Predicting Increase In Productivity with Higher Renewable Energy In 6 West African Countries Using Multiple Linear Regression

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ABSTRACT

Reducing the emission of CO_2 has been on the front burner of recent studies, policy makers all over the world to find alternative ways of production and consumption of electricity. Renewable energy usage has been found out to be the safest way to reduce the emission of C02 into the environment and it is also a strategy to sustainable development and efficient power usage that will also have positive economic impact. The sample data are secondary data for the six West African countries(Benin, Burkina Faso, Cote d' Ivoire, Ghana, Mali, Nigeria) in this study which was gotten from Energy Information Administration (EIA), spanning from 1990 - 2018, while the data for the Gross domestic product (GDP) was from world bank data bank also spanning from 1990 - 2018.

This study aims to look at how renewable energy usage can bring sustainable growth to six West African countries: Benin, Burkina Faso, Cote d' Ivoire, Ghana, Mali, and Nigeria whilst reducing the emission of CO_2 during production and also increasing GDP. This study employs multiple linear regression to conduct a study on the relationships (GDP, Hydroelectricity, and Non-hydro renewable energy) between these six countries. The results of this study show that there is a strong positive relationship between GDP and renewable energy in Mali, but it is moderate and mild in the rest countries except for Nigeria that has no relationship between GDP and renewable energy. Also, the result shows that the Non-hydro form of renewable energy is the most used form of renewable energy production. Multiple regression analysis shows that hydro and non-hydro power generation has a positive effect on the GDP which will, in turn, drive an eco-friendly environment and power usage efficiency.

Further and advanced studies can be carried out looking at the problems surrounding non-hydro power generation. Policy directions can be geared towards the outcome of this study.

Keywords: renewable energy, multiple linear regression, correlation, energy.

ÖZ

CO_2 emisyonunun azaltılması, son zamanlardaki çalışmaların ön araştırması olmuştur, tüm dünyadaki politika yapıcılar, alternatif elektrik üretim ve tüketim yolları bulmaya çalışmaktadır. Yenilenebilir enerji kullanımı çevreye CO_2 emisyonunu azaltmanın en güvenli yolu olduğu tespit edilmiştir ve aynı zamanda olumlu ekonomik etkisi de olacak sürdürülebilir kalkınma ve verimli enerji kullanımı için bir strateji olarak düşünülmektedir. 1990 - 2018 yıllarını kapsayan Enerji Bilgi İdaresi'nden (EIA) alınan bu çalışmada örnek veriler, altı Batı Afrika ülkesi (Benin, Burkina Faso, Fildişi Sahili, Gana, Mali, Nijerya) için ikincil verilerdir. Gayri safi yurtiçi hasıla (GSYİH) verileri, yine 1990 - 2018 yıllarını kapsayan dünya bankası veri bankasından alınmıştır.

Bu çalışmanın amacı, yenilenebilir enerji kullanımının altı Batı Afrika ülkesine (Benin, Burkina Faso, Fildişi Sahili, Gana, Mali ve Nijerya) sürdürülebilir büyümeyi nasıl getirebileceğini, üretim sırasında CO_2 emisyonunu azaltırken ve aynı zamanda GSYİH'yi nasıl artırabileceğini incelemektir. Bu çalışma, bu altı ülke arasındaki ilişkiler (GSYİH, Hidroelektrik ve hidro yenilenebilir olmayan enerji) üzerine bir çalışma yürütmek için çoklu doğrusal regresyon kullanmaktadır. Bu çalışmanın sonuçları, Mali'de GSYİH ile yenilenebilir enerji arasında güçlü bir pozitif ilişki olduğunu, ancak GSYİH ile yenilenebilir enerji arasında hiçbir ilişkisi olmayan Nijerya dışındaki diğer ülkelerde orta ve hafif olduğunu göstermektedir. Ayrıca sonuç, yenilenebilir enerjinin hidro olmayan formunun en çok kullanılan yenilenebilir enerji üretim şekli olduğunu göstermektedir. Çoklu regresyon analizi, hidro ve hidro olmayan elektrik üretiminin GSYİH üzerinde olumlu bir etkisi olduğunu ve bunun da çevre dostu bir çevre ve enerji kullanım verimliliği sağlayacağını göstermektedir.

Hidroelektrik dışı enerji üretimini çevreleyen sorunlara bakarak daha ileri ve ileri çalışmalar yapılabilir. Politika yönergeleri bu çalışmanın sonucuna yönelik olabilir.

Anahtar Kelimeler: yenilenebilir enerji, çoklu doğrusal regresyon, korelasyon, enerji.

DEDICATION

To my family.

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LIST OF ABBREVIATIONS

AICD	Africa Infrastructure Country Diagnostic
BRICS	Brazil, Russia, India, China, and South Africa
CO2	Carbon Dioxide
EKC	Environmental Kuznets Curve
GDP	Gross Domestic Product
kWh	KiloWatt Hour
MW	MegaWatts
NGBM	Nonlinear Grey Bernoulli Model
P-values	Calculated Probability
r	Correlation Coefficient
TWh	TeraWatt Hour
VECM	Vector Error Correction Model

Chapter 1

INTRODUCTION

As we know, power usage in our daily life and activities is very paramount. The continuous power problem in Africa has led to the unstable trend of its GDP, technological innovation, industrialization, and commercialization of goods and services that have been in a poor state. If African countries continue the mode of generating electricity, they will not only be wasting money in generating power, they will continue wasting money on distribution on the said electricity been generated, which will continue to lead to an increase in the cost of generating electricity without reaching the final consumers accordingly.

Why this study is important is because it tends to evaluate why renewable energy is needed and the opportunities that abound. Since the search for economic prosperity, the quality of the environment has been a topical issue amongst stakeholders and researchers. Awodumi, O et al, 2020. Nations in Africa have been looking for ways for sustainable economic growth that would propel an increase in job production, efficiency and at the same time affect the GDP.

No study laid out factors that influence access to electricity rates and policymakers believe that what worked outside Africa might not work in Africa due to differences in circumstance. Onyeji, I. et al (2012).

Two out of three people don't have access to electricity in Sub-Sahara Africa, this shows that there is a strong correlation between poverty and access to electricity, Dagnachew, A., et al, (2017),

As of 2019, the total electricity generated was at 870TWh, in 2018 it was 846TWh that is an increase of 2.9% in 2019. 3 percent of global electricity is generated in Africa since the year 2000, but its generation capacity has grown to about 4.8 percent per year since 2008 if we are to compare it to the global growth of 2.7 percent. Natural gas is the largest mode of generating electricity with 39% of the energy mix, while coal constitutes 29%, followed by hydroelectricity with 15% contribution, oil is 10%, renewable energy is at 5% and lastly nuclear is at 2% (Africanews, 2020).

Renewable energy exploration is still a growing phenomenon in Africa. For so many years it has depended on gas and fossil fuels for most of its electrical needs, of which it is the most used in Africa. There has been a lot of effort within Africa and globally to eradicate or reduce the use of fossils. Renewable energy usage allows countries to be self-sufficient, less dependent on costly imported sources of energy.

One of the major sources of renewable energy is hydro, second to solar and followed by wind. These sources of energy sometimes is a factor of climatic change. Currently, solar and wind are gaining more attention in Africa, prominently is Morocco and Egypt from North and South Africa and Kenya down south of Africa. Solar and wind are projected to increase by 1.5% yearly for the next 9 years.

Most industries in Africa today are responsible for 41% of electricity consumption, while residential consumption stands at 33%, commercial and public services consume

18%, agriculture consumes 4%, other sectors consume 3%, and transportation at approximately 1% (Africanews, 2020).

Energy demand has increased globally to achieve the mission 2050 renewable energy goal, which is to achieve a carbon-neutral environment (United Nations, 2020 & IEA, 2021). Also, many technologies are out there to achieve this future carbon-neutral goal of electrification. Numerous technology that would increase renewable energy usage by 2050 has been developed so far, an example of such technology is the photovoltaic cells/systems. Photovoltaic systems directly convert the energy from the sun to electricity through a semiconductor material, also another technology that is used is concentrated solar systems. Concentrated solar systems can be used to collect energy directly from the sunlight, stored and/or supplied to the national grid. In the United State, 1,815 megawatts or more of concentrated solar systems are in use. (SEIA, 2018). Also, wind turbines use the kinetic nature of the wind to drive the turbines that produce electricity. Although wind speed can be volatile and intermittent as the usage continues to increase so does its sustainability. As of 2016, wind energy provided 6% of renewable energy electricity. (Wind, 2021).

Although different sources give different numbers on electricity access, according to a UNDP study, it is estimated that in 2008 only about 38% of the population in West Africa had access to electricity, with a marked imbalance between urban and rural areas. Excluding the islands of Cabo Verde, only several countries, i.e. Nigeria, Ghana, Cote d'Ivoire, and Senegal have national electricity access above 40%.

To curb this shortfall, looking at different ways to generate power that are affordable, accessible and that will aid industrialization. Using multiple linear regression to analyze the different modes of electric power generation, the data available will be used to generate the most sustainable mode of renewable power generation.

1.1 Renewable Energy Technologies

Renewable energy technologies use renewable energy sources like wind and sunshine to generate electricity and heat. Other sources include biomass, landfill gas, tidal, wave e.t.c all help increase in capacity achieved through increased efficiency or additions of new capacity at an existing renewable. Below are few examples of technologies that are used.

1.1.1 Photovoltaic Device & Concentrating Solar Power (CSV)

Photovoltaic (PV) systems use an electrical process that occurs naturally in certain types of materials called semiconductors to generate power directly from sunshine. Solar energy frees electrons in these materials, which can then be induced to move through an electrical circuit, powering devices, or transmitting electricity to the grid. PV devices can be used to power everything from calculators to huge commercial companies. (SEIA, 2018,Penaherrera, F., & Pehlken, A. 2020)

Concentrated solar power (CSP) on the other hand employ mirrors to concentrate the sun's energy, which is then used to power traditional steam turbines or engines to generate electricity. A CSP plant's concentrated thermal energy can be stored and used to generate electricity whenever it is needed, day or night. Concentrating solar power methods generate electricity by concentrating the sun's energy and reflecting it onto a receiver using reflective devices such as troughs or mirror panels. The high-temperature heat generated is used to power a conventional turbine, which generates electricity. CSP systems are used to generate significant amounts of electricity and require a lot of space to install.

