Afropolitan Journals

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ISSN: 3027-2114 www.afropolitanjournals.com

Energy-Growth Nexus: A Systematic Review of Empirical Evidence and Policy Implications

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DOI: *https://doi.org/10.62154/ajesre.2025.018.010656*

Abstract

The relationships between energy consumption and economic growth have been extensively studied in the economic and energy literature, yet empirical findings remain inconclusive. This systematic review examines the existing theoretical and empirical research on the energy-growth nexus, analyzing studies from developed and developing economies. The review explores four primary hypotheses: the growth hypothesis (energy consumption drives economic expansion), the conservation hypothesis (economic growth influences energy demand), the feedback hypothesis (a bidirectional relationship), and the neutrality hypothesis (no causal relationship). Findings indicate that the energy-growth relationship varies across countries depending on factors such as income levels, energy mix, and methodological approaches. Developed economies tend to exhibit a shift toward energy efficiency and the conservation hypothesis, while developing economies largely support the growth hypothesis, highlighting their dependency on energy for industrialization. The increasing role of renewable energy in sustaining economic growth is also examined, with evidence suggesting that while renewable investments support long-term economic sustainability, short-term transition challenges exist. The review underscores the need for balanced energy policies, renewable energy investment, and technological innovations to ensure sustainable economic growth while minimizing environmental impact. Future research should focus on regional-specific dynamics, the role of institutional factors, and the implications of climate policies on the energy-growth relationship.

Keywords: Energy Consumption, Economic Growth, Energy-Growth Nexus, Renewable Energy, Sustainability.

JEL Classification: Q41, Q43, Q48, O13, C83,

Introduction

The relationship between energy consumption and economic growth has been a subject of intense academic debate for decades. As economies expand, their energy demands typically increase, fueling industrialization, transportation, and modern infrastructure. However, the direction and nature of this relationship remain contested, with scholars proposing four main hypotheses as to whether economic growth drives energy consumption or vice versa: the growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis (Ozturk, 2010; Payne, 2010).

Empirical studies have sought to validate these theoretical hypotheses, often yielding mixed results. Some studies support the growth hypothesis, which states that energy

consumption is a driver of economic expansion. For example, a study by Shahbaz et al. (2013) in developing economies found a unidirectional causality from energy consumption to GDP growth. Conversely, the conservation hypothesis, which suggests that economic growth influences energy demand, has been observed in energy-efficient economies such as Japan and Germany (Narayan & Popp, 2012). Meanwhile, the feedback hypothesis posits a bidirectional relationship, implying that energy and economic growth reinforce each other (Lee & Chang, 2008). Lastly, the neutrality hypothesis argues that there is no significant causal relationship between energy use and economic growth, often observed in economies with diversified energy sources (Chontanawat et al., 2008).

Given the vast body of literature on the subject, a systematic review is essential to synthesize empirical findings, identify gaps, and provide clarity on the energy-growth nexus. Previous meta-analyses, such as those by Ozturk (2010) and Stern (2011), have highlighted the heterogeneous nature of the relationship due to factors like income levels, energy mix, and methodological differences across studies. This paper aims to build upon existing reviews by integrating recent empirical findings and assessing the policy implications for both developed and developing economies.

In light of global energy transitions towards renewable energy sources, the findings of this review are particularly relevant. As countries shift from fossil fuels to sustainable alternatives, understanding whether economic growth can be decoupled from traditional energy consumption becomes imperative (Balcilar et al., 2018). By critically analyzing recent studies, this paper sought to answer the questions: What does the empirical evidence say about the energy consumption–economic growth nexus? What are the main theoretical explanations for the relationship between energy consumption and economic growth? How do empirical studies differ in their findings based on methodology, region, and energy type? What role does renewable energy play in influencing economic growth patterns? What policy recommendations emerge from the literature to ensure sustainable energy and economic growth? Therefore, this paper systematically analyses and synthesises the existing empirical and theoretical literature on the nexus between energy consumption and economic growth. In light of the mixed evidence in the literature, the paper critically examines the methodological approaches used in past studies, highlights key debates, and identifies areas where further research is needed.

The findings would be particularly useful for governments, researchers, and international organizations seeking to formulate energy policies that support sustainable economic growth. As global economies transition toward greener energy sources, understanding the energy-growth nexus is increasingly important. Countries need to balance economic development with energy efficiency, climate commitments, and energy security. Policymakers must consider whether energy conservation strategies could hamper economic growth or whether investment in renewables can sustain long-term

development. This review contributes valuable insights to these discussions by synthesizing current evidence and highlighting gaps for future research.

Understanding the nexus between energy consumption and economic growth is crucial for policymakers, particularly in the context of global energy transitions, economic development strategies, and sustainability goals. It is crucial for designing energy policies, investment strategies, and sustainable development plans (Stern, 2011). Given the increasing importance of renewable energy and global commitments to reducing carbon emissions, the energy-growth nexus has gained renewed attention in academic and policy circles.

The next sections of this paper explore the theoretical framework of the energy-growth nexus, present an empirical review of global studies, discuss methodological approaches, analyse the role of renewable energy, and conclude with policy implications and future research directions.

