CHAPTER TWENTY

ENERGY CONSUMPTION: CONCEPT AND THEORY

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Abstract
Contemporary civilization's vitality is intricately linked to energy consumption, shaping daily life, businesses, and economies. Blessed with diverse energy resources, Nigeria requires a nuanced understanding of energy concepts for sustainable development. This study extensively explores Nigeria's energy landscape, dissecting foundational concepts like energy sources, conversion processes, efficiency, and policies. It underscores the critical role of energy policy, regulations, and technology in shaping consumption patterns. The study categorizes energy into renewable and non-renewable sources, emphasizing their roles in economic development. Energy's crucial role as a production factor for industrialization and economic growth is highlighted, emphasizing the interdependence of energy demand and consumption. A detailed calculated methodology accompanies introduction of primary energy consumption as a metric. Theoretical exploration includes energy efficiency, Jevon's dilemma, rebound effect, Kaya Identity, peak energy hypothesis, transition theory, demand-side management, socioeconomic factors, technological innovation, and policy impact. Insights from related studies stress the importance of renewable energy, environmental considerations, foreign direct investment, and the environmental impact of biomass. The study underscores the need for cohesive policies addressing energy challenges and promoting sustainability. While acknowledging a positive bidirectional relationship between energy consumption and economic growth in Nigeria, recommendations include diversifying energy sources, implementing efficiency measures, improving infrastructure, ensuring policy coherence, and integrating environmentally friendly practices. Adapting strategies to Nigeria's context and ongoing research are crucial for policy adaptability to changing conditions.

Keywords: Energy, Energy Consumption, Energy Demand**.**

Introduction

Modern civilization depends heavily on energy consumption because it is generally essential to businesses, daily living, and economic activities. In addition to influencing a country's growth and prosperity, how it uses its energy resources greatly impact the sustainability of the environment and the global climate. It is critical to comprehend the ideas, theories, and lessons surrounding energy consumption in the context of Nigeria, a country endowed with an abundance of energy resources.

Nigeria, the most populous nation in Africa, is at a turning point in its energy development. Rich in natural gas, oil, and renewable energy sources like wind and sunshine, the country can ensure a promising energy future for its people. However, there are several obstacles to realizing this promise, from affordable and accessible energy to environmental issues and sustainable development objectives.

This discourse delves into the multifaceted world of energy consumption, exploring the fundamental concepts underpinning it, the theories that help us understand its dynamics, and the lessons Nigeria can draw upon to shape its energy potential for economic growth and development. By examining these critical facets of energy consumption, the study aims to shed light on the pathways Nigeria can navigate to ensure a sustainable, inclusive, and resilient energy future that benefits all its citizens while minimizing adverse impacts on the environment.

Concepts

Understanding how energy is used, processed, and controlled in diverse societal sectors is central to concepts of energy consumption. These ideas are essential for solving energy-related problems and maximising the use of available resources.

The use of energy in various forms, such as heat, electricity, or fuel, to carry out operations, run machinery, or satisfy the requirements of people, businesses, and society is referred to as energy consumption. It includes all forms of energy use, including lighting homes and businesses and supplying fuel for industrial and transportation systems. Energy consumption is a vital component of contemporary life and economic activity, and it is commonly quantified in quantities like joules, British thermal units (BTUs), or kilowatt-hours (kWh). Sustainability, cost-

effectiveness, and environmental preservation all depend on an understanding of and ability to control energy consumption. Nonetheless, a few fundamental ideas on energy use centre on different forms of energy:

Energy Sources: The sources of energy are the first place where energy consumption starts. These sources fall into one of four categories: nuclear energy, biomass, renewable energy (such as solar, wind, and hydroelectric power), fossil fuels (such as coal, oil, and natural gas), and biomass. The sustainability of the environment and consumption habits are strongly impacted by the selection of energy sources.

Primary and Secondary Energy: Raw or natural energy sources, including coal or sunlight, are primary energy. The energy obtained from primary sources through conversion processes, such as the creation of petrol or electricity, is known as secondary energy. It is essential to comprehend this distinction to analyze the energy consumption of different sectors.

Energy Conversion: To meet certain needs, energy consumption necessitates converting of one form of energy into another. The conversion of chemical energy in fuel into heat for heating, mechanical energy for transportation, and electrical energy for appliances or lighting are examples of common conversions.

End-Use Sectors: Residential, commercial, industrial, and transportation end-use sectors are the ones into which energy consumption is usually divided. Every industry has different energy needs and usage patterns. For example, the industrial sector uses energy for production operations, whereas the residential and commercial sectors use it mostly for lighting, heating, and cooling.

Energy Intensity: Energy intensity measures the energy required to produce a unit of output, such as GDP or a manufactured product. Lowering energy intensity is a common goal to improve energy efficiency and reduce consumption while maintaining productivity.

Energy Efficiency: Energy efficiency refers to the ratio of useful output energy to input energy. Improving energy efficiency involves using less energy to achieve the same or better results. It is a key strategy for reducing overall energy consumption.

Energy Conservation: Energy conservation is the deliberate reduction of energy use through behavioral adjustments, lifestyle adjustments, and energy-efficient products and methods. It is a means by which people, institutions, and governments may support energy sustainability.