1.1.2 Wind Turbine Technology

Wind energy uses the wind to power turbines that in turn generate electricity. The propeller-like blades of a turbine are turned by the wind around a rotor, which spins a generator, which generates power. The aerodynamic force of the rotor blades, which act similarly to an airplane wing or helicopter rotor blade, converts wind energy into electricity in a wind turbine. The air pressure on one side of the blade lowers when the wind blows across it. Lift and drag are created by the difference in air pressure across the two sides of the blade. The lift force is greater than the drag force, causing the rotor to spin. (Energy.gov, 2021)

Wind turbines can operate independently, they can be connected to a utility power grid, or even be integrated with a PV system. To create a wind plant for utility-scale wind energy, a significant number of wind turbines are typically erected close together. Wind farms are now used by many electrical suppliers to offer power to their consumers. (Renewable world, 2021)

There are three main types of wind turbine technology as stated by (energy.gov, 2021)

- Land-Based Wind Turbines: Turbines installed on land to capture the wind on land and it can produce as large as 100 kilowatts to
- Offshore Wind Turbines: These turbines can capture strong ocean winds and produce massive amounts of energy.
- Distributed Wind Turbines: It is utilized to generate clean, emission-free electricity for families, small businesses, and houses. The distribution might range from small-scale to large-scale operations.

Other notable renewable technology includes hydropower technology, tidal power technology, and biomass. All these renewable technology sources of electricity generation can be controlled, distributed, and managed using microgrid and its application.

A Microgrid system is an auto electrical network that allows you to generate your electricity and utilize it when you need it. As a result, a microgrid is a dispersed energy resource. Microgrids can be operated either connected to the utility grid or in an independent mode. Microgrids increase supply security within the microgrid cell and can provide emergency power by switching between the island and linked modes in this way. It not only integrates renewables for use, but it also keeps your facility's power running during grid outages, and during peak demand, store electricity and sell it back to the grid.

1.2 Research Hypothesis

Environmental pollution has been on the increase since the beginning of the industrial revolution, air pollution has been on the increase, environmental pollution has been on the increase worldwide. Many stable countries have been searching for a sustainable way of growing wealth with less degradation of the air or environment, some countries have set policies to accelerate to reduce air pollution and environmental pollution. In 1963, the United State Congress passed the clean act, which has also been amended as years goes by.

In contrast to Africa, fossil fuels are still the most commonly used energy source for everyday use which in turn degrade the environment and also increases the release of CO_2 into the atmosphere.

Renewable technology adoption in the six selected countries in West Africa used in this study can adopt the use of renewable technology, this will, in turn, increase productivity in both rural and urban areas. Preparing for the future of these regions means that climate change needs to be acknowledged.

Optimizing the most abundant renewable sources which can drive industrialization and small businesses will go a long way in having increase income, improved technology, and also it would lead to a reduction in environmental degradation. This research tends to explore each of these countries to know which of the renewable energy sources in the region can be optimized. It would also point policymakers in the direction of future renewable technology investment. In the six countries that are experiencing power shortages, hydroelectric and non-hydroelectric sources have the potential to solve power problems in the long run and it can also increase GDP.

In light of the above problems H1: Hydro and Non-Hydro electricity affect the GDP.

The rest of the chapter will proceed as follows: Chapter two reviews some important literature. Chapter three discusses the methodology used and the source of the data. Chapter four deals with the result and explanation of analysis carried out in the thesis and lastly, chapter five deals with the conclusion and future work.

Chapter 2

LITERATURE REVIEW

Industrialization is a key ingredient to economic growth. There are a lot of challenges that hinder industrialization, economic prosperity, and globalization. An example of such challenges is power generation. Power generation, distribution, and usage form part of the sub-challenges of the industrialization of Africa. Also, as the world tends to the reduction of CO_2, it is important to build structures that would accommodate the reduction of emission of CO_2 to the atmosphere. More attention should be paid to the reduction of Carbon, planting of trees also should be a continuous process while market strategies such as carbon taxes, emissions trading, alternative energy, and less carbon-intensive fossil fuels should be effective (Kolar, J. 1999). Chien, T., & Hu, J. (2008) confirm that there is a positive relationship between renewable energy and GDP through increasing capital formation but not for the path of increasing trade balance.

Using the translog cost function (Wesseh, P., & Lin, B. 2016) found out that there is limited renewable energy production due to the fact that it is expensive and limited, hence renewable energy cannot be solely depended on. Also, using the endogenous growth theory, (Maji, I. et al 2019) experimental result shows that the use of Biomass in West Africa caused a negative economic growth because most of the Biomass (e.g., wood) used are unclean. Abanda, F., et al (2012) in their research found out that there is a correlation between RE production and GDP, and it was strongly positive hence there is a strong relationship in the West Africa region.

Mahmood, H., et al (2020) in their research found out that North African nations are increasing in GDP and also increasing CO_2 emissions which in their research is the first phase of the EKC. Also, it was discovered the increase in economic growth did not cover all the North African nations. Adequate accessibility to investment is needed for the poorer population to have better access to cleaner energy and healthcare. The increase in GDP has a negative impact on the environment of the region.

Bekun, F., et. al (2019) found that there is a causal relationship between the use of Labour and economic development to CO_2 emissions. The government of South African should be worried due to the unidirectional relationship between energy usage and economic development which causes the increase in the release of CO_2.

There was no visible impact of renewable energy usage in Turkey as stated by Dogan, E. (2016), he concluded that no true visible increase in GDP compared to the usage of non-renewable energy consumption and capital, while labor reduces it on a long and short run. But there was bidirectional VECM Granger causality between non-renewable energy consumption and economic growth and finally, there was a short-run one-way causality between economic growth to renewable energy consumption and longer bidirectional causality between them.

Tsai, S., et al (2017) showed in their forecast prediction using NGBM(1,1), Grey Verhulst model, GM(1,1), and regression analysis. It was predicted that China will use 10.1-10.4% of its total renewable energy consumption as of 2015, it will also grow 15% by 2020 if more effort is put in place. The models used in this forecast can be replicated with other countries.

Ji, Q., & Zhang, D. (2019). Despite China being under significant economic pressure, they have been able to reduce emissions by following a clean and sustainable path of economic growth. The government was open to the foreign direct investment that brought in the capital, technology, experiences which have had more economical effects on the economy since the late 1970s, they have also been able to upgrade their structure of producing clean energy.

Bhattacharya, M., et al (2016), in their research found out that there was a long-run vital relationship between economic growth, traditional energy, and energy-related inputs. It also found that renewable energy had a positive effect on 57% of the countries selected for their research. A time-series analysis carried out on the same data showed some positive elasticities. Green energy consumption will have a long positive effect that would tend to sustainable economic growth and more job creation.

Xu, X., et. al, (2019) in their research stated that due to the poor beginnings of most African nations, having renewable energy generation and development of renewable energy in Africa is generally expensive compared to other regions of the world. Though there is a higher probability of more development of renewable energy as usage of power in Africa has increased over time, and the need for renewable energy has also increased. They predicted that by 2025 the total power generation would rise to about 18% of what was generated in 2016, but renewable energy usage and in terms of generation is lower compared to the total amount that would be generated by 2025. But there is a promising future for renewable energy in Africa at large.

Ben Aïssa, M., et al, (2014) used long-run estimates to show that renewable energy consumption and trade have a significant positive real impact on real GDP. In their export model, lt shows that a 1% increment in renewable energy consumption increased its output by 0.03%, and a 1% increase in exports increases output by 0.19% likewise for the import model, it showed that a 1% increment in renewable energy consumption increases output by 0.05% whilst a 1% increase in imports increases output by 0.21%.

Akintande, O., et al (2020) in their research, found out that population growth, urban population, electricity power demand/consumption, Government effectiveness, political stability, GDP, and control of corruption will up the need for renewable energy consumption. Also, a real investment that is acceptable by the government and that will promote economic activities would speed up the need for renewable energy demand, then reduce the urge for an environmental degrading energy source in the selected countries (Ethiopia, South Africa, Nigeria, Democratic Republic of Congo and Egypt).

Hadi, S., Imam G. (2021) in recent research found out that in the BRICS countries, consumption of fossil energy (coal) affects the economic growth positively and significantly, likewise, oil and natural gas affect economic growth statistically but not significantly and lastly, renewable energy has a negative effect on the economy of the BRICS nations.

Olanrewaju, B., et al found that natural gas causes renewable energy consumption which simply means that there is a positive relationship between the two, also a reduction in carbon usage will give rise to the consumption of renewable energy in Africa. African can contribute to global clean energy if they collectively adopt using renewable energy, reduce coal usage, and support renewable energy growth.

Inglesi-Lotz, R., & Dogan, E. (2018). Found out that more trade openness results in reducing CO2 emissions amongst top power producers in Sub-sahara Africa. Also, they found that increase in renewable consumption reduces environmental pollution using the cointegration test. In the course of their research, there is a unidirectional causality between environmental degradation to renewable energy, from non-renewable energy to pollution, from carbon emissions to trade openness from real income to renewable energy, from openness to real output, from trade openness to renewable energy, from non-renewable energy to trade openness, and from non-renewable energy to renewable energy.

Acheampong, A. (2018), Ergun, S., et al (2019), Wasti, S., & Zaidi, S. (2020), believes that the government should set policies that can accommodate the use of clean, cheap, and accessible renewable energy. Likewise, Muhammad, B. (2019) and Mahmood, H., et al (2020). Concluded that government should reduce the emission of CO_2 by increasing the production of clean energy that can lead to a high level of economic growth in the MENA region. Also, there should be a balance where renewable and clean energy can be affordable with government support and subsidies.

Unlike China where renewable energy has less effect on job creation according to Zhao, X & Luo, D, (2017), renewable energy will create an efficient power supply in the nearest future, clean energy, Abanda, F., et al (2012), it is also going to create more job opportunities thereby increasing productivity and GDP.