Review of Literature

Several theoretical frameworks attempt to explain the relationship between energy consumption and economic growth. *The neoclassical growth theory*, pioneered by Solow (1956), suggests that technological progress drives long-term economic growth, with energy playing a supporting role. Based on Solow's (1956) model, economic growth is primarily driven by labor and capital, with energy playing a secondary role. Energy is considered an input in production, but technological progress is the main determinant of long-term growth. In contrast, the *endogenous growth theory* argues that energy is an essential input in production functions, influencing productivity and capital accumulation (Apergis & Payne, 2012). It emphasizes technological advancements and human capital accumulation (Romer, 1990). Energy is integrated into production functions, implying that its availability directly influences total factor productivity and innovation.

Concerning the link between energy consumption and economic growth, four hypotheses have emerged: the growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis. The *growth hypothesis*, also known as, *energy-led hypothesis*, posits that energy consumption is a driver of economic expansion (Shahbaz et al., 2013). It entails energy consumption affecting economic growth which subsequently means that a reduction in energy consumption as a result of conservation policy will affect economic growth negatively. Energy consumption is assumed to affect economic growth and consequently, any decrease in energy consumption as a result of conservation policy will affect economic growth negatively. On the other hand, the *conservation hypothesis*, also called *growth-led hypothesis* posits that economic growth stimulates energy demand as industries and households consume more energy (Narayan & Popp, 2012). This hypothesis views economic growth as a main factor of energy consumption, and as such, increase in economic growth will invariably leads to increase in energy consumption.

The *feedback hypothesis* postulates that energy consumption and economic growth mutually reinforce each other (Lee & Chang, 2008). It postulates a bi-directional causality, that is, energy consumption affects growth and vice versa. The *neutrality hypothesis* postulates that there is no strong causal link between energy and economic growth, often observed in diversified economies (Chontanawat et al., 2008). The neutrality hypothesis postulates no causal relationship between economic growth and energy consumption
Several studies have been conducted on these four hypotheses though with mixed results. These studies and their respective findings are reviewed as follows.

Studies on Growth Hypothesis

The subsection reviews studies conducted on the growth hypothesis, starting from Hassan et al. (2008) which employed panel data that included variables such as manufacturing performance, energy consumption, capital, labour inputs, corruption variable, and economic freedom variable for sampled low-income and middle-income countries in Sub-Saharan Africa (SSA) between the years 1995 and 2013, examines the connection linking energy consumption with manufacturing performance. The panel cointegration test reveals that there is significant cointegration among the variables for both the low-income level and the middle-income level in the SSA. According to the authors' findings using the Fully Modified Ordinary Least Square analysis, in the long run, an increase in manufacturing performance is associated with an increase in energy consumption. These findings hold true for both the selected low-income and middle-income SSA nations. This indicates that countries in sub-Saharan Africa with both low and middle incomes are reliant on external sources of energy. In this respect, the findings of the research indicate that energy is a significant component in socioeconomic development for both the SSA countries with low incomes and the SSA countries with middle incomes. This study does not consider the influence of institutional factors on energy consumption.

With a difference in geographical scope when compared with the above study, Gbadebo and Chinedu (2009) examined the relationship between energy consumption and the economy of Nigeria from 1970 to 2005 using variables such as real GDP, gross fixed capital formation, labour force, crude oil consumption, electricity consumption, and coal consumption. Coal, petroleum oil, and electricity were the three forms of energy that were utilized in the investigation of this possible connection. The application of the co-integration methodology yielded findings that led to the conclusion that there is a positive relationship between the present-day level of energy consumption and economic growth. Lagged values of energy consumption and economic growth were found to have a negative relationship with the exception of coal, which had a positive association with both variables. The findings of the research suggest that increased energy consumption is a significant factor in economic growth, which has an implicit effect on economic growth during lagging periods and both an implicit and explicit impact on economic growth during the current

period in Nigeria. Therefore, the authors concluded that it is important that the sector be given more significance, even if it means capitalizing on the possibilities that are abundant in the sector, in order to boost overall economic development. This study, however, did not include other institutional factors like rule of law absent of violence and others in its analysis.

Using a different estimation technique when compared above, Adebayo et al. (2021) re-examined the correlation between urbanization, CO_2 emissions, gross capital formation, energy use, and economic growth in South Korea, which has not yet been assessed using recent econometric techniques, based on data covering the period between 1965 and 2019. The methods utilized by the authors include autoregressive distributed lag (ARDL), dynamic ordinary least squares (DOLS), and fully modified ordinary least squares (FMOLS). According to the findings, the ARDL bounds test demonstrates that there is a connection, at least in the long term, between the variables of interest. The accumulation of evidence suggests that CO_2 emissions are directly responsible for economic growth. Therefore, the study concludes that in light of the growing environmental consciousness around the world, it is essential for South Korea to make the transition to renewable energy sources in its energy mix. This will make it possible to make use of renewable energy sources and create an ecosystem that is environmentally sustainable. Aside the fact that this study was basically a country specific outside Africa it also suffered the same short forming as that of Nadeem and Munir (2022).

