra Region of Ghana for the 2015-2021 period. Due to the significant drop in observations owing to the low adoption of some EETs, both fixed-effects and random-effects models were estimated depending on the results of the Hausman specification tests.

Table 5.13: FE-RE Models of Financial Performance of firms in the G/A Region, with different energy efficient technologies (full sample: 2015-2021)

VARIABLES	(7) All EETs	(8) With EE_Machinery	(9) With EE_AC	(10) With EE_Lighting	(11) With EE_Refrig
Grid power costs per unit of output (ln)	1.383	-2.604***	-0.503	-2.791***	-0.738*
	(1.291)	(0.450)	(0.370)	(0.248)	(0.419)
Generator power costs per unit of output (ln)	-2.788	0.049	-0.191	-0.249	2.352**
	(4.015)	(0.479)	(0.632)	(0.438)	(1.007)
Blackout hours per month (ln)	0.086	-0.016	-0.037***	-0.036***	-0.001
	(0.068)	(0.014)	(0.013)	(0.007)	(0.014)
Firms' total capital value (ln)	-0.343	0.222***	0.177*	0.282***	0.331***
	(0.346)	(0.061)	(0.091)	(0.044)	(0.093)
Firm size (ln)	0.959	0.311***	0.372***	0.065	0.535***
	(0.696)	(0.100)	(0.112)	(0.039)	(0.130)
Total monthly internet service expenditure (ln)	1.093***	0.071**	0.147***	0.042**	0.100***
	(0.372)	(0.029)	(0.043)	(0.017)	(0.030)
Firms' R&D expenditure (ln)	-0.116*	0.032*	0.022	0.018	0.045**
	(0.066)	(0.018)	(0.016)	(0.012)	(0.019)
Presence of COVID-19[1]					
Yes	-0.284*	-0.009	-0.071*	-0.083***	-0.044
	(0.159)	(0.042)	(0.036)	(0.022)	(0.040)
Introduced new products[2]					
No	1.012*	-0.196***	-0.087	-0.065	-0.139*
	(0.526)	(0.066)	(0.069)	(0.040)	(0.082)
Firms' primary market[3]					
Outside the district	0.458	0.142	0.274***	0.183**	0.256**
	(0.353)	(0.128)	(0.096)	(0.086)	(0.115)
Organizational structure of the firm[4]					
Sole proprietorship	-	0.056	-0.628**	-0.042	-0.717**
		(0.166)	(0.275)	(0.121)	(0.323)
Energy efficient AC system (ln)	-	-	0.105	-	-
			(0.238)		
Energy efficient lighting system (ln)	1.815**	-	-	0.071*	-
	(0.728)			(0.040)	
Energy efficient machinery (ln)	0.062	0.126**	-	-	-
	(0.119)	(0.064)			
Energy efficient refrigerator system (ln)	-	-	-	-	0.303
					(0.350)
Constant	-2.974	5.033***	5.941***	5.194***	2.942
	(4.572)	(0.685)	(1.395)	(0.513)	(1.802)
Observations	43	290	275	1,419	320
R-squared	0.657	0.391	0.391	0.233	0.328
F-stat (Prob > F)	2.9 (0.02)	157 (0.00)	10.2 (0.00)	26.5 (0.00)	9.1 (0.00)
Number of firm_id	13	78	73	360	85
Hausman Test Result	RE	RE	RE	FE	FE

*NB: Std. err. in parentheses *** p<0.01, ** p<0.05, * p<0.1; Ref. category: 1(No); 2(Yes); 3(In the district); 4(Otherwise)*

Source: Field Survey, 2022

In all five (5) models represented in Table 6.2, the joint F-statistics and their respective probability values suggest that the independent variables jointly explain the variations in the dependent variable (financial performance). In Model (7), all the EETs were included but energy efficient AC and refrigerator systems were omitted because of collinearity problems.

Both EE-lighting and EE-machinery systems had positive associations with financial performance from 2015 to 2021. Similarly in Models (8) and (10) where EE-machinery and EE-lighting were separately included, financial performances were significantly enhanced by increases in the levels of EE-machinery and EE-lighting applications by the firms. In the separate models (9) and (11), EE-AC and EE-refrigerator systems were not found to be statistically significant even though they showed positive associations. On these pieces of evidence, EE-lighting and EE-machinery systems proved to be important enhancers of firms' financial performance from 2015 to 2021. The third hypothesis (as stated in Chapter One) of no impact of energy efficiency practices on the firms' financial performance is, thus, statistically rejected in consideration of energy efficient machinery and lighting usage by the firms.

The increasing effects of the application of energy efficient machinery systems agrees with the findings of Adom et al. (2012) who found industrial efficiency to significantly drive down firms' electricity bills thereby increasing their profitability. Indeed, such mechanisms like automations, retrofitting of equipment, behavioural change regarding machine operations, and the procurement of more modern machines which are practiced by the firms in the GA/R ensure less electricity is consumed to achieve the desired level of output. Ackah (2017) did not find firms' output to be significantly impacted by energy efficiency largely because of inefficiency in energy consumption by small and medium enterprises (SMEs). Though the current study could relate to Ackah (2017)'s findings of low efficiency practices by firms in general if energy efficient lighting systems were excluded from the mix, the current study differs from Ackah (2017) based on the research samples. Ackah (2017) studied SMEs in rural Ghana while the current study focused on firms in the Greater Accra Region of Ghana.

Appendix Tables (C1 – C5) present replicas of Table 5.13, but for power-crisis era, post-power crisis, micro-sized firms, small-sized firms, and medium-large-sized firms' samples. For each of these sub-samples, FE/RE models of financial performance were estimated with the different energy efficiency technologies and other independent variables. Some of the models lack sufficient observations due to the EET variables and, therefore, cannot be relied on for consistent parameter estimates. In the power crisis era, the EETs, though generally positive, were not found to be significantly associated with financial performance. During the post-power crisis period (Model 39), EE-lighting and EE-machinery systems were positively associated with financial performance. In the separate models (40-43), however, they were not found to be significant. EE-lighting systems were positively associated with financial performance for micro-sized firms (Appendix C3), while EE-refrigerator systems positively influenced financial performance for small-sized firms in the Greater Accra Region (Appendix C4). The evidence from the sub-sample estimations also suggests that EETs, particularly EE-lighting and EE-machinery systems enhanced the financial performances of firms in the Greater Accra Region.

5.5.1.1 Robustness and reliability checks on the financial performance models

The first robustness check carried out on the FP models estimated in Table 5.12 was to estimate the same models with monthly profit of the firms as a proxy for the financial performance instead of the total revenue used. The results are presented in Table 5.14. Generally, the results are like those in Table 5.12 in terms of the directional associations. For instance, the grid- and generator-electricity costs per unit of output were negatively and significantly associated with financial performance, the reliability, measured as the blackout hours per month had mixed effects, capital and labour factors of production had positive associations with financial performance, but not significant, and the presence of COVID-19 had negative and significant relationship with financial performance. Additionally, the association between capital and financial performance (profit) was significant in Model (13), while the association between financial performance (profit) and blackout hours per month as well as the generator cost per unit of output were also significant in Model (16). Profit is a good measure of financial performance that is related to the conventional measurement (total revenue) chosen for this study. If the profit models have similar characteristics as the total revenue models, the latter can be relied on for forecasting purposes.

Table 5.15 presents Stochastic frontier models (SFMs) of financial performance of firms in the Greater Accra Region of Ghana. The models have variables that have been transformed into natural logarithms as a pre-requisite for the frontier function. The SFMs assess the effects of the factors of production (independent variables) on the financial performance (or output variable) and the efficiency of the usage of the factors. The associations between the factors and financial performance of the firms in the G/A Region as presented in Table 5.15 are just like the observed relationship in Table 5.12 in terms of magnitude and direction. These similarities show that the results in both Tables 5.12 and 5.15 can be relied on for forecasting purposes.

Additionally, the estimated *gamma* statistics in Table 5.15 are, at least, 92% across all sub-samples and the parameterised (*lgtgamma*) are strongly significant at 1%. These show that at least 92% of the variabilities in the firms' financial performances are attributed to the technical efficiencies of the inputs (independent variables) in the models. In other words, only 8% of the variabilities in the firms' financial performance between 2015 and 2021 are due to random shocks.

Table 5.14: Fixed-Effects Models of Financial Performance (represented by Profit) of the firms in the Greater Accra Region of Ghana

VARIABLES	(12) Full sample	(13) Crisis era: 2015-2017	(14) Post-crisis era: 2019-2021	(15) Micro firms	(16) Small firms	(17) Med-large firms
Grid power costs per unit of output (natural log -ln-)	-4.175***	-2.047*	-4.405***	-4.100***	-7.069***	-10.803**
	(0.776)	(1.211)	(1.445)	(0.861)	(2.585)	(3.934)
Blackout hours per month (ln)	0.007	-0.038	0.006	-0.032	0.130**	0.026
	(0.022)	(0.028)	(0.069)	(0.023)	(0.064)	(0.069)
Generator power costs per unit of output (ln)	0.587	-2.687	0.537	-0.435	7.997*	-2.613
	(1.275)	(1.956)	(5.104)	(1.335)	(4.558)	(6.327)
Firms' total capital value (ln)	0.112	0.359**	0.179	0.081	0.034	-0.029
	(0.107)	(0.176)	(0.262)	(0.122)	(0.324)	(0.098)
Firm size (ln)	0.218	0.179	-0.100	0.338	0.172	0.148
	(0.185)	(0.376)	(0.413)	(0.253)	(0.722)	(0.752)
Total monthly internet service expenditure (ln)	0.033	0.125	-0.052	0.035	0.136	0.525
	(0.049)	(0.083)	(0.142)	(0.056)	(0.129)	(0.427)
Firms' R&D expenditure (ln)	0.014	-0.016	0.033	0.032	0.003	0.051
	(0.032)	(0.071)	(0.056)	(0.047)	(0.058)	(0.048)
Presence of COVID-19[1]						
Yes	-0.285***	-	-0.325***	-0.312***	-0.121	0.091
	(0.068)		(0.088)	(0.075)	(0.198)	(0.157)
Introduced new products[2]						
No	-0.009	0.069	-0.252	0.045	-0.138	-0.221
	(0.128)	(0.193)	(0.279)	(0.142)	(0.359)	(0.273)
Firms' primary market[3]						
Outside the district	0.314	-0.397	0.498	0.218	0.945	-
	(0.310)	(0.657)	(0.693)	(0.428)	(0.678)	
Organizational structure of the firm[4]						
Sole proprietorship	-0.535	-0.113	-0.242	-0.474	-	-
	(0.388)	(0.469)	(1.377)	(0.384)		
Level of energy efficiency technology usage (ln)	0.380	-0.502	-0.835	0.207	4.509	1.835
	(0.366)	(0.377)	(1.881)	(0.361)	(5.607)	(4.244)
Constant	6.264***	3.963*	6.895**	6.422***	4.316	6.675
	(1.231)	(2.119)	(3.461)	(1.328)	(5.190)	(3.809)
Observations	1,334	673	661	1,059	251	24
R-squared	0.070	0.041	0.107	0.074	0.139	0.717
F-stat (Prob > F)	6.11 (0.00)	1.65 (0.08)	3.05 (0.00)	5.04 (0.00)	2.3 (0.01)	2.03 (0.16)
Number of firm_id	344	340	342	290	84	6
Hausman Test Result	FE	FE	FE	FE	FE	FE

NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 *Ref. category: 1(No); 2(Yes); 3(In the district); 4(Otherwise)*

Source: Field Survey, 2022

Table 5.15: Stochastic Frontier Models of financial performance of firms in the Greater Accra Region of Ghana

VARIABLES	(18) Full sample	(19) Crisis era: 2015-2017	(20) Post-crisis era: 2019-2021	(21) Micro firms	(22) Small firms	(23) Med-large firms
Firms' total capital value (natural log -ln-)	0.261***	0.393***	0.285***	0.210***	0.185**	0.0221
	(0.0269)	(0.0342)	(0.0367)	(0.0308)	(0.0726)	(0.0380)
Firm size (ln)	0.167***	0.0799	0.388***	0.487***	0.949***	-0.381*
	(0.0411)	(0.0497)	(0.0934)	(0.0871)	(0.210)	(0.213)
Total monthly internet service expenditure (ln)	0.0814***	0.0968***	0.0967***	0.0644***	0.0814**	0.271**
	(0.0147)	(0.0229)	(0.0217)	(0.0158)	(0.0367)	(0.113)
Firms' R&D expenditure (ln)	0.0196*	0.0371*	0.0282**	0.0433***	-0.0154	0.00791
	(0.0104)	(0.0193)	(0.0142)	(0.0132)	(0.0187)	(0.0154)
Grid power costs per unit of output (ln)	-3.152***	-2.864***	-3.798***	-3.196***	-3.683***	-4.086***
	(0.226)	(0.355)	(0.360)	(0.251)	(0.580)	(0.531)
Generator power costs per unit of output (ln)	-0.467	-1.388*	-0.238	-0.577	-0.822	-3.637*
	(0.445)	(0.710)	(1.306)	(0.460)	(1.432)	(2.051)
Blackout hours per month (ln)	-0.0116*	-0.0280***	-0.00743	-0.0255***	0.0216	-0.0258
	(0.00694)	(0.0101)	(0.0195)	(0.00759)	(0.0180)	(0.0246)
Level of energy efficiency technology usage (ln)	-0.125	-0.293**	-0.157	-0.247**	0.202	3.303**
	(0.124)	(0.142)	(0.272)	(0.125)	(0.609)	(1.367)
Constant	11.04***	9.357***	9.725***	10.60***	9.412***	14.22***
	(3.515)	(1.741)	(2.199)	(3.274)	(1.720)	(1.533)
mu (mean of distribution)	5.575	5.036***	4.920**	5.067	4.675***	2.372
	(3.486)	(1.713)	(2.136)	(3.256)	(1.530)	(4.016)
lnsigma2	0.494***	0.475***	0.413***	0.357***	0.767***	2.781**
	(0.0700)	(0.0701)	(0.0690)	(0.0752)	(0.150)	(1.135)
lgtgamma	2.538***	2.899***	2.467***	2.486***	2.731***	7.752***
	(0.0886)	(0.106)	(0.107)	(0.0964)	(0.197)	(1.187)
Sigma2	1.640	1.608	1.511	1.430	2.154	16.128
Gamma	0.927	0.948	0.922	0.923	0.939	0.999
Sigma_u2	1.520	1.524	1.393	1.320	2.022	16.121
Sigma_v2	0.120	0.084	0.118	0.110	0.132	0.007
Observations	1,593	796	797	1,276	288	29
Number of firm_id	399	398	399	339	95	8

NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Source: Field Survey, 2022

5.7 Conclusion

The empirical results satisfactorily substantiate the quality adjusted multi-factor productivity theory as explained by Elkomy et al. (2020). Capital and labour as the primary factors of production enhanced the financial performance of the firms from 2015 to 2021 while the electricity (from the grid and generators) costs per unit of output produced were negatively associated with financial performance over the same period. Blackouts experienced with the grid-system proved damaging to the financial performances of the firms. Increased blackouts reduced working hands and working hours, raising the operation costs of firms who had the ability to invest in an alternative source (generator) that is rather unsustainable in terms of costs and environmental pollutions as argued by Danso-Wiredu et al. (2016). The COVID-19 pandemic significantly affected the performance of businesses in the Greater Accra Region. Because this was a condition that was out of the firms' control as well as the reliability of the grid system, investing in other key factors like R&D and IT services like internet, which could open opportunities for the firms to discover new products, new market, and new energy systems, enhanced the financial performances of the business enterprises.

Relating the findings to the stated hypothesis in Chapter One, the first hypothesis (i) is rejected in favour of the alternative hypothesis that costs of the grid- and generator-systems significantly influence their financial performance. The second hypothesis (ii) of no impact of the reliability of the fuel systems is also rejected on the basis that the unreliability of the grid-system was found to significantly reduce the financial performances of the firms from 2015 to 2021. Finally, the third hypothesis (iii) is rejected because energy efficient lighting systems and energy efficient machinery systems were found to have positive associations with the financial performance of the firms.

CHAPTER SIX

ENVIRONMENTAL PERFORMANCES OF FIRMS IN THE GREATER ACCRA REGION FROM 2015 TO 2021 VIS-À-VIS THE UTILISATION OF DIFFERENT ENERGY SYSTEMS

6.1 Introduction

This chapter explores the association between the second dimension of firm performance, that is, environmental performance, and the different energy systems as well as other determining factors like capital, labour, IT and R&D expenditure that were used in Chapter Five (5). Specifically, the study examines the relationship between environmental performance on one hand, and reliability of the grid power system (hours of blackouts), usage of generator systems, the extent of energy efficiency technology (EET) usage, and the other control variables on the other hand. The chapter proceeds with a description of the various environmental actions undertaken by the firms from 2015 to 2021 followed by the presentation of estimation results and discussion of the determinants of environmental performance of the firms from 2015 to 2021. The final section concludes the chapter.

6.2 Environmental actions implemented by the firms from 2015 to 2021

With the current global conversations around sustainable development, the true performance of a firm ought to reflect its sensitivity to the environment as much as the social and economic pillars (O'Dochartaigh & Maughan, 2019; Ozili, 2022). The environmental performance (EP) variable is an index created from the firms' levels of recycling or use of recycled materials; re-use of materials; reducing material usage; degradable packaging materials; eco-friendly products; controlled pollution for production process; renewable energy mix; wastewater treatment; sustainable solid and e-waste management; and less paper, more electronic operation system applications (Table.6.1). Nearly 56 percent of the firms were found not to be using any of the environmental strategies/policies. About 30% of the businesses have implemented energy efficiency strategies, 12% have recycled, or use recycled materials, 16% have re-used their materials, 9% have used less paper, more electronic application, and less than 5% of the businesses implemented the remaining strategies. Because the level of energy efficiency technology usage is one of the independent variables, this strategy was excluded as a component from the computation of the environmental performance index.

Table 6.1: Environmental policies/plans implemented by businesses in the GA/R from 2015 to 2021

Environmental plans	Size classification of firms				Era		Total
	Micro	Small	Medium	Large	2015-2017	2019-2021	
Energy efficiency plans	373 (29.0)	94 (31.3)	12 (70.6)	-	234 (28.96)	245 (30.32)	479 (29.64)
Recycling/use of recycled materials	175 (13.6)	26 (8.7)	-	-	99 (12.25)	102 (12.62)	201 (12.44)
Re-use of materials	226 (17.6)	28 (9.3)	4 (23.5)	4 (33.3)	129 (15.97)	133 (16.46)	262 (16.21)
Reducing quantity of material	69 (5.36)	9 (3.0)	-	-	35 (4.33)	43 (5.32)	78 (4.83)
Degradable packaging materials	13 (1.0)	4 (1.3)	-	-	6 (0.74)	11 (1.36)	17 (1.05)
Eco-friendly products	41 (3.19)	6 (2.0)	-	-	23 (2.85)	24 (2.97)	47 (2.91)
Controlled pollution from production	9 (0.7)	8 (2.7)	-	-	8 (0.99)	9 (1.11)	17 (1.05)
Renewable in energy mix	-	4 (1.3)	1 (5.9)	-	2 (0.25)	3 (0.37)	5 (0.31)
Wastewater treatment	4 (0.3)	24 (8.0)	7 (41.2)	-	18 (2.23)	17 (2.10)	35 (2.17)
Sustainable solid and e-waste management	27 (2.1)	8 (2.7)	2 (11.8)	-	17 (2.10)	20 (2.48)	37 (2.29)
Less paper, more electronic systems	104 (8.1)	34 (11.3)	-	1 (8.3)	65 (8.04)	74 (9.16)	139 (8.60)
None	725 (56.3)	168 (56.0)	2 (11.8)	7 (58.3)	456 (56.44)	446 (55.2)	902 (55.82)

Source: Field Survey, 2022 *Percentages in parenthesis*

6.3 The determinants of firms' environmental performance in the G/A Region from 2015 to 2021

Table 6.2 presents six (6) fixed-effects models of environmental performance (EP) of the firms that assessed how the reliability of the grid system, usage of generator systems as well as other control independent variables are associated with the firms' EP in the Greater Accra Region. In all the models presented in Table 6.2, the independent variables are jointly significant in explaining variations in the dependent variable according to the F-Statistics and the associated probability values, except Models (28) and (29).

Experiencing hours of blackouts reduced the environmental performances of the firms significantly according to the estimation results in Table 6.2. During the power-crisis era when firms experienced hours of power outage, businesses used different coping strategies, one of which was to invest in alternative power sources. The preferred alternative had been personal generators that use dirty fuels. Additionally, the firms have little control of the level of air pollution caused by this alternative power source. These are reflected in the estimation results where hours of blackouts are related to reduced environmental performance of the firms from 2015 to 2021 (Table 6.2).

Table 6.2: Fixed-Effects Models of Environmental Performance of firms in the Greater Accra Region of Ghana

VARIABLES	(24) Full sample	(25) Crisis era: 2015-2017	(26) Post-crisis era: 2019-2021	(27) Micro size	(28) Small firms	(29) Med-large firms
Blackout hours per month (natural log -ln-)	-0.002*	-0.003*	0.001	-0.002	-0.002*	-0.008
	(0.001)	(0.002)	(0.003)	(0.001)	(0.001)	(0.014)
Usage of generator at the firm[1]						
Uses generator	-0.025***	-0.028	-0.031	-0.024**	0.004	
	(0.010)	(0.017)	(0.021)	(0.012)	(0.009)	
Firms' total capital value (ln)	0.010*	0.011	-0.004	0.010	0.002	-0.003
	(0.006)	(0.013)	(0.009)	(0.008)	(0.006)	(0.021)
Firm size (ln)	-0.009	-0.011	-0.012	0.012	-0.006	-0.014
	(0.007)	(0.009)	(0.015)	(0.017)	(0.014)	(0.108)
Total monthly internet service expenditure (ln)	0.012***	0.005	0.018***	0.015***	0.001	-0.012
	(0.003)	(0.006)	(0.004)	(0.003)	(0.003)	(0.060)
Firms' R&D expenditure (ln)	0.005***	0.004	0.003	0.008***	-0.001	-0.003
	(0.002)	(0.005)	(0.002)	(0.003)	(0.001)	(0.008)
Presence of COVID-19[2]						
Yes	0.003	-	0.004	0.004	0.003	-0.024
	(0.004)		(0.003)	(0.005)	(0.003)	(0.030)
Introduced new products[3]						
No	0.010	0.001	0.028***	0.015*	0.004	0.021
	(0.007)	(0.013)	(0.010)	(0.008)	(0.007)	(0.060)
Firms' primary market[4]						
Outside the district	0.060***	0.192***	0.016	0.087***	-0.001	-
	(0.015)	(0.035)	(0.021)	(0.020)	(0.013)	
Organizational structure of the firm[5]						
Sole proprietorship	-0.039**	-0.032	-0.001	-0.038*	-	-
	(0.020)	(0.028)	(0.056)	(0.022)		
Level of energy efficiency technology usage (ln)	0.120***	0.069**	0.045	0.102***	0.189*	0.138
	(0.022)	(0.027)	(0.065)	(0.025)	(0.107)	(0.694)
Constant	0.000	0.010	0.149	-0.025	0.062	0.470
	(0.067)	(0.143)	(0.122)	(0.081)	(0.096)	(0.792)
Observations	1,616	808	808	1,287	300	29
R-squared	0.124	0.130	0.078	0.139	0.075	0.056
F-stat (Prob > F)	15.4 (0.00)	5.91 (0.00)	3.04 (0.00)	13.7 (0.00)	1.6 (0.12)	0.1 (0.99)
Number of firm_id	404	404	404	341	98	8
Hausman Test Result	FE	FE	FE	FE	FE	FE

NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 *Ref. category: 1(Does not use generator); 2(No); 3(Yes); 4(In the district); 5(Otherwise)*

A related variable is the dummy created for the usage or ownership of generators which confirms the impacts of the blackouts. For the entire sample, the usage of generators was observed to be negatively associated with the environmental performance of the firms in the Greater Accra Region from 2015 to 2021. Generator electricity cost per unit of output was found to be negatively associated with financial performance in Chapter Five (5) but some firms confirmed in Chapter Four (4) that using generators enhanced their financial performance as they could not do without power. But using this system was found to hurt the environmental performance of the firms just as its cost per unit of output was found to decrease the firms' financial performance. These findings align with studies like Ai et al. (2021), Maniu et al. (2021), Revell et al. (2010), and Zafar et al. (2020) who found businesses' continuous reliance on fossil fuel power generations to downgrade their environmental ratings.

Research and development, as well as investment in IT (internet services) are very important to the environmental performance of the businesses. The different components of the EP index require highly technical sustainability strategies to be implemented. It is not surprising that nearly 56% have not undertaken any environmental strategies for the entire period (Table 6.1) because these strategies require substantive financial investments. When expenditure on internet services increased, the environmental performance of the firms was enhanced. This relationship was found to be significant for the full sample, post-crisis sample and micro-sized firms. Similarly, an increase in R&D expenditure increased the environmental performance of the firms for the full sample (Model 24) and the micro-sized firms (Model 27). The increased investments in R&D and information technologies create opportunities for implementing the sustainable strategies in Table 6.1. These results are supported by Hart (1995) and King and Lenox (2001) but the latter study argues that larger firms with more resources tend to have better environmental performance because of their advantageous investment abilities which is contrary to what was found in this current study.

For the full sample, the total capital value of the firm was found to be positively associated with environmental performance of the firms. This goes to enforce the earlier point that the implementation of the sustainable strategies in Table 6.1 require substantial resources, and one of such important resources is the capital endowment of the firms. When firms marketed and sold their products outside of the districts, their environmental performances were enhanced compared to firms that were limited to their local districts. According to Lopes et al. (2022), Maniu et al. (2021), and Sehnem et al. (2016), businesses have become conscious of the environmental concerns of consumers concerning their products and, therefore, try as much as possible to meet environmental standards when trading their products in foreign markets.