Giving that information technology will play a leading role in realizing a sustainable renewable future, so many IoT (Internet of Things) devices, internet penetration and IoT devices with low energy usage has contributed to the growth of these regions. As

2020 internet penetration in the selected countries stands at 30.5% Benin, Burkina Faso has 21.4%, Cote d' Ivoire has 17.7%, Ghana has 46.5%, Mali has 59.8 and Nigeria has 72.2% penetration respectively. (Statista, 2020)

The fourth industrial revolution is on, and it is envisaged to be powered by modern technologies like the 5G, IOT equipment is the driving force that would make the united nations sustainable development goal achievable(UN. Special Edition: Progress towards the Sustainable Development Goals; UN: New York, NY, USA, 2019.) in these regions because IoT devices tend to help me optimization of energy usage, energy management, and sustainability.

Maqbool, R., & Sudong, Y (2018), highlighted five critical success factors in renewable projects which are communication factors, team factors, technical factors, organizational factors, environmental factors in the case of Pakistan. This can be adopted in the case of the countries selected in these studies to achieve sustainable renewable energy growth and development.

Chapter 3

METHODOLOGY AND DATA

3.1 Data

The sample data used in this study are secondary data for the six West African countries (Benin, Burkina Faso, Cote d' Ivoire, Ghana, Mali, Nigeria). The data for GDP was collected from the World Bank database, which is an open data catalog under the world development indicators to measure the economic growth of various countries. The sources of the data are collated from various officially recognized international sources. Since this write-up is based on comparing countries, "GDP (current US$)" data was collected.

Electricity output, which was gotten from Energy Information Administration (EIA), spanning from 1990 - 2018, in Billion Kilowatts Hour. The Energy Information Administration (EIA) of the United States collects, analyzes, and publicizes independent and unbiased energy data to support smart policymaking, efficient markets, and public knowledge of energy and its relationship to the global economy and environment. The data is made up of a total of utility and non-utility sources of electricity including combined heat and power plants. The reported data are net generation and not gross generation. The solar photovoltaic, solar thermal, and distributed solar generation were available for solar electricity generation, the data also include hydroelectric, and non-hydroelectric renewable electricity. Generation from hydroelectric pumped storage plants is included in total generation.

Each data was collected through an annual questionnaire to each countries energy board for Burkina Faso(Société Nationale d'Electricite du Burkina Faso), Ghana(Energy Commission of Ghana), Nigeria(National Bureau of Statistics, Nigeria) following an annual questionnaire on energy statistics as approved by the International Recommendations for Energy Statistics (IRES) which was embraced by UNSD in February 2011 and an all-inclusive list was gotten from African Energy Commission (AFREC), International Renewable Energy Agency (IRENA)

3.2 Methodology

The electricity output data contains electricity production from 1990 – 2018, it contains fossil production and renewable production in Billion kWh. This study focuses on renewable means of production in relation to GDP. The data was further wrangled to select renewable, renewable energy was an addition of Hydroelectricity production and Non-hydro electricity production which are the independent variables. Further analysis was carried out to compare each country's production output with for hydro production and non-hydro production using excel. The statistical technique adopted was multiple linear regression on Microsoft excel. Microsoft Excel features charting capabilities and the Analysis ToolPak, which provides a collection of data analysis tools such as correlation coefficient 'r', F-stat, P-stat beyond those generally found in spreadsheets, as an alternative to the specialized packages.

The correlation coefficient was developed by Karl Pearson and later introduced by Francis Galton in 1880(Wikipedia, 2021). Pearson's product-moment r necessitates a positively or negatively magnitude and direction. It has a range of -1, 0, and +1, and the values are true and non-dimensional with no units. If the correlation is 0, it means there is no relationship between the two variables being measured (Taylor, R., 1990).

The correlation strength is independent of its direction. It also illustrates the degree to which two variables are related to one another. The R-Squared or Multiple R-Squared (in R) measures how well the model or regression line "fits" the data. It shows how much of the variance in the dependent variable (Y) is explained by the independent variable (X). One or more factors can influence a variable as a result, the R-Squared shows how much variance in the dependent variable is explained by the independent variables. It is the ratio of two variances, which is used to compare statistical models that are best suited to a data set to determine which model is best for a population sample. It's also a measure of the likelihood that a regression model is incorrect, implying that it can't predict anything. 1%, 5%, or 10% are common significance levels, but in this research, a 5% significance level was used. "The probability under a specified statistical model that a statistical summary of the data (eg, the sample mean the difference between the 2 compared groups) would be equal to or more extreme than its observed value." Nicole A. L. & Wasserstein R. L. (2016).

P-stat is similar to the f-stat, but the difference is that the p-value is the measure of the significance of the corresponding coefficient whereas F-value is the significance of the entire model. The percentage of significance commonly used is also 1%, 5%, or 10%. 5% significance was adopted in this study.

Multiple linear regression is a statistical technique used in measuring the relationship between variables, dependent and independent variables. This statistical technique was used to compare the effects of hydro and non-hydro electricity production (independent variable) on GDP (dependent variable) in each of the countries in question. First, the correlation between renewable energy and the GDP of each country was established. Afterward, a multiple regression analysis was carried out separately by using hydro and non-hydro electricity production (independent variable) as separate entities on GDP (dependent variable) in each of the countries.

Applying multiple regression equation below:

$$Y = \beta 0 + \beta 1 X1 + \beta 2 X2 + \cdots + \beta n X n \quad (1)$$

Where:

Y = dependent variable

β_0 = Intercept

β_1 = Slope of the first independent variable

β_2 = Slope of second Independent Variable

X_1 = Independent Variable 1

X_2 = Independent Variable 2

The literature review shows that renewable energy can contribute positively to the GDP of these six countries in the long run as stated by Abanda, F., et al (2012), and on that basis figure 1 is to be tested in this study.

$$\mathrm{GDP} = \beta 0 + \mathrm{Hydro} * \beta 1 + \mathrm{Non-Hydro} * \beta 2 \quad (2)$$

Investment in these countries would accelerate the actualization of meeting up with increases renewable usage in these countries. West African region has significant renewable energy potential, which could be used to meet unmet power demand and provide universal access to electricity while also assisting the region's transition to a low-carbon growth path. The ECOWAS Renewable Energy Policy (EREP) was enacted by the Authority of Heads of State and Government in July 2013, with the goal of increasing the share of renewable energy in the region's overall electricity mix to 35 percent in 2020 and 48 percent in 2030. More private and government interventions like the ECOWAS renewable energy policy will further increase access to renewable electricity.

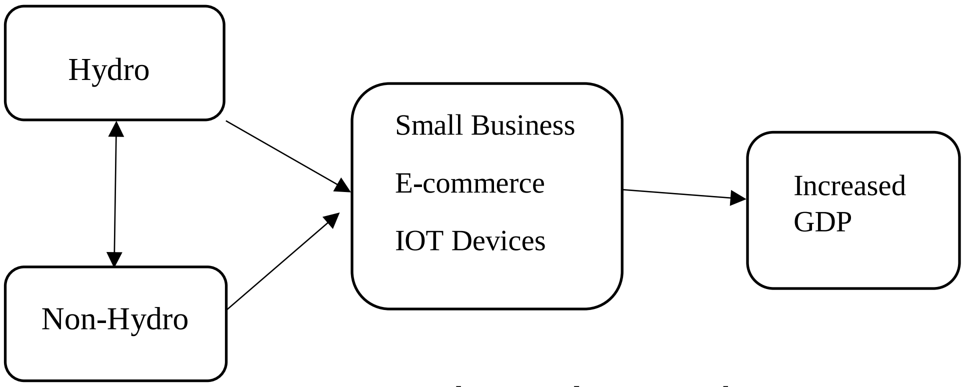

Figure 1: Theoretical Framework

Chapter 4

ANALYSIS AND DISCUSSION

Table 1 depicts the relationship between each country's GDP and renewable energy utilization. According to the table, Mali has a very strong link between GDP and renewable usage, with a correlation coefficient of 0.9653, followed by Benin republic and Burkina Faso, with correlation coefficients of 0.7033 and 0.6633, respectively. With a r value of 0.5916, the GDP of Cote d'Ivoire and renewable energy utilization have a moderate association. Finally, there is a weak link between Ghana's GDP and renewable energy usage, with a r value of 0.3771, whereas there is no correlation between Nigeria's GDP and renewable energy usage, with a r value of 0.0490.

Table 1: Correlation Coefficients

Country	**Correlation Value (r)**
Benin	0.7033
Burkina Faso	0.6633
Cote d’Ivoire	0.5916
Ghana	0.3771
Mali	0.9653
Nigeria	0.0490

4.1 Benin

Figure 1 shows that most of the power generated in the Benin Republic, is generated through fossil fuel with an all-time high of 0.3055 billion kWh in 2017 and that of renewable was 0.0101 billion kWh in 2016. There was no record for renewable able out between 1990 and 1995 and due to the size of Benin republic and its very little coastal region, it has been unable to produce more hydroelectricity, hence the focus on fossil.

