

Effects of Renewable Energy Policies on Greenhouse Gas Emissions in Sub-Saharan Africa

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Abstract

Although several nations in Sub-Saharan Africa have passed legislation pertaining to renewable energy, there are significant differences in the effectiveness and design of these policy tools among African countries. This study provides an examination of renewable energy policies using Granger causality test to track and assess their related impacts on greenhouse gas emissions. Extracts of different renewable energy policies such as tenders, subsidies, tariffs, etc. were tested using regression analysis upon doing a study of a cross section of countries in Sub-Saharan Africa. While policy design has advanced, implementation has proceeded at a varying rate with results showing that countries that have had higher level of RE application indicate some reduction in greenhouse gas emissions as opposed to those that have had lower level of RE application, they indicate little or no inhibition against greenhouse gas emissions.

Scholarly literature shows some gap in policies with regard to carbon credits. This article suggests creating a thorough framework for carbon credit policies to speed up the adoption of clean technology across the Sub-Saharan Region.

Keywords: Competitive Tenders, Subsidies, Feed-in Tariffs for Renewables, Power Purchase Agreements, Renewable Energy Trading and Tariff Structure.

1. Introduction

Most African nations are starting to look for new ways to switch from their reliance on antiquated practices to more contemporary and effective types of energy generation considering the global trend towards more sustainable, cleaner, and renewable energy sources. A thorough assessment of the global energy transition was carried out by IRENA (2019). This is a global issue because renewable energy policies (REPs) will change how governments deal with each other (for example, pitting exporters against importers of gas and oil) and will result in profound structural changes to economies and societies. The increasing global reliance on fossil fuels, which often exacerbate internal violent conflicts, suggests that there may be an alternative beneficial relationship between peace and the energy transformation of the world. States that have made investments in renewable technologies will have greater power in the international arena, while countries that predominantly rely on fossil fuel earnings will face substantial challenges to their economic and social structures [1].

Many American states, as well as a large number of cities and municipalities, have decided to pass legislation that would

promote the use of renewable energy sources. American municipalities are enacting a great deal more regulations to facilitate the transition to renewable energy. Energy-efficient building codes, more energy-efficient municipal vehicle fleet requirements, and climate- and efficiency-related procurement practices (e.g., bulk purchasing agreements for municipal electric vehicle fleets or the use of zero-carbon electric power to operate city facilities) are a few examples of these. Furthermore, the Mayors' National Climate Action Agenda, commonly referred to as the Climate Mayors organisation, has the backing of more than 400 American cities and towns, housing over 70 million people—more than 20% of the nation's total population. For example, the bipartisan Climate Mayors initiative (Climate Mayors 2019) made public declarations opposing the Trump Administration's repeal of the Clean Power Plan and examination of the CAFÉ requirements for autos. Many cities also participate in major international city alliances such as the Carbon Neutral towns Alliance and the C40 grouping. These associations promote the exchange of best practices and support cities' interests regarding global climate issues, particularly during Conference of Parties meetings for the UN Framework Agreement on Climate Change [2].

This study offers some contribution of insights on the policies that must be implemented to transition from the use of fossil fuels to renewable energy sources in Sub-Saharan Africa (SSA). Although there is a wealth of literature on the factors that influence the output of renewable energy, most studies have not focused much on the impact of renewable energy policy as a major driver of greenhouse gas emission reductions. This study therefore, includes sets of variables, that is, renewable energy policy and greenhouse gas emissions in our model. Initially, we investigate this major driver of renewable energy generation for 4 SSA nations (Gabon, Zimbabwe, Benin and Burkina Faso) between 1990 and 2015 using a long-time horizon. Secondly, we incorporate the variable of renewable energy policy as a significant factor in driving the proportion of renewable energy production in the SSA. The human development index (HDI), gas price, trade policy variable, disposal of hazardous waste, and rents from natural resources are all controlled for in the sensitivity section [3-5].

1.1. Background of the study

Various renewable energy policies have been used for years to reduce or fight against greenhouse emissions all over the world. Sub-Saharan Africa is in the right direction in implementing renewable energy policies. According to a study based on publications on countries actively using renewable energy policies, there are several such policies that countries like Gabon and Zimbabwe have implemented them [6-8]. Below are the REPs that Gabon and Zimbabwe have implemented to some higher level:

1.1.1. Competitive tenders

August 2011 saw the release of a Request for Proposals, and concurrent tenders for various technologies were held. Bids could be submitted for several projects and multiple technologies by interested parties. Projects had to be larger than 1 megawatt, and bids for certain technologies must not exceed a certain amount, such as 75 megawatts for photovoltaic projects, 100 megawatts for concentrated solar projects, and 140 megawatts for wind projects. There were two steps in the bid evaluation process [9].