Nadeem and Munir (2022) analysed how various forms of energy use—oil, coal, gas, and electricity—are connected to overall economic growth. Using Pakistani yearly time series data from 1972 to 2016. Employing variables like GDP, capital, labour, human capital, total oil consumption, oil consumption in the industrial sector, oil consumption in the agricultural sector, oil consumption in the transport sector, oil consumption in the power sector, an ARDL bound test and a Granger causality test were carried out. Long-term positive and substantial effect on economic growth was seen for oil used by the manufacturing and transportation sectors, gas consumed by the fertiliser and power sectors, and electricity consumed by the industrial sector. Yet, the negative and severe effects on economic growth are caused by the use of oil in agriculture and power generation, coal in power generation and brick kilns, gas in cement production, and electricity in agriculture. However, the findings also showed that there is no causal relationship between oil consumption and economic growth, while economic growth does have a unidirectional causal relationship with increases in coal consumption in the brick kilns sector, gas consumption in the industrial sector, and electricity consumption in the agricultural sector. The study made a good attempt by analyzing sectoral oil consumption but suffered shortcomings of not including institutional factors as determinants.

Studies on Conservation Hypothesis

Reviewed in this subsection are those studies on conservation hypotheses conducted between 2012 and 2024, beginning from Azlina (2012) which used a vector error-correction model (VECM) to investigate the possibility of a causative relationship between energy consumption and economic growth in Malaysia. The author takes into consideration the dual function that energy plays in both the demand and supply of the resource. The results of applying the Johansen cointegration technique indicate that the long-run movements of economic development, the price of energy, the framework of the economy, capital, labour, and energy use in Malaysia are related by two cointegrating vectors. In addition, the findings demonstrate that there is a unidirectional causative relationship between the economic growth and consumption of energy. The study did not check the impact of other for institutional factors as it only make use of two out of six.

In another study, Dan'maraya (2012) determined how the use of energy changed the manufacturing productivity in Sub-Saharan Africa (SSA) between 1995 and 2012. The study adopted variables such as electricity, fossil fuels, capital, and labour and, he used the Granger causality test and Fully Modified Ordinary Least Squares (FMOLS). The long-term coefficients point to the manufacturing sector's success being determined by its use of electricity, fossil fuels, capital, and labour. In a similar vein, the Granger causality test results in SSA find unidirectional causation between manufacturing performance and energy consumption. The study did not include institutional factors as part of the variables used for this study in order to also capture the diversity of the countries that comprises of the region.

Bayramoglu and Yildirim (2017) examined the link between energy consumption and economic growth utilizing the United States as a case study and achieving the real model via the use of an asymmetric ARDL bounds test technique. The data set for quarterly observations span the years 1973:1 through 2013:4. According to the results, the impact of energy consumption is asymmetrical over the course of a long period of time, but not over a short period of time. The impact of the unfavourable component of energy consumption on the economic growth is negligible and insignificant statistically over the course of a long-time frame. However, the research only took into account two variables and did not take into account any of the other factors that might affect how much energy is used.

In another study, Twerefou et al. (2018) used the panel cointegration techniques and data on total energy consumption, electricity consumption, and petroleum consumption to establish the causal relationship between energy consumption and economic growth in West Africa. The study focused on the relationship between energy consumption and economic growth in West Africa. According to the findings, there is no evidence of a direct link between overall energy, electricity, and hydrocarbon consumption and economic growth in the short term. However, the study finds a relationship flowing in only one direction, and that relationship is from economic growth to the consumption of electricity which suggests that measures aimed at reducing electricity consumption may not have an

impact on economic growth. On the other hand, the researchers discovered that the consumption of electricity and petroleum has a favourable and substantial effect on development over the long term. The study did not include other variables that determine economic growth.

In another study, Ozcan et al. (2019) found that economic growth and patterns of energy consumption contributed to the improvement of countries' environmental performance levels by using a sample of 35 OECD countries over the period of 2000–2014. The data employed includes energy consumption, real gross domestic product (GDP) per capita, and CO_2 emissions. The study findings emphasize that countries' economic growth paths and their patterns of energy consumption have started to correlate with their environmental policies, which is in opposition to the findings of a significant body of empirical research that has been done recently. The authors concludes that the dynamic interrelationships that exist between the levels of energy consumption, economic growth, and environmental degradation that are experienced by different countries reveal the absolute necessity of promoting sustainable development through a coexistence mechanism rather than one that is based on the concept of trade-offs. The study did not disaggregate energy consumption into renewable and non-renewable energy consumption.

Adedoyin et al. (2021) investigated the role that economic policy instability plays in the intersection of energy development and pollution for 32 countries located in Sub-Saharan Africa over the time span of 1996 to 2014. The following variables are employed: CO_2, GDP, the sum of gasoline production, renewable power generation, world uncertainty index, renewable energy generation and economic policy uncertainty index, nonrenewable energy and economic policy uncertainty index. According to the findings using a one-step system-GMM as the estimation technique, real GDP as well as the production of non-renewable energy both contribute to an increase in CO_2 emissions. However, despite the fact that economic policy instability is another factor that contributes to high emission rates in the territory, this factor's moderating influence on the effects of both renewable and non-renewable energy production ultimately results in a lower level of emissions in the region. The study only included 32 countries out of the whole sub-saharan Africa countries there by the result cannot be used for the entire region.