Firms that are structured as corporations or partnership have better chance of improving their environmental performances compared to sole proprietorship firms. Sehnem et al. (2016) argue that maintaining public image is an important goal for companies hence they go all out to pull resources together to invest in sustainability practices. Corporations and partnerships have a better chance of pooling resources together which has reflected in their ability to implement sustainable strategies than sole proprietorship firms. Sharma (2000) for instance, found strong governance structure including the presence of independent directors and environmental committee that may be associated it corporations and partnerships, are associated with environmental performance. Visser (2006) further argues that such corporations are more likely to engage in active CSRs which fosters environmental performance. Finally, the level of energy efficiency technologies usage, measured as an index, was found to be positively associated with the environmental performance of the firms in the Greater Accra Region. This relationship was statistically significant for nearly all the sub-samples of the study. The associations between environmental performance and the four (4) different energy efficient technologies were further assessed in a different set of models in Table 6.3.

Table 6.3: FE-RE Models of Environmental Performance of firms in the G/A Region, with different energy efficient technologies (full sample: 2015-2021)

VARIABLES	(30) All EETs	(31) With EE_Machinery	(32) With EE_AC	(33) With EE_Lighting	(34) With EE_Refrig
Blackout hours per month (natural log -ln-)	-0.028*	-0.006*	-0.005	-0.003**	-0.002
	(0.015)	(0.004)	(0.004)	(0.001)	(0.004)
Usage of generator at the firm[1]					
Uses generator	-0.047	-0.017	-0.096***	-0.030***	-0.050**
	(0.047)	(0.018)	(0.022)	(0.010)	(0.023)
Firms' total capital value (ln)	0.099	0.050***	0.019	0.016*	0.055**
	(0.076)	(0.018)	(0.028)	(0.008)	(0.026)
Firm size (ln)	0.088	-0.002	0.025	-0.009	-0.006
	(0.108)	(0.025)	(0.036)	(0.007)	(0.037)
Total monthly internet service expenditure (ln)	-0.048	-0.001	0.014	0.010***	0.011
	(0.081)	(0.009)	(0.014)	(0.003)	(0.009)
Firms' R&D expenditure (ln)	0.006	-0.005	0.016***	0.005**	0.014**
	(0.012)	(0.005)	(0.005)	(0.002)	(0.005)
Presence of COVID-19[2]					
Yes	-0.009	0.005	0.007	0.004	0.002
	(0.035)	(0.010)	(0.011)	(0.004)	(0.011)
Introduced new products[3]					
No	-0.061	0.030*	0.002	0.018**	0.014
	(0.085)	(0.016)	(0.022)	(0.007)	(0.024)
Firms' primary market[4]					
Outside the district	-0.023	-0.019	0.048	0.062***	0.110***
	(0.072)	(0.033)	(0.031)	(0.015)	(0.033)
Organizational structure of the firm[5]					
Sole proprietorship	-	-0.101**	-0.082	-0.047**	-0.088
		(0.051)	(0.088)	(0.022)	(0.093)
Energy efficient AC system (ln)	-	-	0.162**	-	-
			(0.077)		
Energy efficient lighting system (ln)	-0.223	-	-	0.001	-
	(0.145)			(0.007)	
Energy efficient machinery (ln)	0.112***	0.126***	-	-	-
	(0.026)	(0.017)			
Energy efficient refrigerator system (ln)	-	-	-	-	0.064
					(0.101)
Constant	0.132	-0.585***	-0.630	0.032	-0.554
	(0.999)	(0.206)	(0.439)	(0.094)	(0.514)
Observations	43	290	287	1,438	328
R-squared	0.791	0.374	0.267	0.093	0.189
F-stat (Prob > F)	6.55 (0.00)	10.9 (0.00)	6.63 (0.00)	9.92 (0.00)	4.87 (0.00)
Number of firm_id	13	78	76	364	87
Hausman Test Result	RE	FE	FE	FE	RE

*NB: Std. err. in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(Does not use generator); 2(No); 3(Yes); 4(In the district); 5(Otherwise)*

Source: Field Survey, 2022

Model (30) has all the EETs included while Models (31-34) separately included the technologies. EE-machinery systems were positively and significantly associated with environmental performance in Models (30) and (31). Efficient machinery systems ensure that less energy resources would be required to achieve desired output level compared to what inefficient machinery systems can produce. This finding is in tune with those of Kakulu (2008), Sehnem et al. (2016) and (Sy, 2016) that found an increased economic and environmental performance of firms that practice sustainability measures like efficient production processes.

Energy efficient air-conditioning systems enhanced the environmental performance of businesses in the Greater Accra Region. Air-conditioners are energy-intensive electrical systems. Using energy efficient AC systems means significant energy conservation and cost savings for the firms which ultimately make them more sustainable. Hence, the importance of these systems cannot be over emphasised. Some studies even advocate that consumers should invest in higher-starred AC systems to accrue more efficiency benefits (Opoku et al., 2019).

The FE/RE models of environmental performance of the firms in the Greater Accra Region, with the different EETs are also estimated for different sub-samples and presented in Appendix Tables (C6-C10). For the power crisis era sample (Appendix C6), EE-machinery and EE-AC systems were observed to be positive and significantly associated with the environmental performance of the firms from 2017 to 2019 (Models 55 and 56). Only EE-machinery systems were significant for the post-power crisis era and micro-sized firms' samples (Appendix C7 and C8). The observed relationships were positive between the technology and environmental performance. The EETs were not found to be statistically significant in small-sized firms and medium-large-sized firms' samples (Appendix C9 and C10).

6.4 Conclusion

The chapter explored the determinants of environmental performance of firms in the Greater Accra Region of Ghana, focusing on the association between EP on one hand, and hours of blackouts, usage of generator, the level of energy efficient technologies usage, capital, labour, IT and R&D expenditure and the other variables on the other hand. Hours of blackouts and the consequent usage of generators were found to be negatively associated with the environmental performance of the firms in the Greater Accra Region. The environmental strategies require substantial resources to be implemented. It is therefore not surprising that nearly 56 percent of the firms did not adopt any environmental strategy. Increased capital value and increased expenditure on internet services (IT) and R&D enhanced environmental performance because these resources increase the possibilities of implementing the sustainable strategies.

Like the financial performance in Chapter Five (5), energy efficient machinery and lighting systems were positively associated with the environmental performance of the firms in the Greater Accra Region from 2015 to 2021. The third hypothesis of no relationship between environmental performance and EETs is thus rejected. This suggests that businesses benefit from investing in energy efficiency technologies, particularly energy efficient machinery and lighting technologies to make savings on energy bills and protect the environment at the same time. Firms are, therefore, encouraged to continue investing in these technologies even as they are unable to invest substantially in cleaner power sources like RETs. These environmental gains can be enhanced further if the efficiency levels of the technologies are equally increased such as higher star-rated versions of the AC, lighting, and refrigerator systems.

CHAPTER SEVEN

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

7.1 Introduction

This is the final chapter of the study which summarises the entire work and provides recommendations based on the findings from the data analysis. In between, the researcher highlights the key contributions of the study, the limitations, and grey areas that should be explored in future research activities.

7.2 Summary of key findings of the study

The research sets out to understand three (3) key questions: which energy systems were used by businesses in the Greater Accra Region during and after the 2012-2016 power crisis? Why were some energy systems or electricity sources preferred to others? How did the services of these energy systems affect the financial and environmental performances of the firms in the Greater Accra Region from 2015 to 2021. To answer these questions, the study adopted the explanatory sequential mixed-methods design for the purposes of triangulation, complementarity, and development. Greater Accra Region was purposively selected at the first stage, Accra Metropolis, Tema Metropolis, and Ga South Municipality were selected at the second stage because they house over 60% of all business establishments in the Greater Accra Region, and 404 micro-, small-, medium-, and large-sized businesses were sampled from the three districts with the condition that they use a productive energy. Retrospective data on interesting variables were collected for 2015, 2017, 2019 and 2021 from the 404 firms meaning 1616 data points were collected for the panel analysis. Fixed-effects and Random-effects methods were employed to estimate the relationship between financial and environmental performances on one hand, and the independent variables on the other hand. About 15 firm representatives and key informants participated in the qualitative component of the mixed design while thematic analytical method was used within a broad case-study approach to investigate the energy decisions of businesses in the Greater Accra Region of Ghana.

Nearly all businesses in the Greater Accra Region use the grid electricity system because it is regarded as a solid, secure, and guaranteed system; convenient, reliable, and safe; simply available; and perceived as a cheap system. About 22% of the firms use generators. The reasons are that some of the firms cannot do without generators because their outputs will drop drastically, some see it as the quickest way to self-generate own power, and majority use it because of the unreliability of their primary power source, the national grid system. Many firms, however, chose to overlook RETs because of the high upfront cost; lack of trust in the RETs due to poor quality materials and installations; lack of technical knowhow; the RETs require other supporting systems to function properly; unsupportive policies; information on RETs not penetrating enough; and the lack of practical examples. Accordingly, most businesses in the region can be described as *late majorities* within Rogers' Diffusion of Innovation Theory because they would only be convinced to invest in RETs if they see lots of people using the technologies.

Unwanted energy services like hours of blackouts from the grid system, grid- and generator-costs per unit of output significantly reduced the financial and environmental performances of the firms. On the contrary, useful energy services like energy efficiency technologies, particularly energy efficient lighting and machinery systems, were as important in enhancing firm performance as the capital, labour, and IT and R&D factors of production.

7.3 Key contributions of the study

Businesses around the globe are being encouraged to substitute fossil-powered electricity for increased investment in renewable energy technologies like solar and wind. In developing countries like Ghana, the reverse in happening. Businesses are completely reliant on national grid systems whose composition have become fossil dominated in recent years, and when these systems become unreliable, they are substituted with self-generation plants that are also fossil powered. The current study shows that while investment in RETs is not encouraging, particularly among Ghanaian businesses, an intentional adoption of a different set of sustainable energy technologies is being observed among the firms. These are energy efficiency technology. Firms have massively transitioned to energy efficient lighting systems, while the adoption of energy efficient machinery and air-conditioning systems are also on the rise. These have bolstered the financial performance of the firms in terms of cost savings on energy bills and improved their environmental friendliness through energy conservation. These ultimately serve the purpose of climate change mitigation strategies in the long run.

Several studies have found cost related factors as major impediments to the development of RETs in Ghana. Few have gone further to uncover factors like low awareness, lack of technical abilities, to also hinder RETs adoption. While all these factors are important obstacles and have been observed in the current study as well, the behaviour of the potential adopters has not been fully understood from the previous studies. Most businesses in the Greater Accra Region can best be described as *late majorities* when it comes to the adoption of RETs. A lot of the firms are exercising restrain in the face of the innovation (RET) because they have doubts about how it can be helpful to them. They would like to see other businesses using the technologies before they are encouraged to also try them. Knowing this behaviour of the late majorities should inform policies towards improving the adoption rate of the RETs among firms in Ghana.

7.4 Limitations of the study

Recall bias: The researcher collects historical data from 2015 to 2021 in two-years intervals. The enumerators were specifically asked to request business records from the firm representatives. Only in the absence of any form of records should the respondents be allowed to rely on their recall abilities. Though some enterprise owners kept good business records and, therefore, referred to such records for the information required, others relied on their memories to recall the required data from time past. The researcher is aware of the possibilities of under and, or over declaration of the required information, particularly numerical information when the respondents had to rely on their recall abilities. To minimise these biases, the researcher interrogated outliers with the help of the enumerators used in the survey to ensure that such data points make real sense.

Unbalanced sample: The sample frame of the study was guided by the proportions of business sizes according to the 2014 IBES in Ghana, but not followed strictly. At the end of the day, only willing businesses were enumerated. Consequently, very few large- and medium-sized firms participated in the survey and their numbers were too few to generate enough degree of freedom for a robust analysis. Additionally, only three (3) firms were reported to be using RETs in the final sample. Hence, the study could not carry out any robust inferential analysis for this energy system like what was done for the grid and generator systems.

Issues of endogeneity: The study found some variables to be endogenous in the models via simultaneity relationships. Whiles this was acknowledged, the lack of appropriate instruments in the data meant that the issues could not be completely resolved aside the adoption of fixed-effects methods that in a way, controls for exclusion biases. The study therefore focused on exploring the directional associations between the dependent variable and the predictor variables rather than causal effects relationships.

7.5 Suggestions for future research

According to the representatives of most businesses that participated in the study, they know very little about renewable energy technologies. How they function, the benefits and the challenges are not well known in the business space. However, the firms that have full knowledge of these technologies are using them. Only two firms out of the 10 participants reported to be using RETs. A future study that concentrates on only firms that are generating all, or part of their electricity needs from renewable sources would allow for a wider and deeper investigation using both qualitative and quantitative designs. This will shed useful light on the full benefits firms are accruing from these technologies as well as the challenges they are facing.

The adoption of energy efficient machinery system was found to significantly impact the performance of firms in the Greater Accra Region of Ghana. The empirical results demonstrated that energy efficient machinery system is an important catalyst for firms' financial and environmental performances. This energy efficiency technology was only broadly captured as 'adoption of energy efficient machinery systems' in this study. Generally, future research can focus on exploring the factors that affect firms' adoption of energy efficient technologies in Ghana as a whole. But specifically, the specific energy efficient machinery applications should be explored in future studies to access which applications are more impactful.