To proceed, bidders had to first meet a set of minimal standards in six different categories: financial, technical, commercial, and legal, environment, land, and economic development. For instance, the land review looked at tenure, lease registration, and evidence of land use applications, whereas the environmental assessment investigated approvals. The project's structure and the bidders' acceptance of the Power Purchase Agreement were among the commercial factors. Standard data gathering templates that were connected to an assessors' financial model were part of the financial examination. For every technology, there were established technical requirements. For instance, wind developers must provide an independently validated generation projection together with a year's worth of wind data for the approved location. In particular, the extensive conditions for economic development caused significant uncertainty among the bidders [10].

1.1.2. Public-Private Partnership Investment

More precisely, it refers to formally establishing a long-term collaboration (agreement) between the public and private sectors to provide the public with goods and services at fair prices. In collaboration with the public sector, the private sector allocates resources that facilitate the streamlining of interventions, the mitigation of expenses and hazards, and the promotion of knowledge and experience exchange. Long-term agreements between public and private organisations that guarantee residents' access to essential general services and commodities are covered by the PPPI. The PPPI strategy has been vigorously promoted by the Zimbabwean and South African governments lately in several programmes pertaining to spending, building, energy, and transportation. To address deeply rooted environmental, social, political, and socioeconomic concerns and carry out the mandate of achieving the objectives of both local and international development initiatives, the country has implemented extensive legislation endorsing PPPs as a vital tool.

Modifications to the energy production process through public-private partnerships (PPPs) have the potential to diversify and balance the energy grid, mitigate adverse environmental effects, and foster sustainable growth. Promoting investments in green projects through public-private partnership investment (PPPI) is one effective tactic.

1.1.3. Subsidies for solar panels and solar boilers

You can take advantage of several incentives that offer tax benefits if you wish to purchase or operate solar panels or solar boilers. You will receive a partial reimbursement for smaller-scale investments made in solar panels or solar boilers.

Among the essential prerequisites are:

You install solar panels on your business property. You have a small consumer connection (maximum 3 x 80A) and you apply for a subsidy before purchasing solar panels or solar boilers [11].

1.1.4. VAT refunds on solar panels

VAT will be charged if you purchase solar panels and have them installed on your commercial property. VAT must be paid on the electricity you provide to your energy provider as well. The VAT paid on the purchase and installation can be refunded. Among other things, how you reclaim the VAT depends on the type of business you operate (e.g. sole trader or private limited company). If you are a business owner and install solar panels on your own property, VAT is not required to be paid on these expenses. VAT is required to be paid on the electricity you provide to your energy provider [12,13].

1.1.5. Ambient air quality and biofuels

Outdoor air pollution is one of these problems. As a side effect of lowering greenhouse gas emissions that fuel climate change, renewable energy can help reduce local air pollution. Biofuels comprise the other element. Liquid fuels appear to be the most promising market for biomass used for commercial purposes [14].

1.1.6. Setting a target for renewable electricity generation

Establishing targets is the main thing the government can do to encourage the use of renewable energy in the electrical industry. Setting such a goal is essential to levelling the playing field for renewable energy sources in an environment where the market does not appreciate their social and environmental advantages. The government has already discussed such a goal. According to the draft White Paper on Renewable Energy, an extra 10,000 GWh of renewable energy should be produced annually, or over ten years, primarily from biomass, wind, solar, and small-scale hydropower [15].

1.1.7. Fixing quantity or price

Several policy tools are available for achieving this kind of goal. In general, government policy can be intervened in two ways: either by controlling the amount of renewable electricity produced (by, say, establishing targets for renewable electricity) or by controlling tariffs to regulate prices. The arguments in environmental economics about whether to restrict quantity or set prices are exemplified by the distinctions between these methods.

The benefits and drawbacks of utilising regulatory (such as standards, codes, and targets) and/or economic (such as taxation, subsidies, and tradable permits) instruments are covered in a large portion of this field's literature. The debate's backdrop is the significant transition in environmental policy over the past few decades from traditional, prescriptive "command and control" measures to "economic instruments.". Reducing the cost of compliance by using the "market's" creative force to pollution management has been the justification for the change [16-18].

1.1.8. Feed-in tariffs for renewables

Price serves as the policy instrument in an electricity FIT. The price of renewable electricity is set by the government, which often differentiates rates between various technologies. Tariffs are guaranteed for a predetermined amount of time and are determined by an electrical feed-in law. Distributors are also required by the power feed-in law to purchase all locally produced renewable electricity. The feed-in law for electricity in Germany, for instance, mandates that distributors purchase all their electricity from independent power producers (IPPs) who create renewable energy, but it does not state what proportion of renewable electricity must be purchased [19].