Ene et al. (2022) using data ranging from 1980 to 2019, investigated the effect of Nigeria's electricity supply on the country's manufacturing output. The study incorporates variables such as manufacturing sector output, electricity supply, capital, labour force, inflation rate, exchange rate, and technology. The outcome of running an autoregressive distributed lag (ARDL) model indicated that there is a negative and insignificant relationship between the amount of electricity supplied and the output of the manufacturing sector. On the other hand, technology has a constructive and substantial relationship with the production of the manufacturing sector in the short term. The study is country-specific and the results.

Studies of Feedback Hypothesis

This subsection covers studies carried out on the feedback hypothesis which postulates a bi-directional causality, that is, energy consumption affects growth and vice versa.

To begin with, Ghali and El-Sakka (2004) used a vector error-correction (VEC) model to test for the presence and direction of causation between output growth and energy use in Canada using variables such as capital, labour, and energy. The results show that the long-run movements of production, labour, capital, and energy use in Canada are linked by two cointegrating vectors using the Johansen cointegration method. Then, using a VEC formulation, the short-run dynamics of the variables show that Granger causality between production growth and energy use is running in both directions. The study omitted other important variables that determines growth.

Using different estimating methods and variables, Saboori and Sulaiman (2013) investigated the cointegration as well as the causative connection between economic development, carbon dioxide pollution, and energy consumption in a number of countries that are members of the Organization of Southeast Asian Nations (ASEAN) between the years 1971 and 2009. The Autoregressive Distributed Lag (ARDL) methodology as well as the Granger causation test based on the Vector Error-Correction Model (VECM) were put to use. The variables adopted for the research include per capita CO_2 emissions, per capita real income, and energy use per capita. The study reported a statistically significant positive relationship between carbon pollution and energy consumption in both the short run and the long run. When compared to the short-run elasticities, the long-run elasticities of energy consumption with regard to carbon pollution are significantly greater. This suggests that the amount of carbon pollution has been discovered to increase over time in the designated ASEAN countries in relation to the amount of energy that has been consumed. The findings of the Granger causality test indicated that there is a two-way Granger causal relationship between CO_2 pollution and energy consumption in each of the five ASEAN countries. This suggests that carbon pollution and energy consumption are closely connected to one another in a significant way. The study failed to include other important variables affecting economic growth particularly human capital development.

Using a different methodology and scope when compared with the above, Ouedraogo (2013) using three stages consisting of panel unit root tests, panel cointegration tests, and Granger causality, investigated the dynamic causal relationships that exist between energy consumption, energy prices, and growth, as well as the relationship that exists between electricity consumption, prices, and growth for fifteen ECOWAS countries. The time span covered for this study is from 1980 to 2008 and includes variables such as GDP per capita, energy consumption per capita, and energy prices. The findings suggest that in the long term, GDP and energy consumption, as well as GDP and electricity, move in tandem with one another. The study also discovered unidirectional long-run and short-run causation by predicting these long-run relationships and checking for causality using panel-based error

correction models. The findings show that the direction of causation runs in the opposite direction in the short run, from energy consumption to GDP, and in the long run, from GDP to energy consumption. The author, therefore, indicates that the absence of or restricted access to contemporary energy services could hinder economic growth and jeopardize the development prospects of these countries. Aside the fact that the study covers the scope outside Africa, it has shortcomings of not including institutional factors as part of the control variables.

Using the World Uncertainty Index to determine the long-term relationship between economic policy uncertainty and energy consumption for nations that were considered to have a high level of geopolitical risk between the years 1996 and 2017, Adams et al. (2020) used variables such as energy consumption, economic growth, geopolitical risk, economic policy uncertainty, and carbon dioxide (CO_2) emissions and carried out Panel Pooled Mean Group Autoregressive Distributed latency (PMG-ARDL). The researchers were able to determine that economic growth and energy consumption are both factors that contribute to carbon dioxide pollution. Additionally, there is a substantial relationship between economic instability and CO_2 pollution in the long run. The panel causality analysis carried out demonstrated a bidirectional relationship between CO_2 emissions and energy consumption, economic policy uncertainty and CO_2 emissions, economic growth and CO_2 emissions, but unidirectional causation from CO_2 emissions to international threats. The findings imply that significant adjustments need to be made to energy policies in order to account for the unpredictability of economic policy and the dangers posed by geopolitics. This study suffered the same shortcoming as that of Onatunji (2022).

In another study, Onatunji (2022) used the Toda-Yamamoto causality test and the bootstrap-corrected causality methodology to investigate the causative relationship that exists between the use of electricity and the production of industrial goods in economic communities of West African States (ECOWAS). The variables used include industrial output, electricity consumption, capital, labour, and financial development. Only Benin, Cote d'Ivoire, Gambia, Guinea, Liberia, Nigeria, Senegal, and Sierra Leone's manufacturing production increased as a result of an increase in the availability of electricity, according to the findings of the long-term study. In addition, Benin, Burkina Faso, Gambia, Ghana, and Nigeria, as well as Sierra Leone, show there exists a unidirectional causality extending from the consumption of electricity to the production of industrial goods. However, in Cote d'Ivoire, Guinea Bissau, Liberia, and Niger, no indication of a causal relationship between the consumption of electricity and the production of industrial goods has been established. The author recommends that the relevant energy stakeholders in the subregion need to reprioritize their policy framework so that they can place a greater emphasis on the electricity sector of their economies. This is necessary in light of the fact that electricity consumption has been identified as an important driver of industrial growth in the countries that make up West Africa. The study failed to check for effect of income level in the region.