7.6 Recommendations

Based on the findings discussed in the empirical chapters four, five, and six, the following recommendations are advanced for the consumption of businesses in the Greater Accra Region, and national policy makers in charge of business and energy sectors development in Ghana.

Trumpet the renewable success stories: It has been concluded that most businesses in the capital are *late majority*. In other words, they act by the popular saying *seeing is believing*. There should be a documentary on firms that have successfully invested in renewable energy technologies and such pieces of evidence should be publicised and spread widely by the appropriate authorities like the Energy Commission, and Ministry of Energy, as green enterprise models.

Consistent targeting of the grassroots for renewable energy technology awareness campaigns: Linked to the above point, such documentaries and other promotional packages should go beyond workshops, conferences, and agency meetings. Policy makers have been accused of sitting on information that could be relevant for grassroots enterprises. Most enterprise managers and owners cry that they know very little about RETs. Awareness campaigns developed and implemented by the Energy Commission and other stakeholders in the sustainable energy space must be more aggressive, purpose-driven, target-driven, result-driven, and consistent to ensure that various targeted groups are getting to know what they deserve to know.

Incite public confidence in renewable energy technologies by paying more attention to imitations, inferior material importations, and poor-quality installation and maintenance services: One of the factors that has caused disinterest in the investment in RETs is the prevalence of poor installations and services because of the usage of inferior materials and unqualified service providers. The RET supplies interviewed in this study confirmed that there are too many inferior RET equipment allowed into the country which is breaking the trust of ordinary Ghanaians in RETs. If people see numerous failed installations and investments in RETs, they will not be convinced about the technologies. The Energy Commission should produce and publish the list of certified RETs Service Providers who are guaranteed to provide international standard and quality services to potential customers. They should also carry out and/or supervise regular trainings for RET technicians to improve on their know-how.

Take advantage of the 'grid-dependencia' and make it greener and more reliable: It has been shown that businesses depend massively on the national grid system. One easy way to ensure that businesses are using renewable energy is to make the grid system greener. Renewables (excluding the large hydro plants) contribute 0.55% of the 2021 total electricity generation in Ghana. Technically, it means businesses only use 0.6% RETs in their energy systems. If the share of RETs is increased to say 30% in the national energy mix, it will make sense to reason that firms likewise consume 30% RETs in their energy mix. Government must, therefore, show more commitment towards increasing the share of RETs in the national grid since all targets in the past (of achieving 10% RETs in the energy mix by 2015, then 2020) have all been missed. Additionally, hours of blackouts experienced from the grid system have proven to be detrimental to the financial and environmental positions of the firms. Making the grid system more reliable through infrastructure development is therefore a sustainable and prudent policy call.

Encourage Investment in energy efficiency technologies: Regardless of the power supply situations to enterprises, they are encouraged to continue investing in energy efficiency technologies particularly energy efficient machinery, air-cooling, and efficient lighting systems. These technologies have been found to significantly impact firms' performances than blackouts do. These technologies help to conserve energy and save costs that are channeled into other productive sectors of the enterprises. Knowing the right investment to make in terms of energy efficiency technologies, however, depends on intentional investment in R&D. Appropriate policy instruments like tax incentives must be enforced by government to attract such intentional investments in energy efficient technologies.

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APPENDIX A

HAUSMAN SPECIFICATION TEST OF FE-RE MODELS FOR THE EMPIRICAL MODELS

Appendix A: Hausman Specification Test Results for the empirical models

Model	Null Hypothesis (Ho): Difference in coefficients not systematic (RE model is appropriate)		
	Chi-square (b-B)`[V_b-V_B)^(-1)](b-B)	Prob> chi2	Decision
(1)	63.91	0.00	Ho is rejected at 1% sig. level in favour of FE
(2)	282.95	0.00	Ho is rejected at 1% sig. level in favour of FE
(3)	40.73	0.00	Ho is rejected at 1% sig. level in favour of FE
(4)	292.19	0.00	Ho is rejected at 1% sig. level in favour of FE
(5)	15.37	0.08	Ho is rejected at 10% sig. level in favour of FE
(6)	1018.59	0.00	Ho is rejected at 1% sig. level in favour of FE
(7)	0.44	0.98	The Ho of RE is not rejected
(8)	16.12	0.19	The Ho of RE is not rejected
(9)	3.61	0.99	The Ho of RE is not rejected
(10)	30.58	0.00	Ho is rejected at 1% sig. level in favour of FE
(11)	77.90	0.00	Ho is rejected at 1% sig. level in favour of FE
(12)	30.11	0.00	Ho is rejected at 1% sig. level in favour of FE
(13)	40.23	0.00	Ho is rejected at 1% sig. level in favour of FE
(14)	6.15	0.91	The Ho of RE is not rejected
(15)	22.23	0.04	Ho is rejected at 5% sig. level in favour of FE
(16)	9.47	0.39	The Ho of RE is not rejected
(17)	32.89	0.00	Ho is rejected at 1% sig. level in favour of FE
(24)	411.59	0.00	Ho is rejected at 1% sig. level in favour of FE
(25)	347.63	0.00	Ho is rejected at 1% sig. level in favour of FE
(26)	20.92	0.02	Ho is rejected at 5% sig. level in favour of FE
(27)	58.84	0.00	Ho is rejected at 1% sig. level in favour of FE
(28)	62.75	0.00	Ho is rejected at 1% sig. level in favour of FE
(29)	15.01	0.06	Ho is rejected at 10% sig. level in favour of FE
(30)	9.36	0.59	The Ho of RE is not rejected
(31)	62.74	0.00	Ho is rejected at 1% sig. level in favour of FE
(32)	44.71	0.00	Ho is rejected at 1% sig. level in favour of FE
(33)	297.38	0.00	Ho is rejected at 1% sig. level in favour of FE
(34)	5.16	0.92	The Ho of RE is not rejected

Source: Field Survey, 2022

APPENDIX B

DURBIN-WU-HAUSMAN ENDOGENEITY TEST FOR SUSPECTED VARIABLES

Table B: Durbin-Wu-Hausman Endogeneity test results

Null Hypothesis	F-Statistics	Prob>F
Total capital value (CAP) is uncorrelated with the error term	F(1, 1181) = 3.9e+14	0.0000
Employee size (SIZE) is uncorrelated with the error term	F(1, 1181) = 6.8e+14	0.0000
Monthly internet expenditure (IT) is uncorrelated with the error term	F(1, 1181) = 2.2e+15	0.0000
Monthly R&D expenditure (R&D) is uncorrelated with the error term	F(1, 1181) = 3.2e+13	0.0000
Extent of energy efficiency technology usage (EET) is uncorrelated with the error term	F(1, 1181) = 4.6e+13	0.0000

NB: Residuals were predicted from the regressions of the suspected endogenous variables, and then tested for statistical significance after they have been introduced into the main FP function

Source: Field Survey, 2022

APPENDIX C

FE-RE MODELS OF THE FINANCIAL AND ENVIRONMENTAL PERFORMANCE, WITH DIFFERENT EETS FOR THE DIFFERENT FIRM SAMPLES

Appendix C1: FE-RE Models of Financial Performance of firms in the G/A Region, with different energy efficient technologies (Power crisis era sample: 2015-2017)

VARIABLES	(35) With EE_Machinery	(36) With EE_AC	(37) With EE_Lighting	(38) With EE_Refrig
Grid power costs per unit of output	-3.528***	-0.931***	-2.541***	-0.505
	(0.659)	(0.324)	(0.332)	(0.528)
Blackout hours per month	-0.028	-0.044***	-0.054***	-0.031
	(0.026)	(0.015)	(0.011)	(0.021)
Generator power costs per unit of output	-1.155	-1.258	-1.922***	0.101
	(1.214)	(0.931)	(0.726)	(1.709)
Firms' total capital value	0.504***	0.280***	0.229**	0.569***
	(0.159)	(0.097)	(0.092)	(0.172)
Firm size	0.308	0.129	-0.002	0.004
	(0.322)	(0.169)	(0.045)	(0.363)
Total monthly internet service expenditure	-0.009	0.250***	0.052	0.072**
	(0.096)	(0.070)	(0.035)	(0.036)
Firms' R&D expenditure	-0.031	-0.088*	0.038	-0.302
	(0.043)	(0.048)	(0.028)	(0.219)
Introduced new products[1]				
No	-0.325**	-0.171**	0.045	-0.170
	(0.147)	(0.079)	(0.069)	(0.159)
Firms' primary market[2]				
Outside the district	-	0.375	0.085	0.102
		(0.318)	(0.171)	(0.225)
Organizational structure of the firm[3]				
Sole proprietorship	0.178	-0.335*	0.066	-0.218
	(0.247)	(0.195)	(0.155)	(0.405)
Energy efficient AC systems	-	-0.322*	-	-
		(0.166)		
Energy efficient lighting systems	-	-	0.015	-
			(0.054)	
Energy efficient machinery	0.083	-	-	-
	(0.259)			
Energy efficient refrigeration	-	-	-	1.257
				(1.660)
Constant	2.863	6.707***	6.014***	-2.310
	(1.842)	(1.241)	(1.040)	(7.314)
Observations	137	132	702	152
R-squared	0.466		0.322	0.325
Number of firm_id	74	70	357	77
Hausman Test Result	FE	RE	FE	RE

*NB: Std. err. in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(Yes); 2(In the district); 3(Otherwise). The variables missing in Model (35) are due to collinearity problems. The model with all the EETs could not be estimated due to insufficient observations.*

Appendix C2: FE-RE Models of Financial Performance of firms in the G/A Region, with different energy efficient technologies (Post-power crisis era sample: 2019-2021)

VARIABLES	(39) All EETs	(40) With EE_Machinery	(41) With EE_AC	(42) With EE_Lighting	(43) With EE_Refrig
Grid power costs per unit of output	11.302	-2.018*	-5.254***	-3.371***	-0.872
	(7.688)	(1.190)	(1.241)	(0.515)	(1.398)
Generator power costs per unit of output	-7.495	-3.468*	-0.219	-0.911	-2.011
	(6.302)	(1.879)	(2.723)	(2.263)	(3.973)
Blackout hours per month	-0.507***	0.019	0.020	-0.046**	0.052
	(0.143)	(0.029)	(0.039)	(0.020)	(0.037)
Firms' total capital value	-0.743***	0.177**	0.136	0.133	-0.050
	(0.233)	(0.079)	(0.099)	(0.101)	(0.233)
Firm size	1.966***	0.487***	0.523***	0.156	0.750***
	(0.587)	(0.175)	(0.195)	(0.143)	(0.222)
Total monthly internet service expenditure	1.244***	0.127***	0.164**	0.029	-0.024
	(0.162)	(0.041)	(0.081)	(0.035)	(0.107)
Firms' R&D expenditure	-0.022	0.006	0.002	0.031	0.034
	(0.044)	(0.021)	(0.018)	(0.019)	(0.024)
Presence of COVID-19[1]					
Yes	-0.640***	-0.032	-0.028	-0.084***	0.030
	(0.232)	(0.041)	(0.040)	(0.027)	(0.046)
Introduced new products[2]					
No	-0.913**	-0.177*	-0.102	-0.108	-0.188
	(0.407)	(0.093)	(0.107)	(0.082)	(0.163)
Firms' primary market[3]					
Outside the district	-0.946***	0.151	0.105	0.209	-0.003
	(0.336)	(0.151)	(0.140)	(0.179)	(0.199)
Organizational structure of the firm[4]					
Sole proprietorship	-1.463***	0.099	-0.511	-0.153	-
	(0.519)	(0.261)	(0.359)	(0.434)	
Energy efficient AC systems	-14.098***	-	-0.404	-	-
	(3.158)		(0.259)		
Energy efficient lighting systems	16.072***	-	-	0.541	-
	(3.054)			(0.850)	
Energy efficient machinery	0.530***	0.114	-	-	-
	(0.180)	(0.070)			
Energy efficient refrigeration	-	-	-	-	-1.761
					(6.798)
Constant	0.000	5.028***	8.359***	4.686	15.865
	(0.000)	(0.847)	(1.554)	(4.099)	(29.550)
Observations	25	153	143	717	168
R-squared				0.180	0.228
Number of firm_id	13	77	73	360	85
Hausman Test Result	RE	RE	RE	FE	FE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(No); 2(Yes); 3(In the district); 4(Otherwise). The variable missing in Model (39) is due to collinearity problem.*

Source: Field Survey, 2022

Appendix C3: FE-RE Models of Financial Performance of firms in the G/A Region, with different energy efficient technologies (Micro-sized firms' sample)