However, in Europe, experience has shown that this policy tool has produced the largest increases in capacity. One important element is the provision of relatively high, guaranteed prices, which promises significant returns on investments. The policy is in favour of producer surplus economically. By ensuring a market and a price, it would give developers of renewable electricity plants more security. Cross-subsidies, either from the "green" power users or from all taxpayers, are required to fund the policy's expenses [19-21].

1.1.9. Renewable electricity portfolio standards

A portfolio standard is the policy tool that most directly determines how much electricity comes from renewable sources. Under this policy approach, energy distributors have flexibility in meeting the requirement while the government sets a target through the Renewable Energy Portfolio Standard (REPS). The states of Arizona, Connecticut, Maine, Arizona, Massachusetts, Nevada, New Mexico, New Jersey, Pennsylvania, Texas (2000 MW under Governor Bush), and Wisconsin have passed laws setting targets for the renewable share of generation capacity; bills are pending in Kansas, Nebraska, Iowa, and Vermont. These states have probably the most international experience with REPS [22,23].

1.1.10. Renewables obligation

An additional means of regulating the amount of power produced is through a renewables mandate. A certain amount of electricity generation is "set aside" by the obligation and is put out to bid. Since the price per kWh is the main point of contention, bidding is used to set a price. But this isn't like the FIT, where the price is predetermined by the government. After the tendering procedure is over, the price is guaranteed for the duration of the contract. In the end, green consumers or taxpayers bear the increased expenses. To support renewable energy technology and cover the costs of nuclear stranded assets, the UK launched the NFFO initiative in 1990. This was reformulated as a renewable energy duty in 2000 [20].

Under this method, contracts with renewable energy generators at premium rates would be used to ensure the renewable capacity. Important components consist of the specific quantity of power from renewable sources is ordered by the government (x MWh); developers submit bids for proposed projects within each technology category, such as wind, biomass, etc.; the projects with the lowest per-kWh price are awarded power purchase contracts. Tenders are invited but must meet requirements. As certain technologies get closer to being competitive in the free market, they are released from this responsibility. Purchase of power is secured upon the outcome of a tender, and technologies that are no longer cost-competitive can be eliminated. The regional utilities are required to pay a premium for power from generators that have been awarded by the NFFO. The Fossil Fuel Levy, which is managed by the Non-Fossil Purchasing Agency, provides subsidies for the difference between the premium price and the average monthly power pool purchasing price [24].

1.1.11. Power purchase agreements

Offering PPAs to small-scale renewable IPPs, which would give them a set contract and agreed price over a few years, would minimize risk and providing certainty that they may sell their electricity, is one way to remove the barrier of discriminatory third-party access to the grid. Nonetheless, they are necessary if renewable IPPs are to be certain that they can recover their substantial upfront investment costs. PPAs must, in fact, be especially designed to consider the cost structure of renewable energy sources. "An interim

regulation regarding conditions for the grid connection of power from small and distributed generators to facilitate the implementation of the set aside programme" should be developed by the government, according to a DANCED/DME study. It could be preferable to restrict PPAs to small-scale projects, as renewable energy projects smaller than 50 MW (and energy efficiency equivalent to less than 10 MW), to prevent the lock-in to set costs. It is assumed that as renewable IPPs expand and become more commercialized, they will be able to compete with other technologies; however, in the interim, as these technologies work through their learning curves and lower prices, they will require the stability of permanent contracts [25].

1.1.12. Non-discriminatory access to the grid

Nondiscriminatory grid access is another regulatory criterion to produce renewable energy. Emerging IPPs require guarantees that they will have access to the grid, particularly considering restructuring. A technical standard for a national grid connection code may be developed in the future. The standard would be particular to the kind and magnitude of the electrical resource. These could include guidelines for sharing connection installation expenses and synchronisation requirements. Some power and storage balancing might be required if the amount of renewable energy in the system increased significantly, although this is not anticipated in the short- to medium-term. The benefits encompass lowering transmission losses, postponing investments in increasing the capacity of the transmission and distribution systems and enhancing the quality of the electrical supply in the region of the distributed generator.

1.1.13. Renewable energy trading and tariff structure

The establishment of a trading and tariff structure is necessary to support the expansion of the renewable electricity market. Establishing guidelines that internalise the external costs of all power is a helpful first step. The most crucial aspect of establishing these tariffs is transparency; nevertheless, other proposals include full cost accounting, which accounts for external expenses, estimating costs using the long-term marginal cost of energy, and paying IPPs near loads for averted line losses. Applying such a set of criteria would have the effect of reflecting the true costs of non-renewable energy sources through the inclusion of externalities, hence increasing the relative cost-competitiveness of renewable electricity [25,26].