Studies on Neutrality Hypothesis

The neutrality hypothesis indicates no causal relationship between economic growth and energy consumption. Studies concerned with this hypothesis are reviewed as follows.

Using a multivariate paradigm, Soytas and Sari (2007) looked into the connection between energy and production at the industry level in Turkey. The research demonstrates three cointegrating vectors that link labour, capital investment, energy use, and value addition. The VEC findings show a single line of causality connecting value-added and energy usage. According to the study's findings, output and energy intake seem to be intertwined. Thus, the development of manufacturing value added may be accelerated by energy-saving devices and improved energy efficiency. Human capital development which is an important variable is being omitted in this study.

Merven et al. (2010) analyzed the energy consumption, supply, and resources of some member states of the Southern African Development Community (SADC) in 2005. Using the Long-Range Energy Alternatives Planning (LEAP) model, projects energy consumption in Angola, Botswana, Mozambique, South Africa, Tanzania, Zambia, and Zimbabwe through 2030. The other countries are not included due to a lack of reliable data. The forecasts are made by first establishing a historical relationship between each nation's sectoral GDP and growth in population to energy consumption, and then using both the linkage and the predictions of these variables to estimate energy consumption. The study suggests anticipation of significant growth in consumption in these nations, particularly in the forms of biomass and electricity. The study is lacking as it does not include any institutional variables.

In another study, Yang et al. (2013) suggested a pollutant emissions index that is able to indicate the degree of environmental quality, and it measures the environmental quality of China's 28 provinces from 1995 to 2010 using a dynamic objective assessment approach based on the overall differences for the very first time. After that, a panel data model was used to conduct an analysis of the influence that China's and the region's increasing energy consumption and economic growth have had on the quality of the environment. The variables employed in the analysis include GDP, trade openness, energy efficiency, and energy price. The findings show that there was a significant positive relationship between the emissions index and the scale of economies and industrial structure. On the other hand, there was a significant negative relationship between the emissions index and energy efficiency, energy prices, and trade openness. The results showed that the emissions index varied among different regions and that there was a great potential for emission reduction. The authors recommended that emissions reduction strategies should be developed with the local environment in mind; the study also suggests that increasing energy efficiency is one of the most effective ways to cut emissions. The study did not include other variables that affect energy consumption as well as growth.

Mpatane (2015) investigated the effect that the availability of electricity had on the production of the manufacturing sector in South Africa between the years 1985 and 2014. With variables such as manufactured output, real interest rate, manufacturing employment, inflation rate, and electricity supply, the Cointegrated VAR methodology was used to investigate the influence that South Africa's electricity supply has on the country's total manufactured production. The investigation revealed evidence of two vectors that integrated together. It was discovered that there is a favorable relationship between manufactured output and manufacturing employment over the long term, as well as between manufactured output and the supply of electricity. According to the findings, both the availability of electrical power and the number of people employed in manufacturing sector play a part in achieving a state of homeostasis in manufactured production. The author concludes therefore that it is imperative that decision-makers in South Africa carry on with the process of formulating and enacting policies that are geared toward the promotion and expansion of the electricity industry. This will not only improve the performance of the manufacturing industry but will also result in the creation of additional employment across the country. Aside that this is this specific country study it fails to disaggregate energy into renewable energy and non-renewable energy.

Zeren and Akkus (2020) examined the relationship between economic openness, renewable and non-renewable energy consumption for the Top Emerging Countries of Bloomberg during the period of 1980-2015. With the help of the Dumitrescu-Hurlin panel causation test, the Westerlund panel cointegration test with numerous structural breaks, and the Pesaran CCE-MG cointegration estimator, the authors investigate the long-term relationship that exists between the panels. According to the findings, it was discovered that the consumption of energy sources that do not replenish themselves is one of the primary reasons for the increase in commercial transparency. In addition, it was discovered that an increase in the consumption of renewable energy was a significant component in lowering the degree to which these emerging countries were receptive to conducting trade. The study first to consider the influence of institutional factors.

With a difference in choice of variables employed when compared with the above study, Mensah et al. (2019) evaluated the causative connection between economic growth, consumption of fossil fuels for electricity, carbon pollution, and the price of oil from 1990 to 2015 for 22 African countries. Using variables like growth output, capital stock, labour, energy use (fossil fuel), carbon emissions, and oil price, the study engaged the use of the PMG panel ARDL, the results of which show a bilateral causal link flanked by fossil fuel energy consumption and economic growth as well as fossil fuel energy consumption and carbon emissions in the long and short-term for all panels as well as a unilateral causality from carbon emissions to economic growth in long-term and short-terms for non-oil exporters; however, a bilateral causal relationship only in the long-term for oil exporters. In as much as this study did justice by considering the influence of oil production in the region it does not include institutional factors to show the diversity of the region.