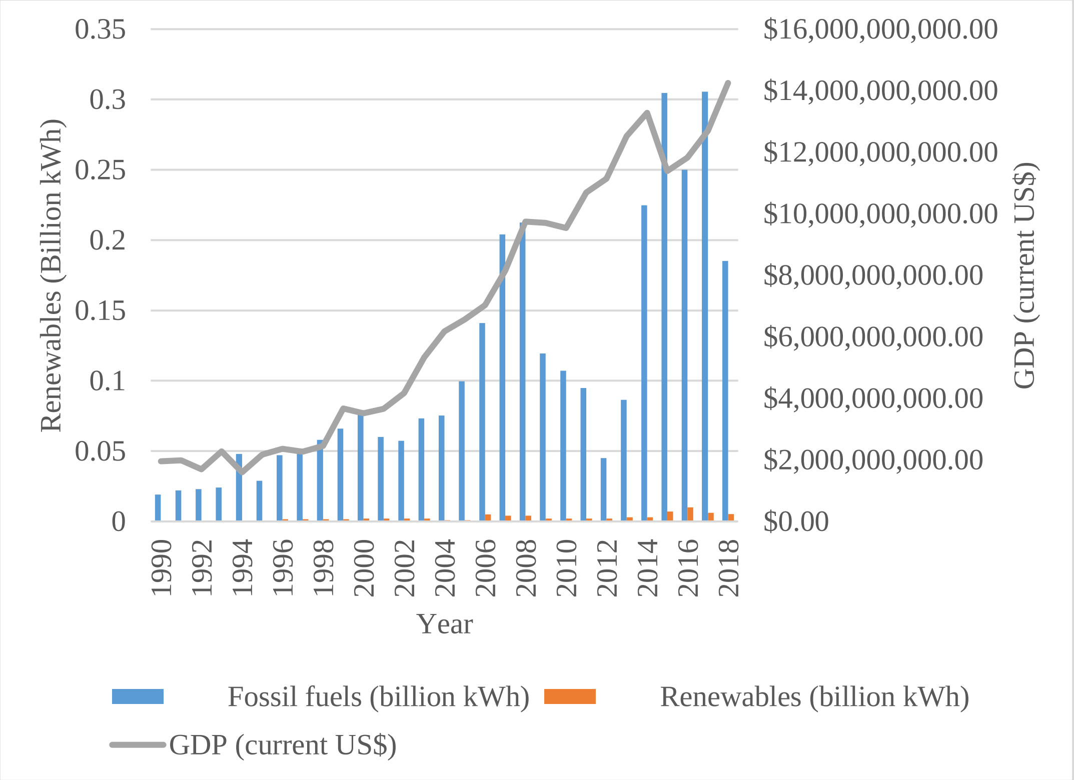

Figure 2: Benin Electricity Growth

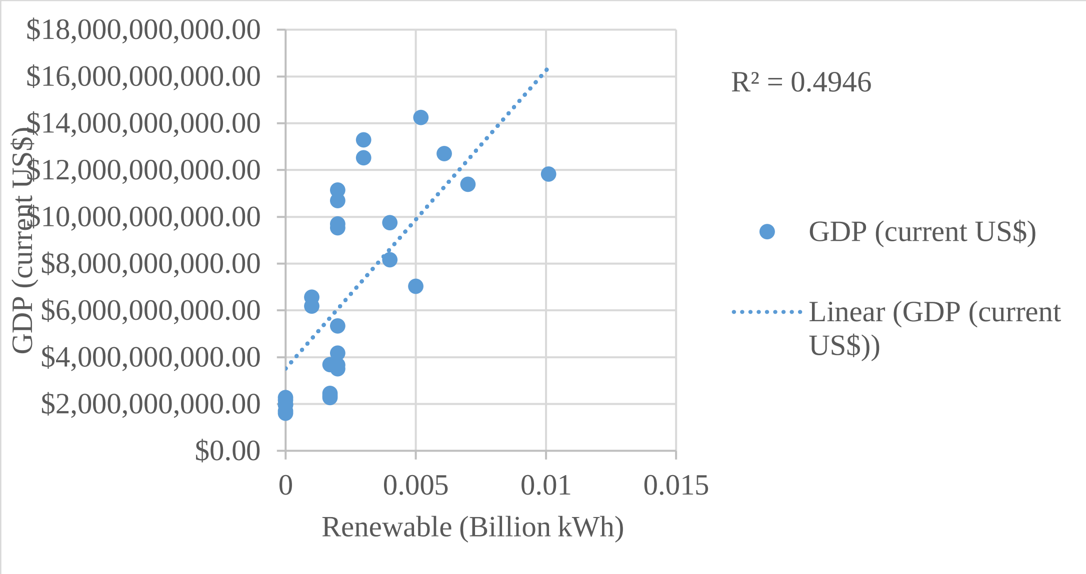

Figure 3: Relationship Between GDP And Renewable Energy In Benin

According to figure 3, there is a linear correlation between power generation in the Republic of Benin and its yearly GDP. With the coefficient **r** at 0.7033 from Table 1 depicts the relationship between each country's GDP and renewable energy utilization. According to the table, Mali has a very strong link between GDP and renewable usage, with a correlation coefficient of 0.9653, followed by Benin republic and Burkina Faso, with correlation coefficients of 0.7033 and 0.6633, respectively. With a r value of 0.5916, the GDP of Cote d'Ivoire and renewable energy utilization have a moderate association. Finally, there is a weak link between Ghana's GDP and renewable energy usage, with a r value of 0.3771, whereas there is no correlation between Nigeria's GDP and renewable energy usage, with a r value of 0.0490.

Table 1, it shows that there is a strong positive linear relationship between power generation and GDP in the Republic of Benin. Also, 49.46% variability in the GDP can be explained by the corresponding variability in the power generated, but 50.54% of the variability is explained by unknown factors.

4.2 Burkina Faso

Burkina Faso approximately generated an average power of 0.500 Billion kWh between 1990 – 2018, fossil power accounted for a total average output of about 78.82% between the year in question, and an average of 21.18% for renewable energy is been accounted for. Between 1994 and 1997, Burkina Faso electricity production share between fossil and renewable was close, but in 1998, the share of fossil fuels grew more than the share of renewable, meaning the share of renewable was unable up until 2018 with an all-time high of 0.1823 billion kWh that same year as shown in figure4.

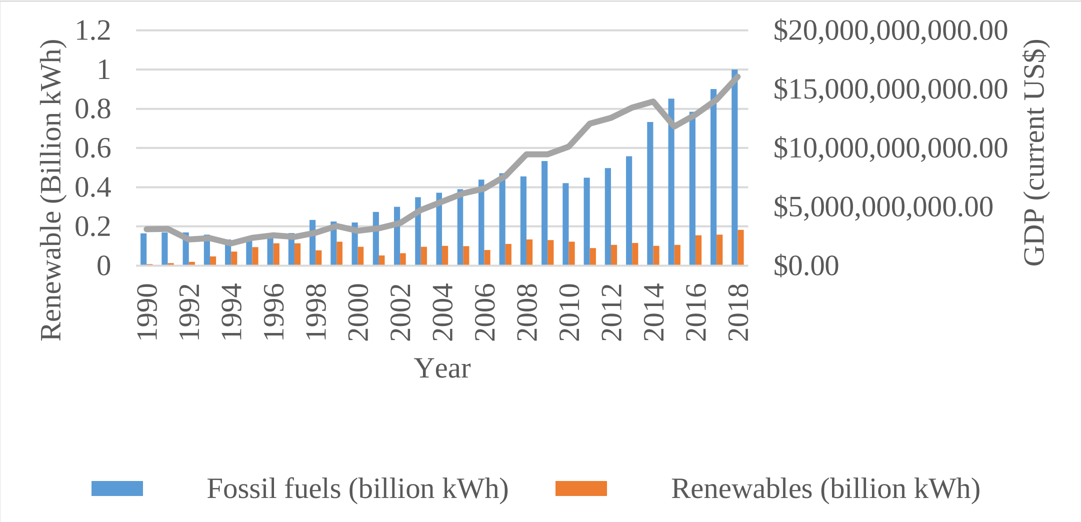

Figure 4: Burkina Faso Electricity growth

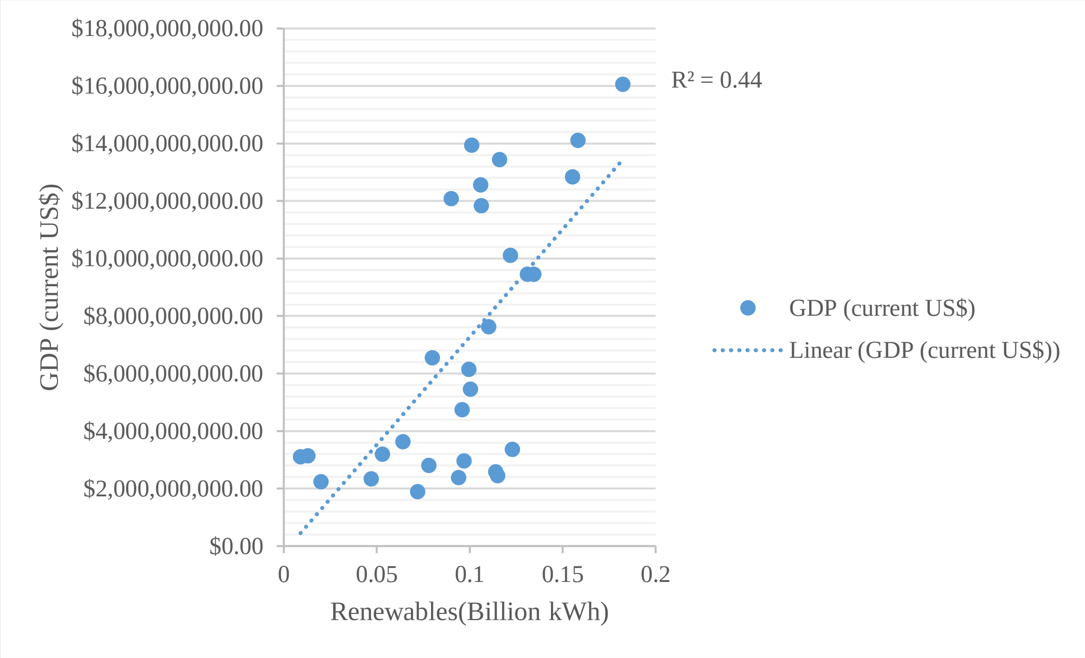

Figure 5: Relationship between GDP and Renewables in Burkina Faso

With the strong correlation coefficient of **r** = 0.6633 (Table 1 depicts the relationship between each country's GDP and renewable energy utilization. According to the table, Mali has a very strong link between GDP and renewable usage, with a correlation coefficient of 0.9653, followed by Benin republic and Burkina Faso, with correlation coefficients of 0.7033 and 0.6633, respectively. With a r value of 0.5916, the GDP of Cote d'Ivoire and renewable energy utilization have a moderate association. Finally, there is a weak link between Ghana's GDP and renewable energy usage, with a r value of 0.3771, whereas there is no correlation between Nigeria's GDP and renewable energy usage, with a r value of 0.0490.

Table 1) to the GDP, and a variation of 44.05% which can be explained by independent variables as shown in figure 5.

4.3 Cote d'Ivoire

Cote d' Ivoire is one of the suppliers of electricity in the sub-Saharan region. They export electricity to the likes of Benin Republic, Togo, Mali, Ghana, and Burkina Faso.