The second stage would be to outline the requirements for "green" electricity. One suggestion is that green certificates could represent the added value of electricity derived from renewable sources. This strategy was tested when providing "green power" at the World Summit on Sustainable Development. To be considered as renewable energy, a conversion's sustainability had to be evaluated and the resources from which the electricity was generated had to be disclosed. Following the Summit, the National Electricity Regulator (NER) made it clear that it would control how the green electricity market developed. On the NER website (www.ner.org.za/gwatts/green_watts_certificates.htm),

several businesses and government organisations are already listed. Its three-year business plan includes green electricity as a fundamental obligation [26].

2. Methodology

The objective of this study is to examine the causal links between renewable energy policies and CO₂ emissions using Granger causality test. The data used are the annual time series data covering the period between 2000 and 2020. CO₂ emissions per capita (in kilotons tons per capita) are taken from the WDI (World Bank Development Indicators). Quantitative and qualitative secondary data have been collected through (1) document or artifact reviews to get comprehensive and historical information, and (2) case studies to fully understand or depict a country's experiences in a policy and conduct comprehensive examination through cross-comparison of cases.

In this scenario, CO₂ emissions is the outcome, and is denoted by Y , this outcome is caused by observed input X and unobserved variable U . These causal relations are characterised by the structural equation

$Y = f(X_1, U)$. In the case of a linear model, we have that

$$Y = \beta_0 + \beta_1 X_1 + U.$$

The counterfactual outcomes are defined by fixing the inputs of function f . The counterfactual outcome Y when variables (X_1, U) are fixed at values (x_1, u) is given by $Y(x_1, u) = \beta_0 + \beta_1 x_1 + u$. The causal effect of a unit increase in input X_1 on outcome Y is the expected difference between the counterfactual outcomes Y when X_1 is fixed to values $x_1 + 1$ and x_1 . Ceteris Paribus means that the remaining inputs of Y , that is U , are fixed at constant values. This setup generates the following effect:

$$\begin{aligned} Y(x_1 + 1, u) - Y(x_1, u) \\ = \beta_0 + \beta_1(x_1 + 1) - (\beta_0 + \beta_1 x_1) \\ = \beta_1(x_1 + 1 - x_1) = \beta_1 \end{aligned}$$

2.1. The causal model

The Structural Causam Model (SCM) dates back to Haavelmo, who describes a causal model characterised by a set T of observed and unobserved variables such that for each variable $Y \in T$ we have an associated autonomous (or structural) function f_Y and an exogenous error term ϵ_Y which are not observed. Arguments of the function f_Y are the variables in T that cause Y . Without loss of generality, we can assume that terms are statistically independent. All variables are defined in common probability space (I, F, P) . A common goal in policy evaluations to evaluate the causal effect of the treatment T on and outcome Y . The identification of causal effects can be broadly understood as methods to control for unobserved confounding variables V that cause both T and Y . Consider a simple model where an endogenous treatment T that causes an unobserved abilities A , and both T, A cause the outcome Y . Agent's unobserved variable V plays the role of a confounder that generates selection bias. V causes both the

treatment choice T and the unobserved skill A [27].

2.2. Sampling strategy: Extreme or deviant cases sampling

The population size is a target population of all 46 countries in Sub-Saharan Africa. My sample size is depended on its targeted population. The mode of selecting samples stems from the goal of identifying information-rich cases that allows me to study a case in depth. The criterion for selection of cases is to choose countries that are unusual or special about renewable energy policy implementation or non-implementation of the same. For example, a country with low record of renewable energy policy implementation is compared with one that has a high record of renewable energy policy implementation. Highly successful policy programs are studied to establish their relevance in carbon dioxide emissions reductions.

2.2.1. Energy supply and CO2 emissions

A sample of four African countries has been made. On one hand, it is Benin and Burkina Faso, whose level of renewable energy policy implementation is partial. On the other hand, it is Gabon and Zimbabwe with improved or higher renewable energy policy implementation. The two sets of countries are tested for carbon dioxide emissions using Granger Causality Test. Benin and Burkina Faso's primary energy supply is dominated by conventional biomass (wood, charcoal, and agricultural waste), which accounts for the majority of the total. This is complemented by imported electricity from adjacent nations, as well as domestic output from thermal (oil-based) and expanding solar power plants. Gabon's energy mix consists mostly of thermal power generation (using indigenous natural gas and imported oil products), significant hydropower resources, and the traditional use of biomass. Hydropower accounts for a significant share of its electrical generatio. Zimbabwe's primary energy supply is distinguished by its extensive domestic coal resources used for power generation and industry, significant hydropower capacity (though frequently affected by droughts), electricity imports to supplement domestic shortfalls, and widespread reliance on biomass for residential heating and cooking [28-31].

3. Results

3.1. Energy supply and CO2 emissions

3.1.1. Benin and Burkina Faso

Table 1, and its corresponding line chart in Figure 2, depict the equivalent carbon dioxide emissions in kilotons by Benin and Burkina Faso. The level of renewable energy policy implementation is lower or partial, and stem from the following:

(a) Overwhelming dependence on fossil fuels and biomass.