In another study, Olubiyi (2020) used a combination of the panel vector autoregressive, and system generalized method of moments (SYS-GMM) to examine the connection between energy consumption, human well-being, and carbon emissions in developing African nations. The research looked at Egypt, Nigeria, and South Africa from 1991 to 2016 using a variety of factors, including carbon dioxide emissions, mortality rate, per capita income, unemployment rate, fuel, coal, and electricity. The findings point to a one-way causal relationship between fuel, coal, and per capita income. The mortality rate was shown to have a direct and causative relationship between coal and carbon dioxide. The mortality rate and energy consumption link are two-way. The findings of SYS-GMM demonstrate the heterogeneous nature of the repercussions of energy use on quality of life. Coal usage decreases the unemployment rate whereas electricity consumption lessens the number of babies dying in infancy. The usage of fuel contributes to an increase in the death rate. The unemployment rate goes down due to Carbon dioxide, but infant mortality keeps rising. Infant mortality rates are decreased by using electricity. Thus, it is suggested that higher coal consumption and efficient use of power must be promoted for the goal of policy harmonization aimed at promoting well-being in the growing economies of Africa. The study only looked at three countries out of the 54 African countries.

Le and Bao (2020) examined the impact of non-renewable and renewable energy consumption in sustainable development in 16 Latin American and Caribbean Emerging markets and developing economies (EMDEs). The study uses annual data from 1990 to 2014 and employs a multivariate methodology to analyze the data. According to the findings, the consumption of both renewable and non-renewable sources of energy, in addition to other factors such as government spending, gross fixed capital formation, trade openness, and financial development, has a positive influence on economic growth in the countries that were chosen. The empirical findings according to the authors imply that the EMDEs in Latin America and the Caribbean should appropriately implement fiscal policies for macroeconomic stabilization in combination with policies regarding finance and international trade as well as effective energy strategies in order to achieve their goals regarding sustainable development. However, the study failed to include relevant variables like human capital development.

Lekana (2020) investigated the effect that the quality of governance has on the correlation between economic growth and energy consumption in a sample of twenty (20) countries located in sub-Saharan Africa (SSA) over the course of 21 years, beginning in 1996 and ending in 2017. The author made use of various methods, including the generalized method of moments (GMM) and the Granger test. The findings indicate that the consumption of energy is an important contributor to the expansion of economic activity in SSA countries and that the level of political and administrative competence is a driving force behind this connection. The study failed to consider all the six variables of the institutional factors.

With a difference in geographical scope when compared with the above, Asaleye et al. (2021) investigated the long-run impact of electricity consumption on the performance of the manufacturing sector using canonical cointegrating regression for the period of time spanning 1981 to 2019 in Nigeria using variables such as output, employment, capital, electricity consumption, interest rate, exchange rate, and capital consumption. The findings of the study show that electricity consumption and credit extended to the manufacturing sector both have a negative relationship with output, as indicated by the facts available by the outcome in the output equation. Also, when it comes to the employment equation, high electricity consumption and high-interest rates both have a negative impact on employment. The authors summarize that the impacts of the consumption of electricity as an input in the manufacturing sector have not resulted in an improvement in the performance of the sector. In the end, the researchers make recommended that according to the findings of the research, one of the most important steps that should be taken to remedy the current state of affairs is to establish a system that will promote energy efficiency by increasing the output of the power sector while simultaneously reducing waste. The study did not include variable as foreign direct investment.

In another study, Usman et al. (2021) investigated the impact of information and communication technology (ICT) on the economic performance of specific South Asian countries, namely Bangladesh, India, Pakistan, and Sri Lanka, from 1990 to 2018. The variables employed in the research include GDP, ICT, energy consumption, and trade openness. The study employed the use of bound testing cointegration technique as well as error correction modelling. According to the results of the research, ICT played a substantial and beneficial role in the expansion of the Indian economy over time. In a similar vein, India is the only nation in South Asia to have attained energy efficiency as a direct consequence of the increased use of ICT. Nevertheless, it was found that energy consumption was a significant factor in determining GDP per capita in India and Pakistan. Additionally, GDP per capita has a significant and substantial effect on both India's and Pakistan's energy consumption. The findings suggest that South Asian economies are trying to increase the significance of ICT in their economies in the same way that their regional partner, India, is doing. This will, on the one side, increase their growth in the economy, and on the other side, help them achieve energy efficiency. In addition, the strategy of reducing energy consumption may end up being deleterious to the industries of South Asian countries. However, the study failed to consider other factors affecting economic growth also it does not include the effect of institutional factors.

Appiah et al. (2022) employ a multi-quantitative strategy to investigate institutional affiliation in determining whether or not there is a connection between sustainable energy and economic expansion. The study analysed the sub-Saharan African countries between the years 1990 and 2020. The authors find a favorable connection between development and renewable sources of energy. On the other hand, the study finds a positive effect with

regard to institutional association, whereas a negative moderating impact with regard to the population was reported. In addition, institutional integrity has a detrimental impact on the developing relationship between renewable energy and energy. The study suggested that in order for Sub-Saharan Africa to achieve long-term growth, the region should increase investment in renewable energy initiatives, establish organizations that are well-resourced, and determine alternative plans for the development of renewable energy. The study failed to dissect the region according to income level.