World bank, AICD(2008). Cote d'Ivoire electricity production is 62.04% of fossil energy and 37.96% renewable. Between 1990 and 1996, the share of renewable energy production was higher than the share of fossil. From 1997 up to 2018, fossil energy production grew more than renewable energy production. Renewable energy production all-time high was in 2018 which produced 3 billion kWh as shown in figure 6.

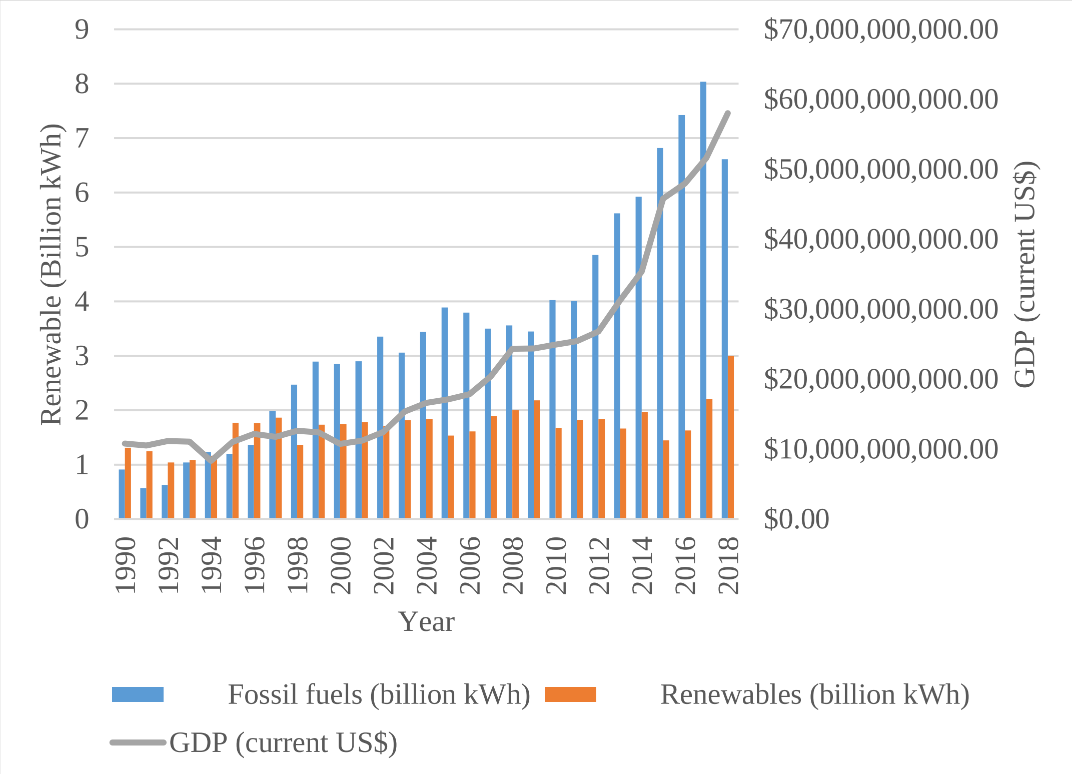

Figure 6: Cote d' Ivoire Electricity Growth

As noted in figure 7, the relationship between the GDP and renewable energy generation has 35.04% variation which can be explained and with a correlation value at r = 0.5916 in Table 1 depicts the relationship between each country's GDP and renewable energy utilization. According to the table, Mali has a very strong link between GDP and renewable usage, with a correlation coefficient of 0.9653, followed by Benin republic and Burkina Faso, with correlation coefficients of 0.7033 and

0.6633, respectively. With a r value of 0.5916, the GDP of Cote d'Ivoire and renewable energy utilization have a moderate association. Finally, there is a weak link between Ghana's GDP and renewable energy usage, with a r value of 0.3771, whereas there is no correlation between Nigeria's GDP and renewable energy usage, with a r value of 0.0490.

Table 1. This means that there are other unknown variables that affect this obvious variation between the regression line and the data points.

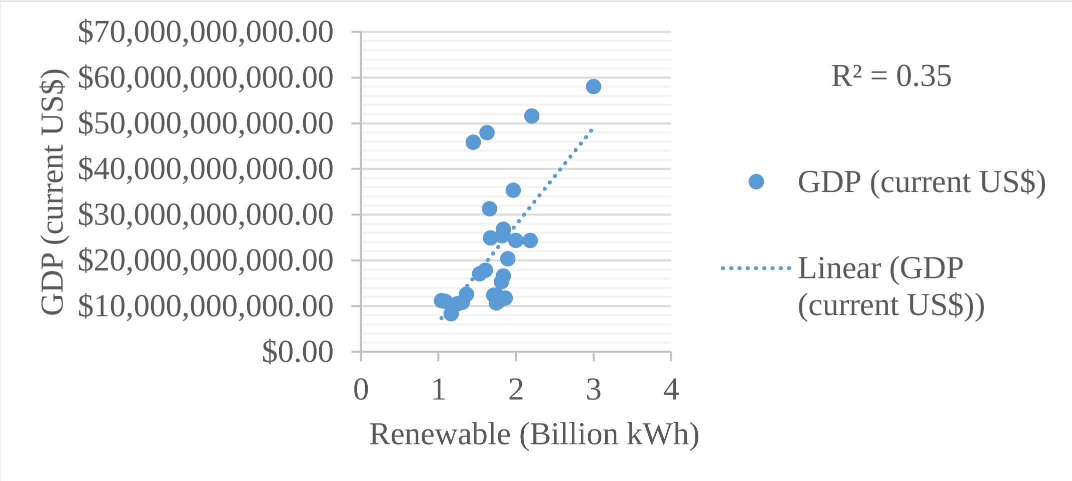

Figure 7: Relationship between GDP and Renewables in Cote d' Ivoire

4.4 Ghana

Figure 8 shows that Ghana's main source of electricity generation is renewable energy generated from hydroelectricity which accounts for 78.58% of total power generated between 1990 – 1998, but as of 1998, renewable energy only accounted for 50.71% while fossil fuels power generated rose to 49.29% in 2018. Also, from the chart, there was a 90% increase in GDP between 2005 and 2006, which means that there was a 142% increase in fossil fuel power generation in one year, this might be one of the factors that affected the increase in GDP in 2005 and 2006. Afterward, there was a continuous increase in GDP but fluctuating increase and decrease between fossil fuel power generation and renewable energy power generation up until 2010 through 2014, there was stability. There was a sharp decline in renewable energy production in 2015 but an increase in fossil production in the same year.

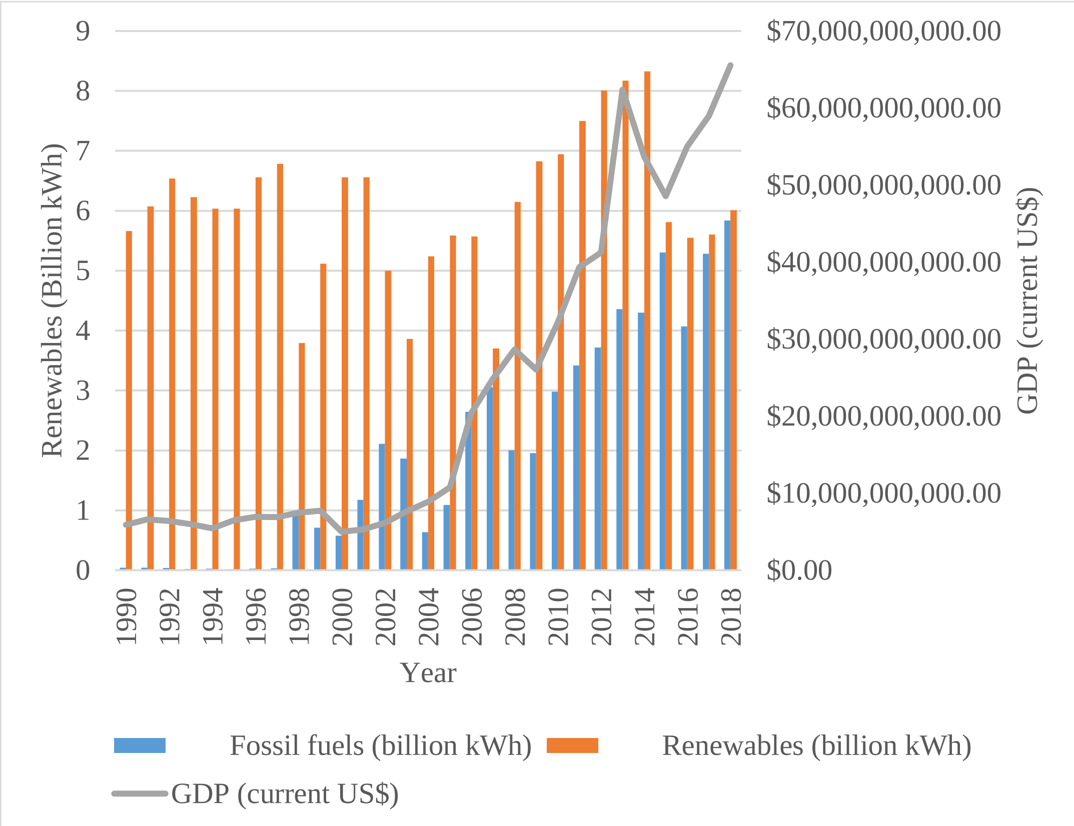

Figure 8: Ghana Electricity Growth

With this moderate linear relationship with a correlation coefficient **r** of 0.3771 from Table 1 depicts the relationship between each country's GDP and renewable energy utilization. According to the table, Mali has a very strong link between GDP and renewable usage, with a correlation coefficient of 0.9653, followed by Benin republic and Burkina Faso, with correlation coefficients of 0.7033 and 0.6633, respectively. With a r value of 0.5916, the GDP of Cote d'Ivoire and renewable energy utilization have a moderate association. Finally, there is a weak link between Ghana's GDP and renewable energy usage, with a r value of 0.3771, whereas there is no correlation between Nigeria's GDP and renewable energy usage, with a r value of 0.0490.

Table 1, it is sufficient to say that there is a positive relationship between the GDP in Ghana and renewable power output, however, the variation that can be explained between them stands at 14.22% with an r^2 of 0.1422 as shown in figure 9.