Both Benin and Burkina Faso have a strongly skewed energy mix that relies on non-renewable and conventional sources, which contribute significantly to carbon emissions [29].

Thermal Power Generation: To meet increasing electricity

demand, both countries rely heavily on diesel and heavy fuel oil power plants. These are extremely inefficient and produce a lot of CO₂ per unit of electricity generated. They are frequently employed as a quick-fix option since they have lower initial capital expenses than large-scale renewable projects [29].

Traditional Biomass: The vast majority of the population, particularly in rural regions, relies on wood, charcoal, and agricultural waste for cooking and heating. This is not included in normal "energy sector" emissions, although it is a significant source of CO₂ and other greenhouse gases due to inefficient burning and deforestation [32].

(b) Key Barriers to Renewable Energy Policy Implementation

(i) Economic and financial constraints

High Initial Capital Costs: Renewable energy infrastructure (solar farms, wind turbines, mini-grids) requires a significant upfront investment. Both Benin and Burkina Faso have low government budgets and struggle to allocate sufficient finances in the absence of external aid or private investment [33,34].

Investment Risks: Political and economic uncertainty might discourage foreign direct investment (FDI) and private sector participation. Investors may perceive initiatives in these countries as riskier than in more stable locations [35]. Limited Access to Finance: Local banks may lack the competence and willingness to make favourable loans for renewable energy projects, which they may regard as experimental and untested [36].

(ii) Infrastructural and technological barriers

Weak Grid Infrastructure: National power grids are frequently underdeveloped, unreliable, and incapable of accommodating intermittent sources such as solar and wind without considerable modifications. Integrating a large percentage of variable renewables necessitates the use of smart grid technology and energy storage technologies, both of which are costly and technically demanding [37].

Technical Expertise Gap: There is a paucity of locally trained people to design, implement, and maintain advanced renewable energy systems. This leads to a reliance on foreign knowledge, which raises costs and undermines long-term viability [38].

(iii) Policy and regulatory challenges

Inconsistent or Unclear Policies: While both countries have stated renewable energy goals (for example, Benin's goal of 25% renewables by 2025), achieving them is sometimes impeded by bureaucratic red tape, a lack of clear implementation standards, and frequent policy changes. This causes ambiguity for developers [39].

Unfavourable regulatory frameworks: The absence of important mechanisms such as Feed-in Tariffs (FiTs) are guaranteed pricing for renewable energy fed into the grid. Power Purchase Agreements (PPAs) are long-term

arrangements that make projects bankable. Net metering allows prosumers (those who both produce and consume energy) to sell excess electricity back to the grid [29].

Subsidies for Fossil Fuels: Governments may subsidise diesel or electricity produced from fossil fuels, making it artificially cheaper and more difficult for renewables to compete on price [40].

(iv) Socio-economic and geographic factors

Priority of Energy Access above Source: Governments frequently prioritise expanding access to power (any electricity) in order to stimulate economic growth and meet fundamental necessities, rather than addressing the carbon footprint of that energy [29].

Distributed Population: A sizable rural population is spread across huge areas. Connecting them to a centralised grid is extremely costly [29]. While decentralised renewables (solar household systems, mini-grids) are the optimum option, implementing them on a global scale necessitates significant coordination and investment.

Affordability: Even if renewable technology is accessible, the initial cost of a solar system may be prohibitively expensive for many households and small businesses, despite the fact that it will be less expensive over time [29].

(v) Country specific distinctions

Burkina Faso: Has a tremendous potential for solar energy (high solar irradiance) and is making progress with projects such as the Zagtouli Solar Power Station, one of West Africa's largest. However, security concerns in certain sections of the country impede development and distract government focus and resources away from energy policy [41].

Benin is focussing on solar and has the ability to generate bioenergy from agricultural waste. Its strategy is frequently linked to regional alliances and programs, which can stymie independent decision-making while also providing access to larger financial pools such as those of the World Bank or African Development Bank [42].

3.1.2. Gabon and Zimbabwe

The core claim is that two African countries, Gabon and Zimbabwe, have implemented strong policies to increase their use of renewable energy (like solar, hydro, or wind). As a direct result of these policies, their national carbon dioxide (CO₂) emissions, measured in kilotons, have begun to consistently decrease. This decrease is visually represented by a downward trend on a line chart. Table 1, with a corresponding line chart in Figure 1, depict the following:

(a) The Policy: "Higher Renewable Energy Policy Implementation"

This statement denotes that governments have actively developed and implemented laws, regulations, incentives, and national plans to shift energy production away from fossil fuels (such as coal, oil, and natural gas) and towards

renewable sources [43]. The policies include:

(i) Financial incentives such as tax exemptions, subsidies, and feed-in tariffs for businesses and homeowners who install solar panels or build renewable energy projects.