VARIABLES	(44) All EETs	(45) With EE_Machinery	(46) With EE_AC	(47) With EE_Lighting	(48) With EE_Refrig
Grid power costs per unit of output	2.677	-3.379***	-0.754	-3.110***	-1.059*
	(2.351)	(0.533)	(0.519)	(0.280)	(0.575)
Generator power costs per unit of output	-0.078	-0.471	-0.278	-0.489	1.921
	(20.526)	(0.541)	(0.791)	(0.473)	(1.560)
Blackout hours per month	0.092	-0.025	-0.019	-0.042***	0.005
	(0.077)	(0.017)	(0.020)	(0.008)	(0.018)
Firms' total capital value	0.312	0.171*	0.158	0.235***	0.308**
	(0.948)	(0.088)	(0.120)	(0.050)	(0.119)
Firm size	-0.485	0.325*	0.245	0.301***	0.576***
	(1.685)	(0.167)	(0.248)	(0.089)	(0.212)
Total monthly internet service expenditure	0.678	0.014	0.288***	0.036*	0.058
	(1.342)	(0.040)	(0.107)	(0.021)	(0.042)
Firms' R&D expenditure	0.632	0.040	0.073**	0.045***	0.070**
	(0.583)	(0.043)	(0.035)	(0.017)	(0.034)
Presence of COVID-19[1]					
Yes	-0.681**	-0.009	-0.157***	-0.075***	-0.054
	(0.227)	(0.051)	(0.056)	(0.025)	(0.057)
Introduced new products[2]					
No	1.567	-0.167**	-0.102	-0.055	-0.139
	(0.883)	(0.080)	(0.094)	(0.047)	(0.122)
Firms' primary market[3]					
Outside the district	-	0.121	0.274*	0.131	0.323
		(0.188)	(0.157)	(0.108)	(0.205)
Organizational structure of the firm[4]					
Sole proprietorship	-	0.111	-0.304	0.012	-0.390
		(0.230)	(0.363)	(0.126)	(0.432)
Energy efficient AC systems	-	-	0.448	-	-
			(1.228)		
Energy efficient lighting systems	2.794*	-	-	0.068	-
	(1.222)			(0.044)	
Energy efficient machinery	-1.279	0.108	-	-	-
	(0.984)	(0.094)			
Energy efficient refrigeration	-	-	-	-	0.291
					(0.414)
Constant	-8.483	5.746***	3.520	5.157***	3.136
	(6.153)	(0.961)	(5.472)	(0.556)	(2.163)
Observations	24	241	167	1,160	212
R-squared	0.907	0.364	0.315	0.256	0.251
Number of firm_id	8	70	50	313	62
Hausman Test Result	RE	RE	RE	FE	FE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(No); 2(Yes); 3(In the district); 4(Otherwise). The variables missing in Model (44) are due to collinearity problems.*

Source: Field Survey, 2022

Appendix C4: FE-RE Models of Financial Performance of firms in the G/A Region, with different energy efficient technologies (Small-sized firms' sample)

VARIABLES	(49) With EE_Machinery	(50) With EE_AC	(51) With EE_Lighting	(52) With EE_Refrig
Grid power costs per unit of output	-6.119	-2.501	-1.420*	-2.819*
	(4.116)	(1.521)	(0.759)	(1.637)
Blackout hours per month	-0.016	-0.056***	-0.025*	-0.039*
	(0.026)	(0.020)	(0.014)	(0.021)
Generator power costs per unit of output	2.975	-1.780	1.898	4.473***
	(5.127)	(1.621)	(1.416)	(1.621)
Firms' total capital value	0.768**	0.097	0.432***	0.200
	(0.328)	(0.210)	(0.117)	(0.226)
Firm size	-0.102	0.874***	0.409**	0.851***
	(0.452)	(0.201)	(0.171)	(0.220)
Total monthly internet service expenditure	0.068	0.065	0.040	0.141***
	(0.208)	(0.057)	(0.029)	(0.042)
Firms' R&D expenditure	0.002	0.023	-0.008	0.026
	(0.016)	(0.016)	(0.013)	(0.018)
Presence of COVID-19[1]				
Yes	0.095	0.002	-0.035	-0.027
	(0.082)	(0.057)	(0.042)	(0.060)
Introduced new products[2]				
No	0.048	-0.268**	-0.026	-0.191*
	(0.121)	(0.112)	(0.075)	(0.112)
Firms' primary market[3]				
Outside the district	0.438*	0.250*	0.335**	0.264*
	(0.242)	(0.128)	(0.151)	(0.141)
Energy efficient AC systems	-	0.091	-	-
		(0.620)		
Energy efficient lighting systems	-	-	0.222	-
			(0.312)	
Energy efficient machinery	0.125	-	-	-
	(0.595)			
Energy efficient refrigeration	-	-	-	1.890*
				(0.955)
Constant	0.046	6.662*	2.185	-3.824
	(4.171)	(3.398)	(1.827)	(4.725)
Observations	49	92	238	96
R-squared	0.794	0.721	0.388	0.688
Number of firm_id	19	32	82	30
Hausman Test Result	RE	FE	RE	FE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(No); 2(Yes); 3(In the district). The model with all the EETs could not be estimated due to insufficient observations. The variables missing in Model (49) are due to collinearity problems.*

Source: Field Survey, 2022

Appendix C5: FE-RE Models of Financial Performance of firms in the G/A Region, with different energy efficient technologies (Medium-Large-sized firms' sample)

VARIABLES	(53) With EE_AC	(54) With EE_Lighting
Grid power costs per unit of output	-5.144	-0.033
	(2.297)	(1.521)
Blackout hours per month	-0.037	-0.043
	(0.031)	(0.040)
Generator power costs per unit of output	-4.170	10.355
	(8.710)	(6.815)
Firms' total capital value	-0.554	1.645**
	(0.830)	(0.599)
Firm size	-7.921	-0.227
	(3.744)	(0.867)
Total monthly internet service expenditure	0.138	0.031
	(0.138)	(0.234)
Firms' R&D expenditure	0.166	-1.001**
	(0.448)	(0.366)
Presence of COVID-19[1]		
Yes	0.059	-0.044
	(0.053)	(0.087)
Introduced new products[2]		
No	-0.057	-0.066
	(0.089)	(0.121)
Energy efficient lighting systems	-	0.558
		(0.580)
Constant	53.465	-14.164
	(25.305)	(7.713)
Observations	16	21
R-squared	0.989	0.974
Number of firm_id	4	6
Hausman Test Result	RE	FE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(Does not use generator); 2(No); 3(Yes); 4(In the district); 5(Otherwise)*

The model with all the EETs, with EE-machinery, and EE-refrigerator could not be estimated due to insufficient observations.

Source: Field Survey, 2022

Appendix C6: FE-RE Models of Environmental Performance of firms in the G/A Region, with different energy efficient technologies (Power crisis era sample: 2015-2017)

VARIABLES	(55) With EE_Machinery	(56) With EE_AC	(57) With EE_Lighting	(58) With EE_Refrig
Blackout hours per month	-0.006	-0.013	-0.003	-0.006
	(0.005)	(0.010)	(0.002)	(0.006)
Usage of generator at the firm[1]				
Uses generator	0.035	-0.099**	-0.030	0.040
	(0.046)	(0.048)	(0.019)	(0.052)
Firms' total capital value	0.001	-0.055	0.023	0.027
	(0.032)	(0.115)	(0.019)	(0.048)
Firm size	-0.101	0.064	-0.009	0.109
	(0.061)	(0.131)	(0.009)	(0.101)
Total monthly internet service expenditure	0.016	-0.003	0.006	-0.003
	(0.020)	(0.058)	(0.007)	(0.010)
Firms' R&D expenditure	0.005	0.014	-0.002	0.039
	(0.009)	(0.091)	(0.006)	(0.061)
Introduced new products[2]				
No	0.072**	-0.038	0.006	-0.003
	(0.029)	(0.047)	(0.014)	(0.043)
Firms' primary market[3]				
Outside the district	-	-	0.190***	0.393***
			(0.035)	(0.063)
Organizational structure of the firm[4]				
Sole proprietorship	-0.144***	-0.099	-0.041	-0.078
	(0.050)	(0.147)	(0.032)	(0.114)
Energy efficient AC system	-	0.296*	-	-
		(0.151)		
Energy efficient lighting system	-	-	0.001	-
			(0.011)	
Energy efficient machinery	0.174***	-	-	-
	(0.053)			
Energy efficient refrigerator system	-	-	-	-0.125
				(0.470)
Constant	-0.228	-0.245	-0.060	0.277
	(0.371)	(1.370)	(0.214)	(2.070)
Observations	137	138	712	156
R-squared	0.372	0.184	0.124	0.411
Number of firm_id	74	73	362	79
Hausman Test Result	FE	FE	FE	FE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(Does not use generator); 2(Yes); 3(In the district); 4(Otherwise)*

The model with all the EETs could not be estimated due to insufficient observations.

Source: Field Survey, 2022

Appendix C7: FE-RE Models of Environmental Performance of firms in the G/A Region, with different energy efficient technologies (Post-power crisis era sample: 2017-2021)

VARIABLES	(59) All EETs	(60) With EE_Machinery	(61) With EE_AC	(62) With EE_Lighting	(63) With EE_Refrig
Blackout hours per month	-0.086	-0.001	0.010	0.001	0.003
	(0.108)	(0.007)	(0.011)	(0.003)	(0.008)
Usage of generator at the firm[1]					
Uses generator	0.061	-0.037	0.005	-0.037	-0.068
	(0.260)	(0.037)	(0.051)	(0.024)	(0.054)
Firms' total capital value	-0.266	0.016	0.047	-0.008	0.042
	(0.331)	(0.026)	(0.048)	(0.014)	(0.052)
Firm size	-0.614	0.009	-0.037	-0.019	-0.003
	(0.524)	(0.045)	(0.065)	(0.019)	(0.050)
Total monthly internet service expenditure	0.350	0.007	0.027	0.020***	-0.001
	(0.395)	(0.022)	(0.049)	(0.005)	(0.024)
Firms' R&D expenditure	-0.211	0.004	0.008	0.005*	0.009*
	(0.111)	(0.006)	(0.005)	(0.003)	(0.005)
Presence of COVID-19[2]					
Yes	0.008	0.008	0.009	0.005	0.001
	(0.046)	(0.010)	(0.011)	(0.004)	(0.010)
Introduced new products[3]					
No	2.158	-0.009	0.030	0.032***	0.059
	(0.922)	(0.022)	(0.029)	(0.011)	(0.037)
Firms' primary market[4]					
Outside the district	2.037	-0.005	0.019	0.017	0.045
	(1.037)	(0.041)	(0.040)	(0.023)	(0.045)
Energy efficient AC system	-	-	-0.166	-	-
			(1.091)		
Energy efficient lighting system	-	-	-	-0.012	-
				(0.115)	
Energy efficient machinery	-	0.096***	-	-	-
		(0.017)			
Energy efficient refrigerator system	-	-	-	-	0.842
					(1.464)
Constant	2.618	-0.252	0.432	0.299	-3.847
	(3.333)	(0.297)	(4.823)	(0.556)	(6.379)
Observations	25	153	149	726	172
R-squared	0.966	0.501	0.162	0.089	0.182
Number of firm_id	13	77	76	364	87
Hausman Test Result	FE	FE	RE	FE	FE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(Does not use generator); 2(No); 3(Yes); 4(In the district)*

The variables missing in Model (59) are due to collinearity problems.

Source: Field Survey, 2022

Appendix C8: FE-RE Models of Environmental Performance of firms in the G/A Region, with different energy efficient technologies (Micro-sized firms' sample)

VARIABLES	(64) All EETs	(65) With EE_Machinery	(66) With EE_AC	(67) With EE_Lighting	(68) With EE_Refrig
Blackout hours per month	-0.018	-0.006	-0.008	-0.003*	-0.005
	(0.037)	(0.004)	(0.006)	(0.002)	(0.005)
Usage of generator at the firm[1]					
Uses generator	-0.059	-0.028	-0.103***	-0.031**	-0.037
	(0.096)	(0.022)	(0.029)	(0.012)	(0.028)
Firms' total capital value	-0.002	0.054**	0.023	0.011	0.052
	(0.202)	(0.022)	(0.039)	(0.009)	(0.033)
Firm size	0.349	0.029	0.056	0.020	0.091
	(0.454)	(0.042)	(0.081)	(0.017)	(0.060)
Total monthly internet service expenditure	0.040	-0.004	0.003	0.013***	0.005
	(0.234)	(0.010)	(0.036)	(0.004)	(0.012)
Firms' R&D expenditure	-0.149	-0.025**	0.055***	0.009***	0.028***
	(0.248)	(0.011)	(0.012)	(0.003)	(0.010)
Presence of COVID-19[2]					
Yes	0.038	0.013	0.001	0.006	0.008
	(0.103)	(0.013)	(0.018)	(0.005)	(0.016)
Introduced new products[3]					
No	-0.053	0.024	0.000	0.023**	0.011
	(0.144)	(0.020)	(0.031)	(0.009)	(0.034)
Firms' primary market[4]					
Outside the district	-	-0.056	0.147***	0.091***	0.330***
		(0.047)	(0.052)	(0.020)	(0.059)
Organizational structure of the firm[5]					
Sole proprietorship	-	-0.133**	-0.054	-0.047*	-0.057
		(0.057)	(0.119)	(0.024)	(0.124)
Energy efficient AC system	-	-	-0.040	-	-
			(0.406)		
Energy efficient lighting system	-0.238	-	-	-0.004	-
	(0.289)			(0.009)	
Energy efficient machinery	0.367	0.156***	-	-	-
	(0.430)	(0.024)			
Energy efficient refrigerator system	-	-	-	-	0.038
					(0.119)
Constant	0.324	-0.678***	0.127	0.042	-0.495
	(1.946)	(0.237)	(1.803)	(0.106)	(0.615)
Observations	24	241	171	1,171	212
R-squared	0.829	0.408	0.412	0.111	0.351
Number of firm_id	8	70	51	315	62
Hausman Test Result	RE	FE	RE	FE	RE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(Does not use generator); 2(No); 3(Yes); 4(In the district); 5(Otherwise)*

The variables missing in Model (64) are due to collinearity problems.