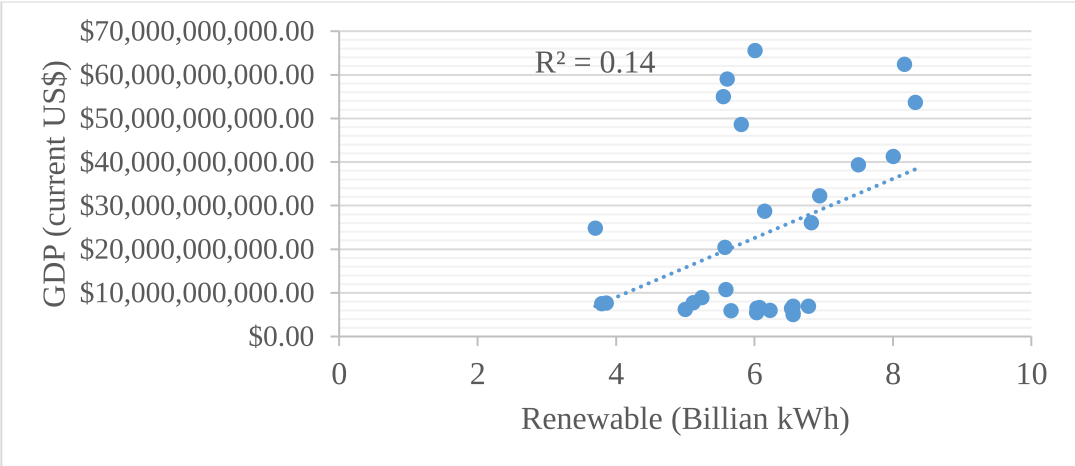

Figure 9: Relationship between GDP and Renewable Energy in Ghana

4.5 Mali

Mali is one of the biggest countries in West Africa with a total area of 1.2million Km^2 Mali - Wikipedia. (2021). Due to its vast land spread, there is potential for the vast deployment of solar-powered generation plants that should serve the urban and rural areas. 61.02% of its power generated was from renewable energy while 38.98% is from fossil. The share of renewable energy and fossil energy production had an average of 0.22 billion kWh and 0.13 billion kWh respectively between 1990 and 2004, however, in 2005, there was a steady increase for both renewable energy and fossil energy production through to 2016, but in 2017 and 2018, the share of production of fossil surpassed that of renewable energy with an all-time high of 2.08 billion kWh for fossil in 2018 and approximately 1.57 billion kWh all-time high in 2017 for renewable energy as shown in figure 10.

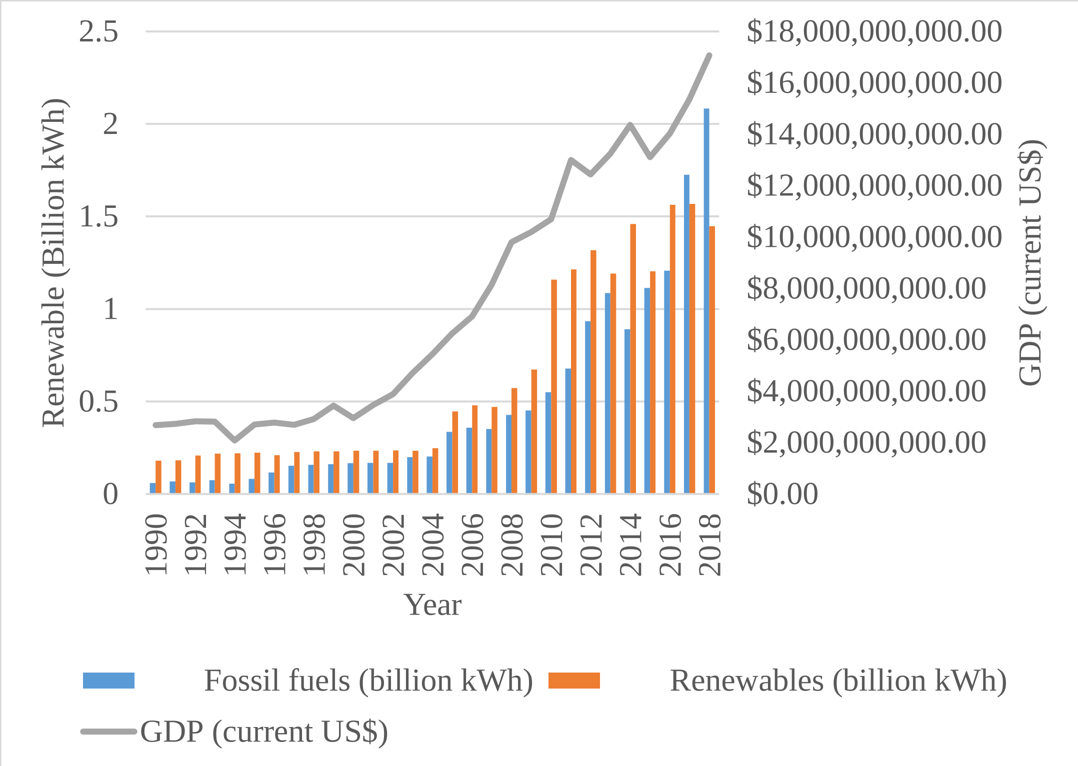

Figure 10: Mali Electricity Growth

With a strong positive relationship between renewable energy usage and the country's GDP which has a correlation coefficient of **r** = 0.9653 from Table 1 depicts the relationship between each country's GDP and renewable energy utilization. According to the table, Mali has a very strong link between GDP and renewable usage, with a correlation coefficient of 0.9653, followed by Benin republic and Burkina Faso, with correlation coefficients of 0.7033 and 0.6633, respectively. With a r value of 0.5916, the GDP of Cote d'Ivoire and renewable energy utilization have a moderate association. Finally, there is a weak link between Ghana's GDP and renewable energy usage, with a r value of 0.3771, whereas there is no correlation between Nigeria's GDP and renewable energy usage, with a r value of 0.0490.

Table 1 and r^2 value of 0.93 as seen in figure 11, it is safe to say that we can predict what the future holds for renewable energy in Mali.

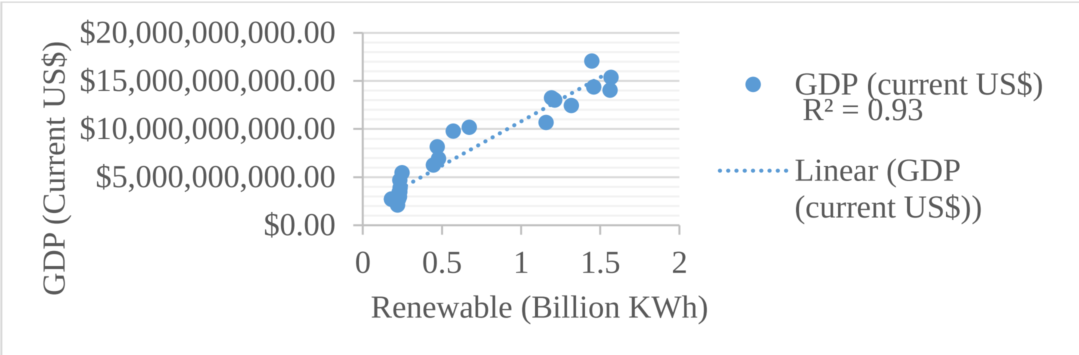

Figure 11: Relationship between GDP and Renewable in Mali

4.6 Nigeria

Nigeria is the largest economy in West African and Sub-Saharan Africa, also it is one of the biggest economies in Africa. It has the potential to grow its economy beyond the current state, but due to the deplorable state of the power generating equipment, it is unable to go beyond the 4000MW it generates. Its hydroelectricity has the potential to grow up to or more than 11,000MW (Nigeria iha, 2018 & Power Africa in Nigeria, 2021), reducing the dependence on fossils and emissions of CO_2 to the environment. Industrialization in Nigeria depends on fossil fuels for its survival which is why there is an increase in its GDP. From 1990 – 2001, Nigeria produced an average of approximately 8.65 billion kWh of fossil between 1990 and 2001 while approximately 5.86 billion kWh of renewable was produced in the same year. Share of fossil experienced steady growth from 2002 down to 2018 save for few reductions in between those years. Meanwhile, renewable energy production's total average is about 6.11 billion kWh between 1990 to 2018 with all-time high of 8.16 billion kWh in 2002 as shown in figure 12.

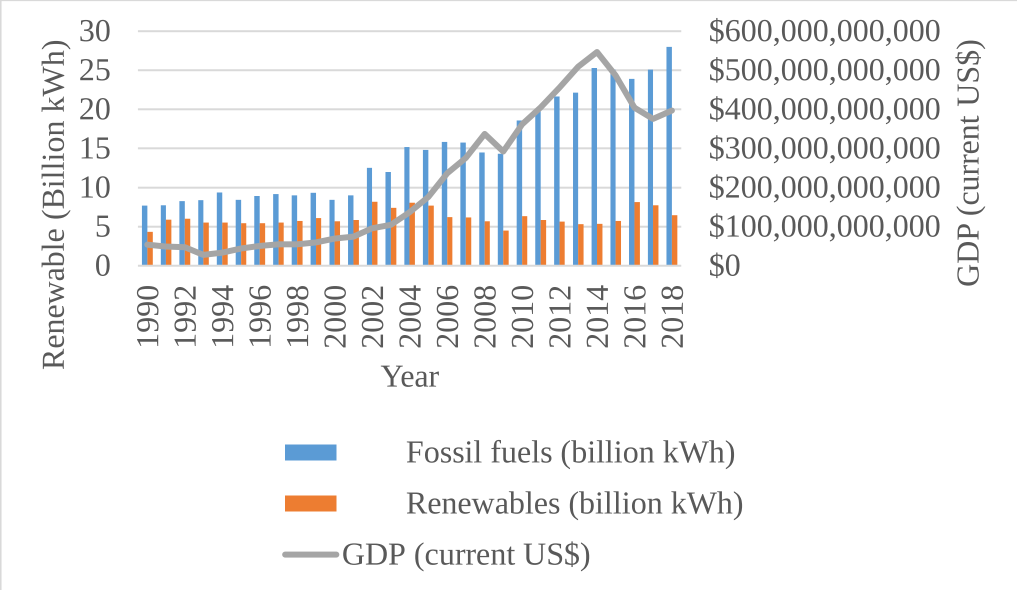

Figure 12: Nigeria Electricity Growth

Figure 13 shows that there is no correlation between renewable energy usage and the GDP, this means that the variables do not appear to be statistically related; the value of GDP does not appear to rise or fall in correlation with the use of renewable energy, however, this doesn’t mean that renewable energy doesn’t contribute to the Nigeria economy. The low r^2 of 0.0024 as shown in figure 13 and correlation coefficient r of 0.049 as seen in Table 1 depicts the relationship between each country's GDP and renewable energy utilization. According to the table, Mali has a very strong link between GDP and renewable usage, with a correlation coefficient of 0.9653, followed by Benin republic and Burkina Faso, with correlation coefficients of 0.7033 and 0.6633, respectively. With a r value of 0.5916, the GDP of Cote d'Ivoire and renewable energy utilization have a moderate association. Finally, there is a weak link between Ghana's GDP and renewable energy usage, with a r value of 0.3771, whereas there is no correlation between Nigeria's GDP and renewable energy usage, with a r value of 0.0490.