(ii) Regulatory targets: Establishing mandated national targets, such as "50% of all energy must come from renewables by 2030."

(iii) Infrastructure investment refers to government funding for large-scale projects such as solar farms, wind parks, and the modernisation of hydroelectric facilities.

(iv) Research and Development (R&D): Funding for local universities and businesses to create new renewable technologies appropriate for the local environment.

(v) Removing Barriers: Simplifying the process of acquiring licenses for renewable projects and upgrading the grid to accommodate variable energy sources such as solar and wind.

(vi) Hydropower: Because both countries have extensive river systems, hydropower is an obvious and significant renewable energy source.

(vii) Solar: Both are located in areas with strong sun irradiation, making solar energy quite practical.

(b) Measured Outcome: "Continuous decrease in CO₂ equivalent emissions."

This is evidence that the policies are effective.

CO₂ equivalent emissions (CO₂e) translates the influence of all greenhouse gases (such as methane from agriculture or landfills, and nitrous oxide) into an equivalent amount of CO₂ with the same global warming potential. This provides a comprehensive picture of a country's overall contribution to climate change.

Steady downward movement: This suggests a trend, not a one-year anomaly. A "steady" fall on a line chart indicates that the reduction is long-term and is most likely due to structural changes (such as new energy infrastructure) rather than temporary reasons (such as an economic slump).

(c) Causality: How Policies Lead to Reduction

Granger Causality Test confirms the results, particularly of Gabon and Zimbabwe. Renewable energy initiatives reduce emissions through a direct displacement effect: Transitioning from fossil fuel energy to renewable energy leads to reduced emissions.

A country's electricity grid is a combination of energy sources. When a new solar plant or hydro dam goes online, it produces electricity. This clean electricity replaces electricity produced by a fossil-fuel-powered facility (such as a coal or diesel generator). Because renewable energy generates electricity with zero or extremely low emissions, overall emissions from the electrical sector decrease. As additional renewables are introduced to the grid, the displacement effect increases, resulting in a "steady downward movement" in the emissions line chart.

(d) The Bigger Picture and Importance

The case of Gabon and Zimbabwe is interesting for various

reasons:

Leadership in the Global South: It illustrates that poor countries are not simply waiting for developed nations to address climate change. They are taking on active leadership roles in the energy transition [36].

Economic Benefits: Beyond environmental benefits, these policies boost energy security (by reducing reliance on imported fossil fuels), create new opportunities in the renewable sector, and have the potential to improve air quality and public health [36].

Meeting International commitments: This step helps both countries satisfy their commitments under international agreements such as the Paris Accord, which require governments to reduce their emissions.

Data-Driven Policy: The fact that this result is being recorded and displayed on a chart emphasises the significance of monitoring and data in evaluating the effectiveness of government initiatives. Government policy has led to a transition towards renewable energy infrastructure, resulting in verifiable and long-term environmental benefits (lower CO₂e emissions). This establishes a clear cause-and-effect story [44].

Gabon and Zimbabwe are typical examples of how focused policies can effectively propel a country towards a more sustainable and low-carbon future.

3.2. Causal relationship

Heavy reliance on fossil fuels and traditional biomass in Benin and Burkina Faso causes high carbon emissions due to inefficient energy use. Insufficient renewable policies stem from economic constraints, weak infrastructure, and regulatory challenges, which perpetuate dependence on carbon-intensive sources. In contrast, Gabon and Zimbabwe's strong renewable energy policies directly lead to a consistent decline in CO₂ emissions by displacing fossil fuel-based power. These cases demonstrate that targeted policy implementation is a primary driver in reducing national carbon emissions.