Methodological Approaches in the Literature

All these studies reviewed used various econometric methods, had varying regional scopes, and used different explanatory factors in their models. The methodological approaches employed in the literature include granger causality tests, cointegration and error correction models, and panel data econometrics.

Granger causality tests, which were used to determine the direction of causality between energy consumption and GDP, show mixed results: Some studies found unidirectional causality from energy to GDP growth (Shahbaz et al., 2013), some bidirectional causality, and others found feedback effect between energy and economic growth (Lee & Chang, 2008). However, no causality (neutrality) was found in some economies with diverse energy sources (Chontanawat et al., 2008).

As regards cointegration and error correction models, studies that used Johansen cointegration test identified long-term relationships between variables (Narayan & Popp, 2012) while vector error correction models (VECM) was used to analyze short-run and long-run dynamics. With studies conducted using dynamic panel models (e.g., Arellano-Bond estimator) for cross-country comparisons, results were found to vary based on country-specific characteristics.

Methodology

This study adopts a systematic review methodology to analyse the existing literature on the relationship between energy consumption and economic growth. The approach involves identifying, selecting, and synthesizing relevant empirical and theoretical studies to provide a comprehensive understanding of the energy-growth nexus.

Data Sources and Search Strategy

Relevant academic articles, working papers, and policy reports were sourced from peer-reviewed journals and databases such as Scopus, Web of Science, Google Scholar, ScienceDirect, and EconLit. The search keywords used were combinations of "energy consumption," "economic growth," "energy-growth nexus," "renewable energy," "causality," "cointegration," and "Granger causality". The sampling technique employed was snowballing (backward/forward reference tracking).

Selection Criteria

This study employs the inclusion/exclusion selection criteria. The inclusion criteria for selecting studies were (1) empirical studies published in the last two decades (2000-2024) focusing on energy consumption and economic growth; (2) studies employing econometric methodologies, including Granger causality, cointegration analysis, and panel data models; (3) research covering both developed and developing economies to provide a comparative perspective; and (4) papers analysing the role of renewable energy in the energy-growth relationship. These inclusion criteria as well as the exclusion criteria are summarised in Table 1.

Table 1 Inclusion/Exclusion Criteria

Criteria	Inclusion	Exclusion
Publication type	Peer-reviewed journal articles, working papers, and policy reports.	Books, conference abstracts, non-English publications.
Methodology	Empirical studies using econometric techniques.	Theoretical papers without empirical analysis.
Geographical scope	Studies covering developed and developing economies.	Studies limited to non-global regions (e.g., single-city analyses).
Energy focus	Explicit analysis of energy consumption (total/renewable/non-renewable) and GDP.	Studies on energy efficiency without growth linkages.
Time frame	2000–2024.	Pre-2000 studies (unless seminal).

The review classifies studies based on theoretical perspectives—growth, conservation, feedback, and neutrality hypotheses—in an ascending chronological order.

Study Selection Process

This study adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to synthesize empirical evidence on the energy-growth nexus. The approach involves identification, screening, eligibility assessment, and inclusion of relevant studies to provide a comprehensive understanding of the energy-growth nexus. The selection process followed in the study is illustrated by the PRISMA flowchart in Figure 1.