Source: Field Survey, 2022

Appendix C9: FE-RE Models of Environmental Performance of firms in the G/A Region, with different energy efficient technologies (Small-sized firms' sample)

VARIABLES	(69) All EETs	(70) With EE_Machinery	(71) With EE_AC	(72) With EE_Lighting	(73) With EE_Refrig
Blackout hours per month	0.024	-0.007	-0.007*	-0.003**	-0.005
	(0.181)	(0.005)	(0.004)	(0.001)	(0.003)
Usage of generator at the firm[1]					
Uses generator	-	0.044	0.011	0.007	0.004
		(0.053)	(0.028)	(0.012)	(0.038)
Firms' total capital value	0.334	0.050	0.022	0.012	0.030
	(2.362)	(0.059)	(0.036)	(0.011)	(0.032)
Firm size	0.548	0.157*	-0.018	-0.010	-0.023
	(0.325)	(0.087)	(0.039)	(0.018)	(0.035)
Total monthly internet service expenditure	0.225	0.039	0.002	0.001	0.006
	(0.740)	(0.037)	(0.011)	(0.003)	(0.008)
Firms' R&D expenditure	0.375	0.002	-0.002	-0.001	0.001
	(1.225)	(0.003)	(0.003)	(0.001)	(0.003)
Presence of COVID-19[2]					
Yes	-0.085	-0.021	0.003	0.003	0.000
	(0.237)	(0.015)	(0.010)	(0.004)	(0.009)
Introduced new products[3]					
No	-3.523	0.002	0.012	0.005	0.019
	(11.093)	(0.024)	(0.022)	(0.008)	(0.018)
Firms' primary market[4]					
Outside the district	-0.486	-0.089*	-0.008	-0.004	-0.004
	(2.512)	(0.046)	(0.025)	(0.016)	(0.023)
Energy efficient AC system	-	-	0.130	-	-
			(0.120)		
Energy efficient lighting system	-9.498	-	-	0.011	-
	(27.237)			(0.032)	
Energy efficient machinery	-1.279	-0.185	-	-	-
	(9.088)	(0.118)			
Energy efficient refrigerator system	-	-	-	-	0.174
					(0.150)
Constant	44.222	0.059	-0.455	0.043	-0.857
	(136.280)	(0.792)	(0.635)	(0.182)	(0.682)
Observations	19	49	100	246	104
R-squared	0.867	0.441	0.173	0.088	0.186
Number of firm_id	7	19	34	84	32
Hausman Test Result	RE	RE	RE	RE	FE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Ref. category: 1(Does not use generator); 2(No); 3(Yes); 4(In the district)*

The variables missing in Model (55) are due to collinearity problems.

Source: Field Survey, 2022

Appendix C10: FE-RE Models of Environmental Performance of firms in the G/A Region, with different energy efficient technologies (Medium-Large-sized firms' sample)

VARIABLES	(74) With EE_AC	(75) With EE_Lighting	(76) With EE_Refrig
Blackout hours per month	-0.019	-0.018	-0.028
	(0.037)	(0.028)	(0.058)
Firms' total capital value	0.068	0.170	-14.182
	(0.239)	(0.275)	(20.343)
Firm size	0.677	-0.075	-
	(2.547)	(0.470)	
Total monthly internet service expenditure	-0.042	-0.121	0.979
	(0.167)	(0.169)	(1.483)
Firms' R&D expenditure	-0.063	-0.140	12.542
	(0.250)	(0.240)	(18.015)
Presence of COVID-19[1]			
Yes	-0.044	-0.061	-0.109
	(0.064)	(0.064)	(0.132)
Introduced new products[2]			
No	0.030	0.036	1.515
	(0.108)	(0.090)	(2.128)
Energy efficient AC system	-	-	-
Energy efficient lighting system	-	0.251	-
		(0.427)	
Energy efficient refrigerator system	-	-	-22.181
			(31.803)
Constant	-3.069	-1.933	271.077
	(13.416)	(4.269)	(387.345)
Observations	16	21	12
R-squared	0.108	0.135	0.284
Number of firm_id	4	6	3
Hausman Test Result	RE	RE	RE

*NB: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1   Ref. category: 2(No); 3(Yes)*

The model with all the EETs and with EE-machinery could not be estimated due to insufficient observations.

Source: Field Survey, 2022

APPENDIX D

SURVEY INSTRUMENTS

Appendix D1: Quantitative Survey Questionnaire

Targeted Research Sample Units:

The sampling unit is firms or businesses in the Greater Accra Region. The study targets adult (18+ years) and knowledgeable representatives from the sampled firms. Specifically, the research senior officers and those in managerial positions who have sufficient knowledge about the operations of the business and who are part of the key decision makers of the firm.

The research also targets businesses that use at least one form/type of energy for their productive activities to assess how these energy types might affect the general performance of the business.

Finally, the research intends to investigate the energy investment decisions taken during the last severe power crises (2012-2016) hence the study will carry out some recalls of performance, cost, and other productive indicators from 2015. Therefore, only firms that have been in existence before or established in 2015 will be sampled for the study.

Screener Questions:

1. Does the firm use any form of energy in its productive activities?

[A] Yes [B] No

2. Is the firm representative/respondent part of the decision makers of the firm?

[A] Yes [B] No

3. Has the firm been in existence by 2015 or before?

[A] Yes [B] No

NAVIGATION

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SECTION A: IDENTIFICATION INFORMATION

Please, I will begin by taking some little information about you (the respondent). As I mentioned earlier, this is just to build a profile of my respondents and not for any other purpose.

No.	**Question**	**Responses**
1	Enumerator ID	1. 2. 3.
2	Respondent ID	
	Gender of respondent	1. Male 2. Female
3	What is your position/designation in this firm?	1. CEO / Co-CEO 2. Executive member (Managers/Directors) 3. Senior Officer (Finance/Budget/IT/ Tech/Procurement/HR/Estate/ etc.)
4	Age category of the respondent (firm representative)	1. 18-35 2. 36-60 3. Above 60
5	Highest educational level attained by the respondent	1. No formal education 2. Basic (primary) 3. JSS/JHS/Middle School 4. Secondary 5. Tertiary 6. Vocational

SECTION B: BUSINESS CLASSIFICATIONS

At this point, I would like to ask you about some key characteristics of the business.

No.	Question	Response
1	Year of establishment of the firm	
2	Location of the firm (Municipality)	1. AMA 2. TMA 3. Ga South
3	Ownership of the firm/business as of 2015, 2017, 2019, and 2021	1. State-owned 2. Private 3. Private-Public Partnership
4	What was the legal structure of the firm as of 2015, 2017, 2019, and 2021?	1. Sole proprietorship 2. Partnership 3. Corporation
5	Sector of the firm	1. Industry 2. Service
6	What is the primary industrial activity of this business?	1. Mining & quarrying 2. Processing and preserving of agric. products 3. Manufacture of packaged food and beverage products 4. Manufacture or repair of clothing products (e.g., tailor, sewing, seamstress, tanner) 5. Manufacture or repair of footwear (e.g., shoemaker, cobbler, shoe shiner) 6. Manufacture of wood products (carpentry) 7. Manufacture of rubber or plastic products 8. Manufacture or repair of metal or glass products (e.g., welding, metal work, glass work) 9. Manufacture or repair of electronic goods and household appliances 10. Manufacture or repair of electric machines, parts, and accessories 11. Manufacture or repair of furniture 12. Other manufacturing activities 13. Supply of electricity, gas, steam, and air conditioning 14. Water supply, sewerage, and waste management services 15. General construction activities 16. Plumbing and electricity services 17. Wholesale of agricultural raw materials (i.e., in bulk) 18. Wholesale of processed/packaged foods and beverages (i.e., in bulk) 19. Wholesale of household goods (i.e., in bulk) 20. Wholesale of machinery, tools, and equipment (i.e., in bulk) 21. Other wholesale activities (i.e., in bulk)

		22. Sale and repair of motor vehicles, parts, and fuel 23. Retail sale in non-specialized shop (general groceries: packaged foods or drinks, toiletries, etc.) 24. Specialized retail sale of electronics items 25. Specialized retail sale of household goods and equipment 26. Specialized retail sale of recreational and cultural goods (e.g., toys, athletic equipment, books, music, etc.) 27. Specialized retail sale of unprocessed meat or fish products 28. Specialized retail sale of unprocessed agricultural produce (vegetables, fruits, and grains) 29. Specialized retail sale of processed and unprocessed food items (general foods) 30. Specialized retail sale of water and beverages 31. Specialized retail sale of clothing items 32. Specialized retail sale of energy items (e.g., kerosene, charcoal, gas, wood, etc.) 33. Specialized retail of medical goods (e.g., pharmacy) 34. Transportation and storage services 35. Accommodation services (e.g., hotel) 36. Food services: restaurant/café with seats/catering 37. Food services: take-away/ready to eat 38. Beverage serving activities (e.g., bar) 39. Information and communication services (e.g., computers, newspapers, video, radio, television, telecommunications, data management, etc.) 40. Personal care services (e.g., barber, hairdresser, beautician, massage, etc.) 41. Financial and insurance activities (e.g., banks, insurance, mobile money, etc.) 42. Real estate activities 43. Legal activities 44. Accounting, bookkeeping, and auditing activities 45. Photographic activities 46. Other professional, scientific, and technical activities 47. Computing service activities (printing, copying, internet, stationary shop, make CDs, etc.) 48. Administrative and support service activities 49. Cleaning activities (e.g., house cleaning, laundry, clothes washing, street sweeping, etc.) 50. Medical activities (e.g., hospital, doctor, dentist, veterinarian, nurse, etc.) 51. Education 52. Religious establishment or provision of religious goods and services 53. Other human health and social work activities 54. Creative, arts, cultural, and entertainment activities 55. Gambling and betting activities 56. Sports, fitness, and recreation activities 57. Other service activities
7	Is the business involved in any other significant secondary activity?	1. Yes 2. No
8	State the secondary (significant) activity	Choose from the list above

9	Was the business formally registered as of 2015, 2017, 2019, 2021? (Having a TIN and/or business license)	1. Yes 2. No			
		2015	**2017**	**2019**	**2021**
10	Where did the business market and sell its products or services as of …?	1. The district 2. The G/A Region 3. Beyond the G/A but not all the regions 4. The entire country 5. Beyond Ghana to Africa 6. Beyond Ghana to the international market	1. The district 2. The G/A Region 3. Beyond the G/A but not all the regions 4. The entire country 5. Beyond Ghana to Africa 6. Beyond Ghana to the international market	1. The district 2. The G/A Region 3. Beyond the G/A but not all the regions 4. The entire country 5. Beyond Ghana to Africa 6. Beyond Ghana to the international market	1. The district 2. The G/A Region 3. Beyond the G/A but not all the regions 4. The entire country 5. Beyond Ghana to Africa 6. Beyond Ghana to the international market
11	How much share (in terms of %) did your product/brand hold in the district market?				
12	How much share (in terms of %) did your product/brand hold in the G/A Region market?				
13	How much share (in terms of %) did your product/brand hold in the entire country?				
14	How much share (in terms of %) did your product/brand hold in the African market?				
15	How much share (in terms of %) did your product/brand hold in the international market?				

SECTION C: CAPITAL ASSETS OF THE BUSINESS

With your best recollection supported by your records, I will like you to give me some information about the assets owned or rented by this business as of 2015, 2017, 2019, and 2021

No.	**Question**	**Response**			
		2015	**2017**	**2019**	**2021**
1	How much will you value the total land space owned/rented by the company in…? (GHS)				
2	How many auto vehicles were owned by the business in …				
3	What was the estimated value of the fleet of vehicles the firm owned in …(if applicable)? (GHS)				
4	ow many building structures consisting of administrative blocks, operation blocks, warehouses etc. did the business own/rent in …?				
5	In your view, what was the total estimated value of ALL the building structures (administration blocks, operation blocks, warehouses, etc.) owned or the rent value if rented…?				
6	What was the estimated total value of the production equipment units as of…?				
7	What was the estimated total value of the firm's closing stock (raw materials, products-in-process, and finished goods) as of?				
8	What was the estimated total value of all TV sets as of				
9	What was the est. total value of all the refrigerators as of				
10	What was the estimated total value of all the electric fans as of				
11	What was the estimated total value of all AC units as of				
12	What was the estimated total value of all ovens owned by the firm as of				
13	What is the estimated total value of all the stoves owned by the firm as of				
14	What is the estimated total value of all washing machines owned by the firm as of				

15	What is the estimated total value of all the sets of kitchen equipment owned by the firm in ..?				
16	What is the estimated total value of all other capital assets owned by the firm in ..?				

SECTION D: LABOUR RESOURCES OF THE BUSINESS

Again, with your best recollection coupled with your records, I will like to take some information about the employees or staff of this business as of 2015, 2017, 2019, and 2021.