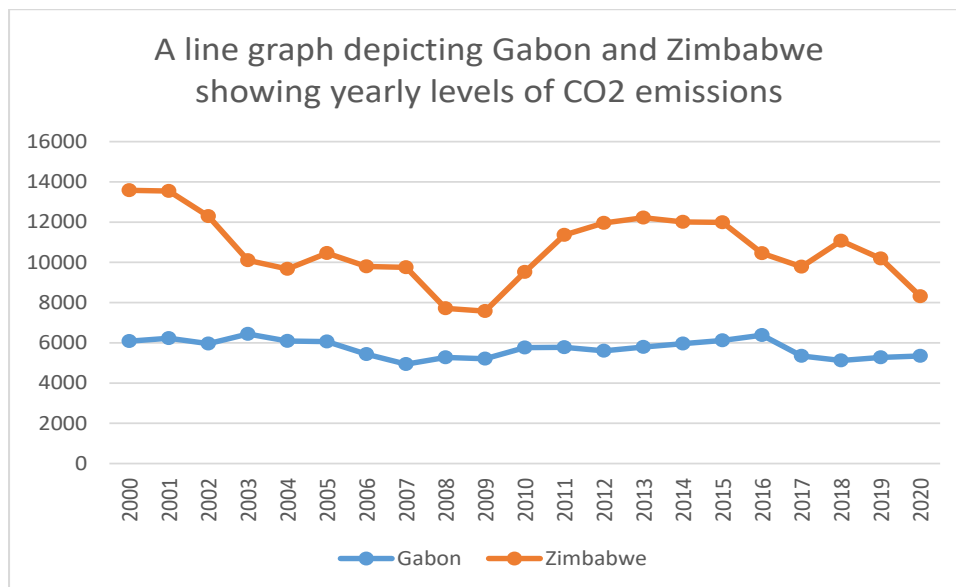
3.3. Renewable energy policies Vs. CO₂ emissions, in table and figures

Table 1 Shows two sets of Sub-Saharan African countries on trend of carbon emissions (CO₂): the first set is for those that are adequately utilizing renewable energy policies and the second set are those that do not adequately utilize renewable energy policies, over a period of 2000-2020.

Name of country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<i>A cross-section of countries that are adequately applying renewable energy policies</i>																					
Gabon	6080	6225.75	5955.4	6436.4	6091.1	6058.3	5437.1	4941.11	5272.57	5207.58	5762.09	5777.14	5601.97	5790.27	5962.05	6115.8	6383.7	5344.7	5120.4	5274.5	5349.2
Zimbabwe	13578.9	13545.4	12293.4	10103.3	9672.3	10455.9	9791.8	9754.3	7711.6	7572.7	9518	11357.6	11954.9	12216.8	12010.7	11988.7	10450.2	9781	11069.9	10185.3	8312.5
<i>A cross-section of countries that are yet to adequately apply renewable energy policies</i>																					
Benin	1424.5	1735.1	2177.3	2443.2	2646.4	2899.6	3471.4	3998.2	4017.6	4417.2	4825.1	4652.6	4444.7	4676.4	5186.1	5505.6	6739	6876.2	7604	7475.5	7980.4
Burkina Faso	1048.93	1024.23	1027.23	1102.48	1133.84	1151.29	1400.48	1682.82	1909.6	1930.1	2094.3	2200.4	2693	2947	2997	3801.8	3997.8	4625.2	5147.7	5646.5	5456.7

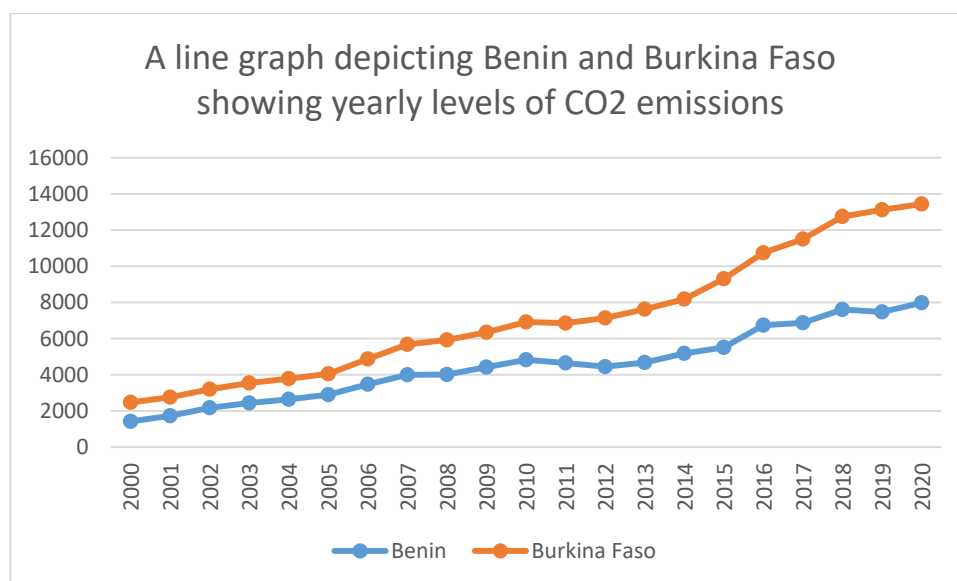
Data source: World Development Indicators

Table 1: Shows Two Sets of Countries: Gabon and Zimbabwe; Benin and Burkina Faso



Source: Extrapolation from Table 1 above

Figure 1: A Line Graph of the First Set of Countries (Gabon and Zimbabwe), with Improvement in Utilizing Renewable Energy Policies



Source: Extrapolation from Table 1 above

Figure 2: A Line Graph of the Second Set of Countries (Benin and Burkina Faso), with a Slack in Utilizing Renewable Energy Policies

4. Discussion

Climate change poses a threat to several significant African businesses, including agriculture, energy, and water supply. The combustion of fossil fuels is responsible for around 80% of anthropogenic greenhouse gas emissions, making it the single biggest human contributor to climate change. Africa's CO₂ emissions are expected to rise in the next decades despite declining emissions elsewhere (such as in Europe and the America), particularly if complete implementation of renewable energy policy receives less emphasis.