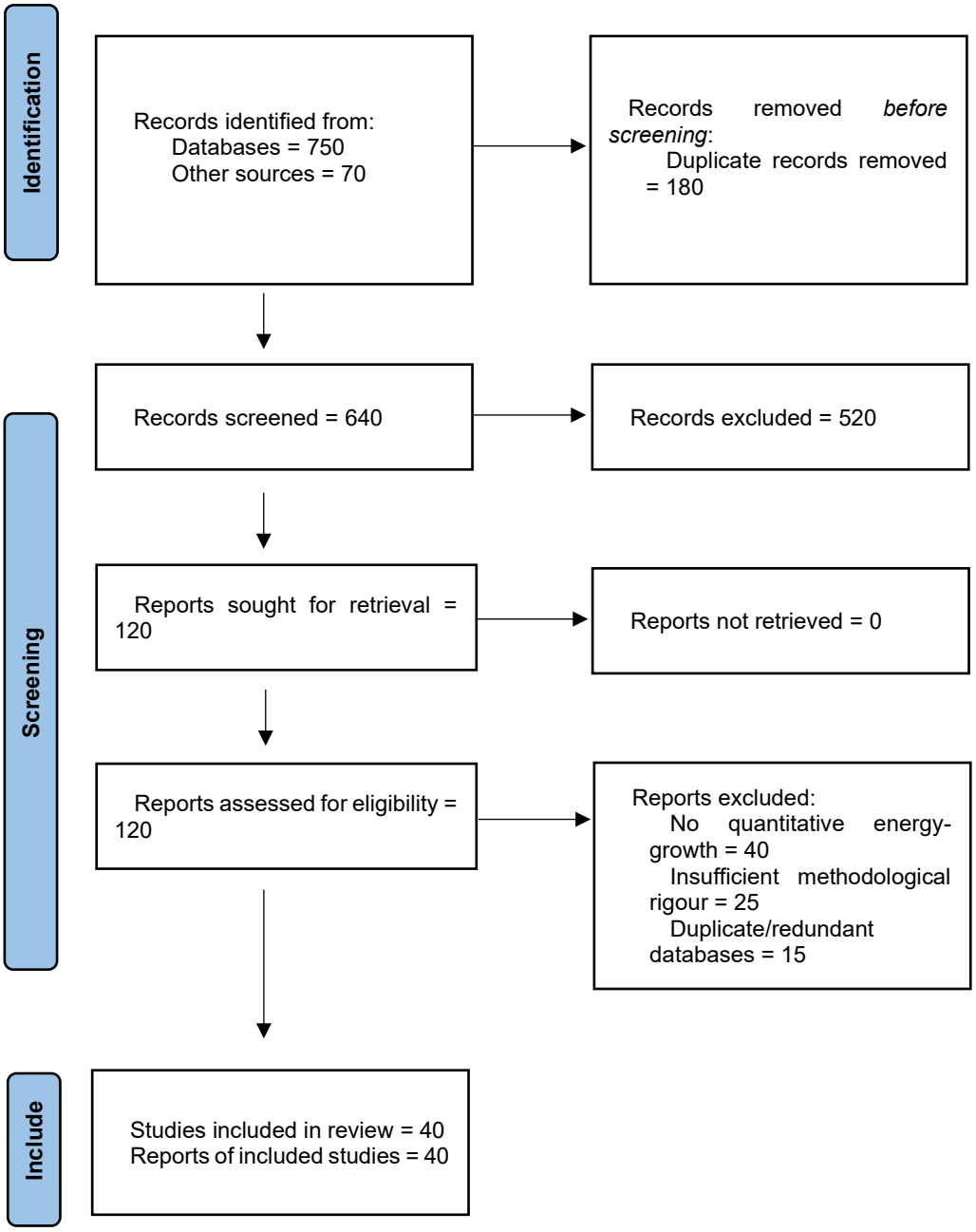


Figure 1 PRISMA Flow Diagram for Energy-Growth Nexus Systematic Review

Results and Discussion

Global Trends in the Energy-Growth Nexus

Empirical findings indicate varying energy-growth relationships across different regions. Studies on developed economies suggest a shift towards the conservation hypothesis, where economic growth is decoupling from energy consumption due to efficiency

improvements and structural economic changes (Sadorsky, 2011). On developing economies, evidence largely supports the growth hypothesis, as energy consumption remains a crucial driver of industrialization and economic expansion (Shahbaz et al., 2013).

Methodological Insights

Different methodologies yield different results. Granger causality tests show bidirectional causality in some economies (Lee & Chang, 2008), while others report unidirectional effects (Narayan & Popp, 2012). Cointegration analysis confirms long-run relationships between energy and GDP, but short-run dynamics vary (Ozturk, 2010). Panel data approaches highlight heterogeneous effects depending on country-specific characteristics (Apergis & Payne, 2012).

The Role of Renewable Energy

Recent studies emphasize the growing impact of renewables on economic growth. Countries investing in renewable energy experience sustained growth with lower emissions (Balcilar et al., 2018). However, some economies face transitional challenges, where high initial costs slow short-term growth (Payne, 2010).

Concluding Remarks

This review has provided a comprehensive analysis of the nexus between energy consumption and economic growth, highlighting the complexities and variations across different economies. The energy-growth nexus remains a highly debated topic, with evidence supporting various hypotheses. The evidence suggests that while energy consumption is crucial for economic development, its impact varies depending on the stage of economic development, energy mix, and policy environment. Developed economies have improved energy efficiency, while developing economies remain energy-dependent. The shift to renewables presents both opportunities and challenges. Countries that improve energy efficiency experience long-term economic benefits (Stern, 2011). Policies promoting clean energy innovations can decouple economic growth from energy consumption

The findings underscore the importance of adopting tailored energy policies that balance economic growth with sustainability. For developing nations, ensuring energy security while investing in renewables is key to long-term economic resilience. Meanwhile, developed countries must continue enhancing energy efficiency and supporting technological advancements in clean energy.

Policy implications emerging from this review is that

a) Developed countries should continue investing in energy efficiency to maintain sustainable growth.

b) Developing economies need balanced policies that ensure energy security while promoting cleaner energy sources, and that ensure economic expansion while reducing environmental impact.
c) Governments should invest in renewable energy infrastructure to sustain growth. Global cooperation on renewable energy financing and technology transfer is essential for sustainable economic development.

Given the limitations of the existing studies reviewed in this study, future research should consider more regional-specific and sector-specific studies (e.g., African economies), examine the role of technological innovation in reducing energy dependency, and investigate the impact of climate policies on the energy-growth relationship in order to provide deeper insights into the evolving energy-growth relationship in the context of climate change and global energy transitions. Future research should explore the role of emerging technologies, such as artificial intelligence and smart grids, in optimizing energy use for economic growth. Besides, future studies should explore policy-driven approaches to ensure sustainable economic growth without excessive energy dependency.

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