No.	**Question**	**Response**			
		2015	**2017**	**2019**	**2021**
1	How many staff did the firm engage as of …?				
2	How many male staff did you engage as of …?				
3	In your opinion, what percentage of the staff will you regard as highly skilled? (%)				
4	In your opinion, what percentage of the staff will you regard as highly experienced (worked 5 years plus)? (%)				
5	Did you offer training opportunities for your staffs in?	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No
6	In total, how much did the business spend in training staffs as of?				

SECTION E: TECHNOLOGICAL INCLINATION OF THE BUSINESS

To assess the technological inclination of this business, I will like you to give me some information concerning I.T and other technologies the business has used for its productive activities as of 2015, 2017, 2019, and 2021.

No.	**Question**	**Response**			
		2015	**2017**	**2019**	**2021**
1	Did the business have a department/office/desk dedicated to I.T activities as of	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No
2	Did the business have officer(s) solely in charge of IT issues?	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No
3	What percentage of the firm's productive activities depended on computer systems as of …?				
4	What percentage of the firm's productive activities depended on the internet as of? (%)				
5	How much did the business spend on internet services monthly on average in? (GHS)				
6	Did the business use electronic transaction systems in its operations?	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No

SECTION F: RESEARCH & DEVELOPMENT ANGLE OF THE BUSINESS

Now I will like you to give me some information regarding the research and development(R&D) activities that the business has engaged in as of 2015, 2017, 2019, and 2021

No.	**Question**	**Response**			
		2015	**2017**	**2019**	**2021**
1	Did the business engage in any R&D activity in …?	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No

2	If yes, in what areas did the business research into and developed as of?	1. New markets 2. Demand & Supply 3. Pricing 4. New Products/ Services 5. Processes 6. Supply chain 7. New tech/IT 8. Other	1. New markets 2. Demand & Supply 3. Pricing 4. New Products/ Services 5. Processes 6. Supply chain 7. New tech/IT 8. Other	1. New markets 2. Demand & Supply 3. Pricing 4. New Products/ Services 5. Processes 6. Supply chain 7. New tech/IT 8. Other	1. New markets 2. Demand & Supply 3. Pricing 4. New Products/ Services 5. Processes 6. Supply chain 7. New tech/IT 8. Other
3	How much did the business actually spend on R&D in ….?				
4	Did the business introduce any new products or services in …?	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No
5	Did the business invest in new production processes in …?	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No
6	Did the business undertake any organizational changes in ….?	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No

SECTION G: ENERGY LANDSCAPE OF THE BUSINESS

Now to the core objective of the research, energy. It will only take a little while. With your best recollection supported by your records, can you please take me through the energy landscape of this business as of 2015, 2017, 2019 and 2021 in respect of certain indicators.

No.	**Question**	**Response**
2015 (This will be replicated for 2017, 2019, and 2021)		
1	Which of the following energy sources did the business use in 2015?	1.Dry cell batteries 2. Car or other rechargeable batteries 3. Gas/LPG 4. Kerosene 5. Biogas 6. Charcoal

		7. Firewood/Crop residue 8. Diesel/Petrol (for other machine operations, not generators) 9. Electricity (national grid) 10. Electricity (self-generation) 11. Electricity (renewables)
2	What did the business use the [Dry cell batteries] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
3	Why did the business choose to invest in [Dry cell batteries]?	1.It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 5. Forced by policy instrument
4	How much did you spend averagely on [Dry cell batteries] in a month?	
5	What equivalent units of [Dry cell batteries] did the business use in a month?	
6	How available/accessible was [Dry cell batteries] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4. Mostly unavailable/scarce
7	What was the quality of the energy from [Dry cell batteries] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
8	What did you use the [Car or other rechargeable batteries] for?	4. Lighting 5. Cooking and/or boiling water 6. Space cooling or heating 7. Operating equipment

3	Why did the business choose to invest in [Car or other rechargeable batteries]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
9	How much did you spend averagely on [Car or other rechargeable batteries] in a month?	
10	How available/accessible was [Car or other rechargeable batteries] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce
	What was the quality of the energy from [Car or other rechargeable batteries] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
10	What did you use the [Gas/LPG] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
3	Why did the business choose to invest in [Gas/LPG]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable

		9. Encouraged by policy instrument 10. Forced by policy instrument
11	How much did you spend averagely on [Gas/LPG] in a month?	
12	What equivalent kg quantity of [Gas/LPG] did the business use in a month?	
13	How available/accessible was [Gas/LPG] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce
14	What was the quality of the energy from [Gas/LPG] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
15	What did you use the [Kerosene] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
3	Why did the business choose to invest in [Kerosene]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
16	How much did you spend averagely on [Kerosene] in a month?	
17	What equivalent liter quantity of [Kerosene] did the business use in a month?	

18	How available/accessible was [Kerosene] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce
19	What was the quality of the energy from [Kerosene] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
20	What did you use the [Biogas] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
3	Why did the business choose to invest in [Biogas]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
21	How much did you spend averagely on [Biogas] in a month?	
22	What equivalent kg quantity of [Biogas] did the business use in a month?	
23	How available/accessible was [Biogas] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce

24	What was the quality of the energy from [Biogas] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
25	What did you use the [Charcoal] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
3	Why did the business choose to invest in [Charcoal]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
26	How much did you spend averagely on [Charcoal] in a month?	
27	What equivalent kg quantity of [Charcoal] did the business use in a month?	
28	How available/accessible was [Charcoal] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce
29	What was the quality of the energy from [Charcoal] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
30	What did you use the [Firewood/crop residue] for?	1. Lighting 2. Cooking and/or boiling water

		3. Space cooling or heating 4. Operating equipment
3	Why did the business choose to invest in [Firewood/crop residue]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
31	How much did you spend averagely on [Firewood/crop residue] in a month?	
32	What equivalent kg quantity of [Firewood/crop residue] did the business use in a month?	
33	How available/accessible was [Firewood/crop residue] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce
34	What was the quality of the energy from [Firewood/crop residue] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
35	What did you use the [Diesel/Petrol] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
3	Why did the business choose to invest in [Firewood/crop residue]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available

		5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
36	How much did you spend averagely on [Diesel/Petrol] in a month?	
37	How many equivalent units of [Diesel/Petrol] did the business use in a month?	
38	How available/accessible was [Diesel/Petrol] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce
39	What was the quality of the energy from [Diesel/Petrol] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
40	What did you use the [Electricity-national grid] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
41	Why did the business choose to invest in [Electricity-national grid]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument

42	How much did you spend averagely on [Electricity-national grid] in a month? (Installations, maintenance, bills)	
43	How many hours per week did you use the Electricity-national grid]?	
44	Is your electricity connectivity through pre-paid, post-paid, or directly from the grid	1. Pre-paid 2. Post-paid 1. Directly from grid
45	Did you use multiple phase system from electricity connectivity from the grid?	1. Yes 1. No
46	How often did you switch phases typically in 2015?	1. Never 2. Almost everyday 3. A few times per week 4. Once per week / several times per month 5. Once a month or less 1. Only a few times per year
47	Why did you have to switch phases?	1. Outage happened 2. Voltage fluctuation 3. During certain times of the day 1. It is cheaper
48	How much did you spend to install the multi-phase system?	
49	Within a typical week in 2015, did you experience power outage at least 1 minute?	1. Yes 1. No
50	Within a typical week in 2015, how many different times did you experience power outage?	
51	On average, how long was the power usually out?	
52	Unit	1. Minute 2. Hour 3. Days 4. Week 1. Month
53	what was the longest single outage you experienced in 2015?	

	Unit	1. Minute 2. Hour 3. Days 4. Week 1. Month
55	Of all the outages that happened in 2015, for what PERCENTAGE were you notified in advance that it was going to happen, for example through a newspaper or radio or social media announcement?	
56	Within a typical week in 2015, did you experience voltage fluctuation at least 1 minute?	1. Yes 1. No
57	Within a typical week in 2015, how many different times did you experience voltage fluctuation?	
58	On average, how long was the voltage fluctuation?	
59	Unit	1. Minute 2. Hour 3. Days 4. Week 1. Month
60	Thinking back to 2015, what was the longest single voltage fluctuation you experienced?	
61	Unit	1. Minute 2. Hour 3. Days 4. Week 1. Month
62	What aspect of the national grid-electricity provision is an obstacle to the operations of the business in 2015?	1. High cost of electricity 2. Unpredictability of costs 3. Hours of outages 4. Unpredictability of outages 5. Frequency of outages 6. Voltage fluctuations 1. Other …………………..

63	How did you deal with the high or unpredictability of the cost of electricity from the national grid as of 2015?	1.Manually regulated power usage 2. Invested in alternative cheaper power source 3. Invested in energy efficiency technologies 4. Temporarily stopped using power from national grid 5. Carried out electrical engineering work to check consumption 1. Did nothing
64	Which cheaper alternatives power sources did you invest in?	1. Generators 2. Mini-grid 3. RET – Solar 4. RET – Wind 1. RET – Biogas
65	How did you deal with power outages and/or voltage fluctuations in 2015?	1. Temporarily switched to using power from alternative energy sources and continue working as before 2. Temporarily switched to power from alternative energy source but reduce amount of work or change employees' assignments 3. Stopped working until power returned, and work less on that day 4. Postponed working until the electricity returned, and work the same amount on the day 5. Temporarily switched to using different tools, machine, or labour 6. Temporarily switched to working on different business activities that did not require electricity 7. Continue working while the electricity was out, but with fewer people working 8. Moved to a new location 9. Permanently changed business operations to use tools or machines that do not require electricity 10. Permanently changed business operations to use more labor instead of electric appliances 1. Permanently shifted to a different type of business that depends less on electricity
66	If you temporarily or permanently switched to an alternative energy source due to power outages/voltage fluctuations, which sources did you switch to?	1.Generators 2. Mini-grid 3. RET – Solar 4. RET – Wind 5. RET – Biogas
67	What did you use the [Mini-grid electricity] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating

		4. Operating equipment
68	Why did the business choose to invest in [Mini-grid electricity]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
69	How much did you spend averagely on [Mini-grid electricity] in a month? (Installations, maintenance, bills)	
70	How many hours per week did you use the [Mini-grid electricity]?	
71	What aspect of the Mini-grid electricity provision is an obstacle to the operations of the business in 2015?	1. High cost of electricity 2. Unpredictability of costs 3. Hours of outages 4. Unpredictability of outages 5. Frequency of outages 6. Voltage fluctuations 7. Other …………………..
72	How did you deal with the high cost of electricity from the Mini-grid as of 2015?	1. Manually regulated power usage 2. Invested in alternative cheaper power source 3. Invested in energy efficiency technologies 4. Temporarily stopped using power from mini grid 5. Carried out electrical engineering work to check consumption 6. Did nothing
73	Which cheaper alternatives power sources did you invest in?	1. Generators 2. Mini-grid 3. RET – Solar 4. RET – Wind 1. RET – Biogas

74	Availability and accessibility of the [Mini-grid electricity] when it is needed to be used by the firm for production	1. Available (abundance supply) and accessible (easy to find in market) 2. Available and inaccessible 3. Accessible yet unavailable 4. Unavailable and Inaccessible
75	What did you use the [Self-generated electricity] for?	1. Lighting 2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
76	Why did the business choose to invest in an alternative [Self-generated electricity]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
77	What is the size of the generator (kW or kVa)?	
78	Unit	1. kW 2. kVa
79	How much did you spend averagely on [Self-generated electricity] in a month? (Installations, maintenance, fuels purchase)	
80	What equivalent kWh quantity of [Self-generated electricity] did the business use in a month?	1.
81	How frequently was your generator turned on in 2015?	1. Never 2. Almost every day 3. A few times per week 4. Once per week/several times per month 5. Once per month or less

		6. Only a few times per years
82	How many hours per week did you use the [Self-generated electricity]?	
83	What aspect of the [Self-generated electricity] provision is an obstacle to the operations of the business in 2015?	1. High cost of electricity 2. Unpredictability of costs 3. Hours of outages 4. Unpredictability of outages 5. Frequency of outages 6. Voltage fluctuations 7. Other …………………..
84	How did you deal with the high cost of electricity from the self-generators as of 2015?	1.Manually regulated power usage 2. Invested in alternative cheaper power source 3. Invested in energy efficiency technologies 4. Temporarily stopped using power from generators 5. Carried out electrical engineering work to check consumption 6. Did nothing
85	Which cheaper alternatives power sources did you invest in?	1. National-grid 2. Generators 3. Mini-grid 4. RET – Solar 5. RET – Wind 6. RET – Biogas
	How available/accessible was [Self-generated electricity] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce
86	What was the quality of the energy from [Self-generated electricity] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality
87	What did you use the [RET-electricity] for?	1. Lighting

		2. Cooking and/or boiling water 3. Space cooling or heating 4. Operating equipment
88	Why did the business choose to invest in an alternative [RET-electricity]?	1. It is a cheaper source 2. It is environmentally friendly 3. It is easily accessible 4. It is readily available 5. It is my main electricity source 6. It is used as complementary to the main electricity source 7. It is used as a back-up to the main electricity source 8. Because the main source is so unreliable 9. Encouraged by policy instrument 10. Forced by policy instrument
89	How much did you spend averagely on [RET-electricity] in a month? (Installations, maintenance)	
90	What equivalent kWh quantity of [RET-electricity] did the business use in a month?	
91	How many hours per week did you use the [RET-electricity]?	
92	What aspect of the [RET-electricity] provision is an obstacle to the operations of the business in 2015?	1. High cost of electricity 2. Unpredictability of costs 3. Hours of outages 4. Unpredictability of outages 5. Frequency of outages 6. Voltage fluctuations Other …………………..
93	How did you deal with the high cost of electricity from RETs as of 2015?	1.Manually regulated power usage 2. Invested in alternative cheaper power source 3. Invested in energy efficiency technologies 4. Temporarily stopped using power from RETs 5. Carried out electrical engineering work to check consumption Did nothing
94	Which cheaper alternatives power sources did you invest in?	1.National-grid

		2. Generators 3. Mini-grid 4. RET – Solar 5. RET – Wind 6. RET – Biogas
	How available/accessible was [RET-electricity] when it was needed to be used by the firm for production or rendering services in 2015?	1. Highly available 2. Available 3. Somehow available 4, Mostly unavailable/scarce
95	What was the quality of the energy from [RET-electricity] when it was needed to be used by the firm for production or rendering services in 2015?	1. High quality 2. Medium quality 3. Poor quality

No.	**Energy efficiency questions**	**Response**			
		2015	**2017**	**2019**	**2021**
96	Did the business use energy efficient technologies (EETs) in any of the following areas of the business as of?	1. Lighting 2. Machinery 3. Refrigeration 4. Air-conditioning 5. None	1. Lighting 2. Machinery 3. Refrigeration 4. Air-conditioning 5. None	1. Lighting 2. Machinery 3. Refrigeration 4. Air-conditioning 5. None	1. Lighting 2. Machinery 3. Refrigeration 4. Air-conditioning 5. None
97	What percentage of the lighting system of the firm uses energy efficiency technologies (LEDs and Fluorescent bulbs) as of?				
98	What percentage of the machinery system of the firm used energy efficient technologies as of?				