Based on the results from Table 1 and its corresponding Figure 1 above, investing in renewable energy policies (REPs) has the potential to significantly reduce carbon dioxide emissions and accelerate the shift to a low-carbon energy system, hence lowering energy intensity. The mechanisms known as the "multiplier effect," "structural effect," and "technique effect" can be used to classify the effects of the amount of money invested in renewable energy on carbon dioxide emissions. According to the "multiplier effect" mechanism, shifts in the economy brought about by the amount of money allocated to renewable energy have an impact on emissions of carbon dioxide. Similarly, increasing investments in REPs can reduce greenhouse gas emissions through structural and technological effects. The causal relationship between REPs and GHG emissions was examined using annual data from 2000 to 2020. In summary, nations that modified or tightened their energy policies saw a decrease in GHG emissions, in particular, Gabon and Zimbabwe. On the contrary, nations (Benin and Burkina Faso) that paid less attention to the application of REPs, saw an increase in GHG emissions.

A regression model is used to observe and analyse the link between the independent (RE policy) and dependent (MtCo₂) variables as shown by the equations below. In this

work, regression model estimate was employed to ascertain the impact of the RE policy on the decline in greenhouse gas emissions. Below is the regression model for the conditions in Sub-Saharan Africa.

$$MtCO_2 = \lambda + \beta (RE \text{ policy})$$

In the absence of a policy (REP), the regression model for the assumption in Sub-Saharan Africa is given the below model.

$$MtCO_2 = \lambda + \beta (0)$$

In this scenario, putting all factors constant, there will be a rise in GHG emissions. Benin and Burkina Faso is close to this scenario.

And finally the regression model equation below, is for the scenario in which eleven RE strategies are used applied (and in this case, Gabon and Zimbabwe) to observe and analyse the movement in toxic gas emissions in Sub-Saharan Africa.

$$MtCO_2/GWh = \lambda + \beta (11)$$

With a higher level of REPs application/implementation, a reduction in GHG emissions is evident, *ceteris paribus*. This study therefore, focuses on the causal links between two variables: carbon dioxide emissions and renewable energy policies, whilst controlling for other independent variables such as human development index (HDI), gas price, trade policy variable, disposal of hazardous waste, and rents from natural resources. The long-term correlation between CO₂ emissions and renewable energy regulations is investigated. The results of the econometric analysis verify that policies supporting renewable energy sources and CO₂ emissions have a positive long-term relationship.

Otherwise, the causality relationships vary greatly between the countries, making it impossible to give any universal policy recommendations [45,46].

5. Conclusion

Despite the other causalities to CO₂ emissions, renewable energy policy is just one of the other initiatives put in place to curb the adverse effects of climate change. This study looks at how renewable energy regulations mentioned above can help implement environmentally friendly technology that have negligible or no impact on the environment. It does this by looking at the issue through the lens of carbon dioxide emissions (CO₂). It is possible to adopt a low-carbon policy that benefits the environment. Hence, understanding the causality relationships between the variables will assist policy-makers in designing the appropriate policies. This study examines the causal association between CO₂ emissions and renewable energy policies for SSA's four countries over the period of 2000–2020, and to assess this association, we have used Granger (1969) causality test.

Furthermore, it is undeniable that the market for carbon credits is expanding quickly and is contributing to the transition away from fossil fuel energy sources and towards a low-carbon economy. To ignite the revolutionary activity that will result in a low-carbon economy in emerging nations, financial transfer is required. To accelerate the adoption of clean technology throughout the economy, the paper recommends developing a comprehensive framework for carbon credit regulations. To this end, REPs catalyse the fight against climate change effects by contributing to the reduction of GHG emissions, for a safer planet [47].

Declarations:

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Data Availability Statement: I, the main/corresponding author, am the point of contact with reference to obtaining access to raw data used in analysing this study. The data described can be freely and openly accessed through the following links:

<https://databank.worldbank.org/reports.aspx?source=2&series=EG.FEC.RNEW.ZS&country=GAB,ZWE,BEN,BFA>

<https://databank.worldbank.org/reports.aspx?source=2&series=EN.ATM.CO2E.PC&country=GAB,ZWE,BEN,BFA>

<https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS>
<https://data.worldbank.org/indicator/EN.ATM.CO2E.PC>
data.worldbank.org.

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