Table 1, shows that renewable energy contributed little to nothing to the GDP of Nigeria. Much of the variables of renewable energy and GDP cannot be explained. Hence, renewable energy usage does not affect the GDP.

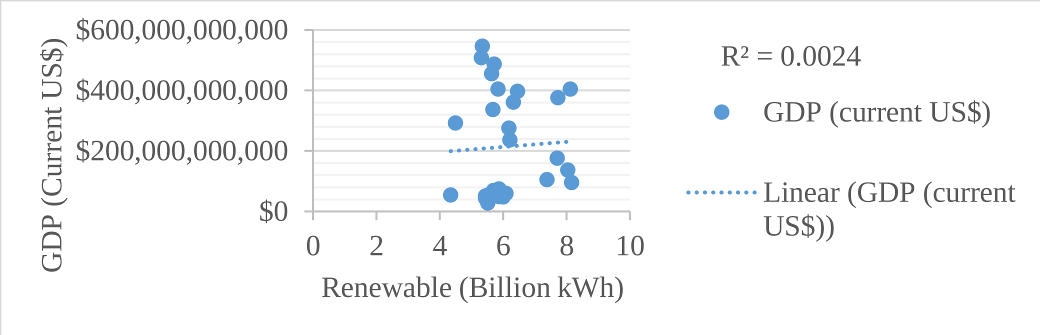

Figure 13: Relationship between GDP and Renewable in Nigeria

Lack of power infrastructure for generation and supply of power is one of the major causes of inefficient power generation and supply. Also, proper metering, accountability by agencies in charge of power generation and distribution are part of the causes. Lack of investment openness to allow private investment to come in and make renewable electric power accessible to the rural and urban dwellers.

Figure 14 shows a chart series of hydroelectricity production amongst the six selected countries. Nigeria, Ghana, and Cote d' Ivoire lead the chart with the highest hydroelectricity production values through the years between 1990-2018 with the sum of hydroelectricity production of 176.85, 175.39, and 48.22 billion kWh respectively as seen in Figure 16. Figure 14 shows that Ghana has an all-time high of about 8.326 billion kWh in 2014, Nigeria with 8.165 billion kWh all-time high in 2002, Cote d'Ivoire has an all-time high of 3.00 billion kWh in 2018. Mali and Burkina Faso have low production value while Benin only started hydroelectricity in 1996 according to figure 14.

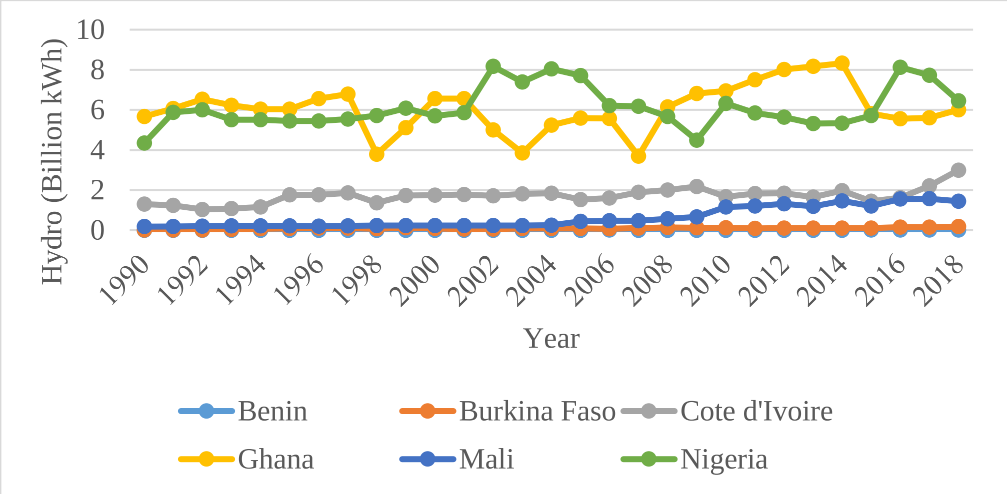

Figure 14: Hydro Electricity Production

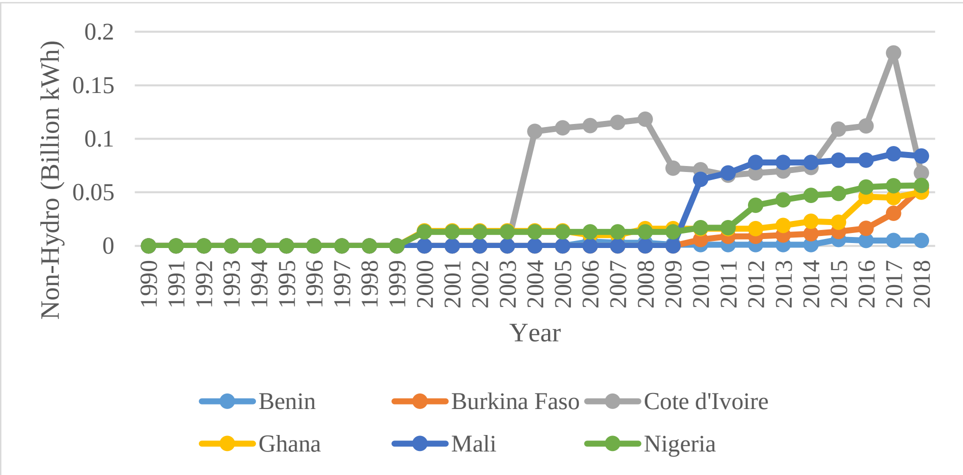

Figure 15: Non-Hydro Electricity Production

Figure 15 shows that between the years 1990 - 1999, there was no record of non-hydro electricity production amongst the six selected countries, but by the year 2000, Ghana and Nigeria recorded a starting production of 0.014 and 0.013 billion kWh respectively, by 2004 Cote d' Ivoire recorded a production output of 0.107 billion kWh which was significantly closer to the sum of what Ghana and Nigeria produced has been producing before it started production.

Benin recorded output of 0.004 billion kWh in 2006, by 2010, Burkina Faso and Mali also recorded output of 0.006 billion kWh and 0.062 billion kWh respectively. However Cote d' Ivoire has an all-time high of 0.18 billion kWh in 2017, surprisingly, despite coming in late into the mix Mali had an all-time high of 0.086 billion kWh. System failure and bad sector organization are contributing factors to the poor state of electricity distribution between the six selected countries. Also, recently, power system failures in countries like Nigeria have seen its power generation fall below 5000Kw.

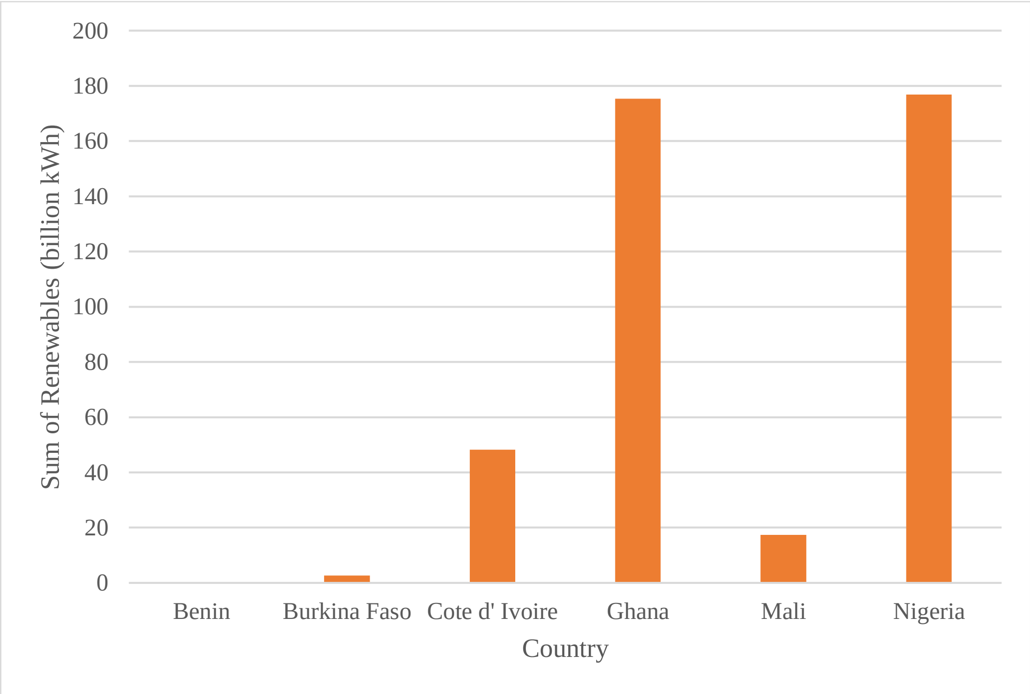

Figure 16: Sum of Hydro (Billion kWh) by Country

Looking at the sum of output in figure 16, between 1990 to 2018 the total sum of output for hydroelectricity for the six countries was 420.5 billion kWh while for non-hydro electricity was 3.24 billion kWh within the years in review. A conclusion can be drawn from figure 16 that, hydro-power generation can be used to drive industrialization in the six selected countries. Nigeria, Ghana, and Cote d’ Ivoire resources can be leveraged in these regions to act as support to others.