99	What percentage of the refrigeration system of the firm used energy efficient technologies (EC label and stared fridges) as of?				
100	What percentage of the air-conditioning system of the firm used energy efficient technologies ((EC label and stared ACs) as of?				

SECTION H: FIRM PERFORMANCE INDICATORS OF THE BUSINESS

We are at the final section please. Just a few more questions and we are done please. Thank you for your time, patience, and support. I will now take some information on the financial and environmental performances of this business in 2015, 2017, 2019, and 2021

No.	**Question**	**Response**			
		2015	**2017**	**2019**	**2021**
1	What was the average monthly total revenue for this business? (Revenue is the total amount of money the business earned by selling or providing goods and/or services)				
2	What was the average monthly total cost (rent, raw materials, water, energy, fuel, transportation, communication, wages/salaries, maintenance) of this business in …..?				
	How much did the business pay as taxes/levies on average in a typical month in …?				
3	How do you rate the average monthly performance of your sales in …. over the previous year	1. Increased sales 2. Decreased sales 3. No change	1. Increased sales 2. Decreased sales 3. No change	1. Increased sales 2. Decreased sales 3. No change	1. Increased sales 2. Decreased sales 3. No change
4	What was responsible for the observed increased in the business' monthly sales in?	1. Increased production 2. Increased sales 3. Low costs of raw materials	1. Increased production 2. Increased sales 3. Low costs of raw materials	1. Increased production 2. Increased sales 3. Low costs of raw materials	1. Increased production 2. Increased sales 3. Low costs of raw materials

		4. Expansion of the business (locally) 5. Expansion of the business (internationally) 6. New markets (locally) 7. New markets (internationally) 8. Increased labour 9. New technologies 10. Increased capital assets 11. Access to loan facilities 12. Low interest rates for loans 13. Other	4. Expansion of the business (locally) 5. Expansion of the business (internationally) 6. New markets (locally) 7. New markets (internationally) 8. Increased labour 9. New technologies 10. Increased capital assets 11. Access to loan facilities 12. Low interest rates for loans 13. Other	4. Expansion of the business (locally) 5. Expansion of the business (internationally) 6. New markets (locally) 7. New markets (internationally) 8. Increased labour 9. New technologies 10. Increased capital assets 11. Access to loan facilities 12. Low interest rates for loans 13. Other	4. Expansion of the business (locally) 5. Expansion of the business (internationally) 6. New markets (locally) 7. New markets (internationally) 8. Increased labour 9. New technologies 10. Increased capital assets 11. Access to loan facilities 12. Low interest rates for loans 13. Other
5	What was responsible for the observed decreased in the business' monthly sales?	1. Lay offs 2. Decreased production 3. Deceases sales 4. COVID-19 5. Inability to secure loans 6. High interest rates on loan facilities 7. High exchange rates 8. High cost of raw materials 9. High energy cost 10. Reduced markets (locally) 11. Reduced markets (internationally) 12. Lack of business growth Other	1. Lay offs 2. Decreased production 3. Deceases sales 4. COVID-19 5. Inability to secure loans 6. High interest rates on loan facilities 7. High exchange rates 8. High cost of raw materials 9. High energy cost 10. Reduced markets (locally) 11. Reduced markets (internationally) 12. Lack of business growth Other	1. Lay offs 2. Decreased production 3. Deceases sales 4. COVID-19 5. Inability to secure loans 6. High interest rates on loan facilities 7. High exchange rates 8. High cost of raw materials 9. High energy cost 10. Reduced markets (locally) 11. Reduced markets (internationally) 12. Lack of business growth Other	1. Lay offs 2. Decreased production 3. Deceases sales 4. COVID-19 5. Inability to secure loans 6. High interest rates on loan facilities 7. High exchange rates 8. High cost of raw materials 9. High energy cost 10. Reduced markets (locally) 11. Reduced markets (internationally) 12. Lack of business growth Other

6	Did the company have any of the following environmental policies as of …? 1. Energy efficiency plans 2. Recycling/use of recycled materials 3. Reuse of materials 4. Reducing quantity of materials 5. Degradable packaging materials 6. Eco-friendly products 7. Controlled pollution from the production process 8. Renewable energy mix 9. Waste water treatment 10. Sustainable solid and e-waste management 11. Less paper, more electronic operation system 12. None	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No
7	What percentage of your production process in … will you say depended on energy efficiency technologies?				
8	What percentage of your total materials are recycled or recycled materials used in your production process as of ….?				
9	What percentage of your materials did you reuse in your production process as of … ?				
10	How much (in percentage) have you cut down on material usage as of ….. ?				
11	What percentage of your products and packaging materials are eco-friendly as of …. ?				
12	What percentage of your energy are sourced from renewable energy technologies as of …. ?				

13	What percentage of your waste (liquid/solid/e-waste) are treated/sustainably managed as of 2015				
14	Contact no.				

END OF THE SURVEY. I WILL LIKE TO THANK YOU AND YOUR ORGANIZATION FOR YOUR TIME AND SUPPORT.

Appendix D2: In-Depth Interview (IDI) Guide (for selected business representatives)

Purpose and assurance of confidentiality

You have already been visited by an enumerator who collected information on your business, its characteristics, investments, energy usage, and performances. The purpose of meeting you again is to gain a deeper understanding regarding the energy systems you use, the underlying reasons for using them, why alternative systems are overlooked among others. This is purely for academic purposes, and I assure you of full confidentiality regarding your participation in this survey.

Consent

In order not to lose out on key responses that will be coming from you, I will ask permission to record the interview which will be transcribed later from an audio to a text data. do I have your consent to continue?

i. Yes *ii. No >> Thank the participant and go on to identify the next participant*

Questions

Profile

1. Could you please tell me a little bit about your business in terms of its history, locations, products/services, and the general health of your business?
2. What position do you hold in the business and what are your key roles?

Focus

1. During the 2012-2016 power crises, which productive energy (fuel) did your business invest in or use?
    a. Why did the business choose these fuels?
    b. How did these fuels enhance the productivity of the business during the crisis period?
    c. How did these fuels adversely affect the productivity of the business during the crisis period?
    d. Why did the business not invest in other alternatives like renewables? How would these alternatives have made any difference in terms of the productivity of the business?
2. Which productive energy (fuel) did your business invest in, or use in the post-crisis era?
    a. Why did the business choose these fuels?
    b. How did these fuels enhance the productivity of the business during the crisis period?
    c. How did these fuels adversely affect the productivity of the business during the crisis period?
    d. Why did the business not invest in other alternatives like renewables? How would these alternatives have made any difference in terms of the productivity of the business?
3. Which energy efficiency technologies (EETs) did you use in the power crisis and post-crisis periods?
    a. Why did you choose to invest in these EETs?
    b. How has energy efficiency technologies affected the cost and general productivity of the business during the power crisis and post-crisis periods?

Appendix D3: Key Informant Interview (KII) Guide (for policy makers)

Purpose and assurance of confidentiality

I am a PhD candidate at ISSER, University of Ghana studying "Firms' decisions on energy systems utilization and their implications on performance from 2015 to 2021". The purpose of this meeting is to gain deeper understanding of why firms invest in, and use certain energy systems at the expense of other systems. This is purely for academic purposes, and I assure you of full confidentiality regarding your participation in this survey.

Consent

In order not to lose out on key responses that will be coming from you, I will ask permission to record the interview which will be transcribed later from an audio to a text data. do I have your consent to continue?

i. Yes *ii. No >> Thank the participant and go on to identify the next participant*

Questions

Profile

1. Could you please tell me a little bit about your institution and its basic mandates?
2. What position do you hold in the institute and what are your key roles?

Focus

1. How do you assess Ghana's energy policy landscape in relation to productive energy for businesses in Greater Accra Region or Ghana as a whole
2. To the best of your knowledge, which productive energy (fuels) did businesses in the Greater Accra Region invest in or use during the dumsor period (2012-2016)?
    a. Why did they invest in these fuels?
    b. Why did they not consider other fuels like renewables?
3. How do policy instruments or the lack of them influenced the decisions of firms towards investing in certain fuels (mention fuels from Q1) and not others during the dumsor era?
4. Beyond the power crisis, how has the utilization of productive fuels by businesses in the G/A Region changed from the situation during the dumsor era and what are the underlying reasons?
5. How have policies contributed to energy utilisation dynamics in the post-crisis era?
6. In what ways did businesses in the Greater Accra Region employ energy efficiency technologies during the 2012-2016 crisis and post-crisis eras?
7. How have policies contributed to the utilization of energy efficiency technologies in the crisis and post-crisis eras?

Appendix D4: Key Informant Interview (KII) Guide (for fuel suppliers)

Purpose and assurance of confidentiality

I am a PhD candidate at ISSER, University of Ghana studying "Firms' decisions on energy systems utilization and their implications on performance from 2015 to 2021". The purpose of this meeting is to gain deeper understanding of why firms invest in, and use certain energy systems at the expense of other systems. This is purely for academic purposes, and I assure you of full confidentiality regarding your participation in this survey.

Consent

In order not to lose out on key responses that will be coming from you, I will ask permission to record the interview which will be transcribed later from an audio to a text data. do I have your consent to continue?

i. Yes *ii. No >> Thank the participant and go on to identify the next participant*

Questions

Profile

1. Could you please tell me a little bit about your institution and its basic mandates?
2. What position do you hold in the institute and what are your key roles?

Focus

1. How easily accessible and available is the fuel supplied by your institution to businesses in the Greater Accra Region?
2. In your view, to what extent do businesses in the Greater Accra Region invest in or use fuel supplied by your institution?

3. Why do businesses invest in or use your supplied fuel?
4. Considering the supply and reliability issues, how does your supplied fuel affect the productivity of businesses in the Greater Accra Region?

   OR
5. Why do businesses don't often invest in or use your supplied fuel?
6. What difference do you think your supplied fuel would have made to the productivity of businesses in the Greater Accra Region

APPENDIX E

APPROVAL LETTER FOR ECH 350-21-22

UNIVERSITY OF GHANA
ETHICS COMMITTEE FOR THE HUMANITIES (ECH)
P. O. Box LG 74, Legon, Accra, Ghana

My Ref. No…ECH 350/ 21-22 …

1st August, 2022.

Mr. Innocent S.K. Agbelie
ISSER
University of Ghana
Ghana

ETHICAL CLEARANCE
(ECH 350/ 21-22)

The protocol title below has been reviewed and approved by the ECH Committee.

TITLE OF PROTOCOL: **FIRM'S PRODUCTIVE ENERGY DECISIONS AND THE IMPLICATIONS ON FIRMS PERFORMANCE FROM 2015 TO 2021: THE CASE OF BUSINESSES IN THE GREATER ACCRA REGION**

PRINCIPAL INVESTIGATOR: Mr. Innocent S.K. Agbelie

Please note that the final review report must be submitted to the Committee at the completion of the study. Your research records may be audited at any time during or after the implementation. Any modification of this research project must be submitted to ECH for review and approval prior to implementation.

Please report all serious adverse events related to this study to ECH within seven (7) days verbally and in writing within fourteen (14) days.

This certificate is valid till July 19, 2023. You are required to submit annual reports for continuing review.

Please accept my congratulations.

Yours Sincerely,

Professor C. Charles Mate-Kole
ECH Chair

Cc: Dr. Simon Bawakyillenuo, ISSER, UG
Dr. William Bekoe, ISSER, UG
Dr. RichmondAttaAnkomah, ISSER, UG

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