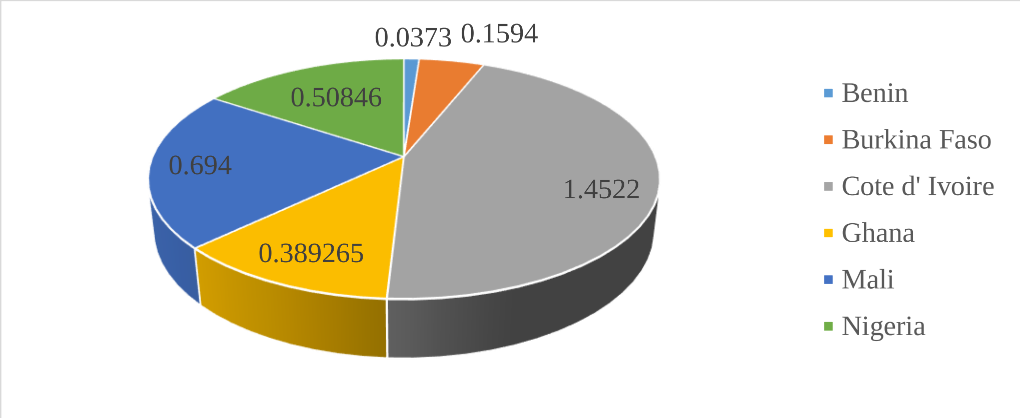

Figure 17: Sum of Non-Hydroelectricity Generation (Billion kWh)

Figure 17 has Cote d' Ivoire with the highest sum of non-hydro electricity production with a value at 1.45 billion kWh, Mali at 0.69 billion kWh, and Nigeria at approximately 0.51 billion kWh. Also, looking at the non-hydroelectric power generation, solar power for those in the landlocked area like in the case of Mali and Burkina Faso, while for countries in the coastal region can build a wind-powered generating plant to support the existing hydropower plant. Mini-grid systems can drive industrialization if all equipment needed for the mini-grid system is locally produced and also subsidized so that once it is been produce, they can supply excess power to the rural and urban areas. This will drive small businesses to work round the clock without having power issues.

Most business in Africa relies on power for sustainability and survival, once these problems can be fixed, it would be a win-win situation for both the country, its citizens and this will massively lead to growth in GDP.

4.7 Measure of Significance

This phase is just to confirm the statistical relevance of the variables in this research. It is always necessary to carry a significant test to evaluate the overall model.

Table 2: Significance Level

Country	Significance F
Benin	6.30439E-05
Burkina Faso	3.23732E-06
Cote d'Ivoire	4.70512E-06
Ghana	3.85467E-09
Mali	1.90588E-17
Nigeria	2.76007E-09

From the significance level table 2, all the significant F values for the six countries fall below 5% which means that we can rely on the regression result. The smaller the significant value to 0.05 the greater the probability that the regression is not by chance.

4.8 Measure of Reliability

To confirm the reliability of each coefficient in the model. The p-value is the probability of error. The difference between the p-value and significance F is that the p-value tends to check the relevance of each coefficient in the regression model while the significant F value checks the whole model itself.

Table 3: Analysis Result

Country		Coefficients	P-value	Lower 95%	Upper 95%
Benin	Intercept	4020082522	0.000182139	2124620940	5915544104
	Hydro (billion kWh)	6.09137E+11	0.296887242	-5.67091E+11	1.78537E+12
	Non-hydro (billion kWh)	1.50139E+12	3.6471E-05	8.80307E+11	2.12248E+12
Burkina Faso	Intercept	2091566830	0.192761878	-1123734590	5306868249
	Hydro (billion kWh)	38822515384	0.03111567	3807340464	73837690304
	Non-hydro (billion kWh)	2.49287E+11	4.77871E-05	1.43995E+11	3.5458E+11
Cote d'Ivoire	Intercept	-8010080778	0.317979056	-24181225083	8161063527
	Hydro (billion kWh)	13156564015	0.010918766	3291634983	23021493048
	Non-hydro (billion kWh)	1.56223E+11	5.96312E-05	89081734410	2.23364E+11
Ghana	Intercept	-25908724204	0.019169046	-47233189924	-4584258484
	Hydro (billion kWh)	5422057795	0.003415897	1962388467	8881727123
	Non-hydro (billion kWh)	1.1993E+12	4.52929E-09	9.12354E+11	1.48625E+12
Mali	Intercept	382870797.4	0.490334241	-741916103.6	1507657698
	Hydro (billion kWh)	13678160078	6.51778E-09	10343428814	17012891343
	Non-hydro (billion kWh)	-52129750056	0.021687256	-95998746136	-8260753977
Nigeria	Intercept	3.07382E+11	0.004709473	1.02995E+11	5.11769E+11
	Hydro (billion kWh)	-39097107868	0.026455923	-73249064188	-4945151548
	Non-hydro (billion kWh)	8.29024E+12	4.86199E-10	6.51629E+12	1.00642E+13

The P-values are shown in table 3 also prove that the linear models are reliable and all results are significant. At the %5 levels of significance, the results show that the P-values are significant, save for Benin hydro P-value and the intercepts P-value for Burkina Faso, Cote d'Ivoire, and Mali which also has higher P-value. We can further reject the null hypothesis for the remaining countries.

Also, the confidence interval shows that the estimated ranges with 95% confidence of the relationship between the GDP and Hydro and Non-Hydro forms of renewables. The result shows that the model in equation **Error! Reference source not found.** fits in this study.

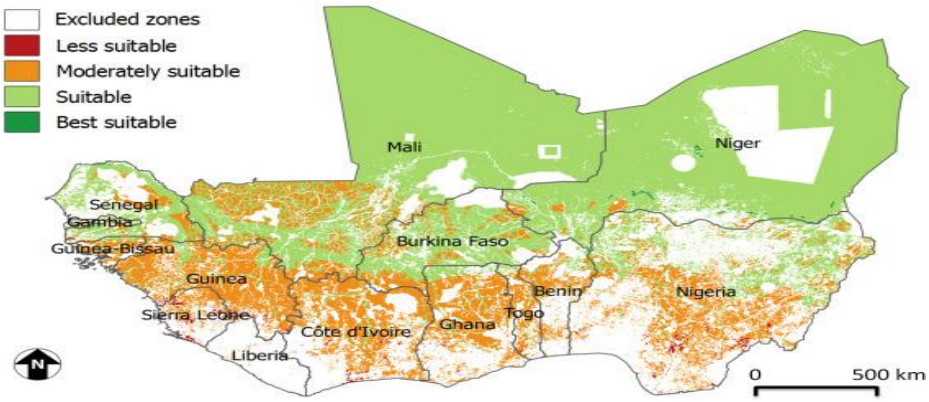

Figure 18: Land Suitability Classes

Chapter 5

CONCLUSION

These six selected African countries have the potential to become power blocks if the vast coastal lands are put to good use for wind and hydroelectricity while the Sahara can be a hub for a huge solar plant. In a short run, renewable energy may not be beneficial to the selected country however, in the long run, it would be beneficial for the these country because electricity generated through hydro can be channeled towards big manufacturing industries, while non-hydroelectricity generation to be channeled to homes, small scale businesses, and farms.

Benin and Burkina Faso are one of the poorest amongst the 6 countries that are affected by the inefficiencies of their country's regulator, however, Benin and Ghana are most likely to improve in the cost-effectiveness of rural electrification because most of their citizens live close to existing power lines, all that is needed is to make it accessible for their citizens respectively.

Regionally, Cote d'Ivoire, Ghana, and Nigeria can act as a support system to the other 3 countries, they have the capacity to produce 14%, 21.5%, and 47.5% of electricity, and combined, they account for 82.5% of the market in terms of capacity and almost 90% in terms of electricity generation, IAEA(2016). Though they rely on natural gas for more supply, hydroelectricity capacity can be improved since it is the second major most widely used way of generating power. Also, extensive solar power supply system should be built around the communities that have vast underutilized land, Yushchenko, A., et al (figure 17) estimated that large-scale grid-connected solar power systems in the best suitable areas have a technical potential of about 700–1800 TWh/year (or 2–5 MWh/year per capita) in the case of concentrated solar power, and 900–3200 TWh/year (or 3–9 MWh/year per capita) in the case of Photovoltaic and lastly, Off-grid photovoltaic technical potential is about 81 TWh/year in best countries around the West African region and them Mali and Burkina Faso in the case of this study. This leverage will go a long way to support these smaller countries and rural communities close to these regions. Likewise, Mentis, D. et al, 2015 submitted that minimal wind energy has been used, and Africa in its entirety has so much wind energy potential, also it should be abundantly localized, synchronized with the socio-economic systems. Nigeria is on the high yield of yearly wind energy while Benin is on the least wind power potential.

Furthermore, IoT (Internet of Things) technology will introduce great opportunities for sensing, processing, communicating, and integrating different microgrid systems to act as energy management systems that can be used for power efficiency and improved technological advancement.

5.1 Study Limitation

The results of this study must be seen in the context of some limitations. Non-renewables data was first collected in 1999 for Ghana and Nigeria, 2014 for Cote d'Ivoire, 2006 for the Benin Republic, and 2010 for Burkina Faso and Mali. This study's outcome may have been influenced by the small sample size. Second, because the data used in this study spans 29 years from 1990 to 2018, data analysis toolpak in Microsoft Excel was used to conduct the regression analysis. Because the data utilized in this study spans 29 years, analytical tool such as SPSS was not used. Finally, to have more reliable data to analyze, the share of solar and wind energy was collapsed into non-hydro electricity. These constraints might be alleviated if further research was conducted on each of the selected countries to gain a better understanding of the production location, production capacity, and so on.

Finally, from a practical point of view, this study may be a basic touchstone and can be added to the body of researches to drive valuable policy directions to address the lapses in the areas mentioned here. Further and advanced research can be carried out looking at the problems surrounding non-hydroelectric power generation. Also, the data used for this research can be used for further machine learning analysis with foreign direct investment data to check its effect on the usage of renewables.

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