Peak Demand: The maximum amount of energy used in a given period, usually during hot summer days when air conditioning is at its highest, is peak demand. Peak demand management is crucial to maintaining a steady supply of energy.

Grid and Off-Grid Systems: Energy use can be connected to decentralised systems to function independently off the grid (for gas, electricity, and water), or it can be linked to centralised grids. The system selection may impact reliability, resilience, and energy access.

Carbon Footprint: The carbon footprint is an indicator of the greenhouse gas emissions linked to energy use. Comprehending the carbon footprint facilitates the assessment of the ecological consequences of energy decisions and bolsters endeavours aimed at diminishing emissions.

Energy Policy and Regulation: Through policies and regulations, governments frequently have a major influence on the energy consumption patterns. These are few examples of carbon pricing schemes, renewable energy incentives, and energy efficiency regulations.

Technological Developments: New developments in technology have an ongoing impact on energy usage. Advancement in renewable energy technology, energy-efficient appliances and transportation can alter energy consumption patterns of individuals and enterprises..
Individuals, organizations, and governments must comprehend these ideas related to energy consumption to make well-informed decisions regarding energy use, promote sustainability, and effectively address the issues of energy security and climate change.

Energy

Energy can be defined as the strength and vitality needed for sustained physical or mental activity. It is the ability and capacity to do work. Energy can be transformed from one form to another, but it cannot be changed. Energy can be divided into two groups: Potential Energy and Kinetic

Energy. The potential energy is energy that can be moved, while Kinetic energy is that energy that can be stored. Potential Energy is associated with nature, position or state (chemical energy, electrical energy, or nuclear energy), and Kinetic Energy is associated with motion (such as a moving car or a spinning wheel). Energy exists in various forms including thermal, chemical, mechanical and electric energy.

Energy is broadly classified into two main groups- renewable and non-renewable. Renewable energy is the energy generated from natural resources, such as sun, wind, rain, and tides and can be generated repeatedly when required. Renewable energy could be solar, hydropower, geothermal, wind, and tidal energy (Sweeney, 2001). Non-renewable energy is taken from sources available on the earth in limited quantity and will vanish after a certain period. They are a non-renewable source because it cannot be regenerated within a short period. Non-renewable energy sources exist in the form of fossil fuels, natural gas, oil and coal (Atoloye-Kayode, 2013). Energy commodities such as gasoline, diesel, fuel, natural gas, propane, coal and electricity can be used to provide energy services for human activities such as lighting, space heating, water heating, cooking, motive power, and electronic activities. Energy resources such as crude oil, natural gas, coal, biomass, hydro, wind, and sunlight or geothermal deposits can be harvested to produce energy commodities (Sweeney, 2001; Atoloye-Kayode, 2013).

Energy has been at the heart of industrial development and plays several roles in any economy. Its importance arises from the energy industry creating jobs and value by extracting, transforming, and distributing energy goods and services throughout the economy. Energy is an essential factor of production. In addition to labor and capital, it is important in driving any country's industrialization and economic development (Sari *et al*. 2008). Stern (2000) acknowledged this importance by considering energy as a significant factor of production and a vital variable in the production process because it can be used directly to produce a final product.

Energy Demand and Energy Consumption

The term ''Energy Demand'' can mean different things to different users. Normally, it refers to any kind of energy used to satisfy individual energy

needs for cooking, heating, travelling, etc., in which case, energy products are used as fuel and, therefore, generate demand for energy purposes. Energy products are also used as raw materials (i.e. for non-energy purposes) in petrochemical industries or elsewhere, and the energy demand here is to exploit certain chemical properties rather than their heat content. Similarly, the focus may differ for different users: a scientist may focus on equipment or process-level energy demand (i.e. energy used in a chemical reaction). At the same time, planners and policy-makers would view the aggregate demand from a regional or national point of view. Energy demand can correspond to the amount of energy required in a country (i.e. primary energy demand) or to the amount supplied to the consumers (i.e. final energy demand). Often, the context would clarify the meaning of the term; it is better to define the term clearly whenever used.

A distinction is sometimes made between energy consumption and energy demand. Energy demand describes a relationship between the price (or income or some such economic variable) and quantity of energy either for an energy carrier (e.g. electricity) or for final use (such as cooking). It exists before the purchasing decision is made (i.e. it is an ex-ante concept: once a good is purchased, consumption starts). Demand indicates what quantities will be purchased at a given price and how price changes will affect the quantities sought. It can include an unsatisfied portion, but the demand without supply restrictions is not observable.

Conversely, consumption takes place once the decision is made to purchase and consume (i.e. it is an ex-post concept). It refers to the manifestation of satisfied demand and can be measured. However, demand and consumption are used interchangeably. Energy demand is a derived demand as energy is consumed through equipment. Energy is not consumed for the sake of consumption but for an ulterior purpose (e.g. for mobility, for producing goods and services, or for obtaining a certain level of comfort, etc.). The need is specific concerning location, technology and user. The derived nature of demand influences energy demand in several ways (discussed below), which in turn has influenced the demand analysis by creating two distinct traditions; one following the neoclassical economic tradition while the other focuses on the engineering principles coupled with economic information (Worrell, Stephan & Gale, 2004).

In addition to the definition of energy consumption, primary energy consumption measures the total energy demand of a country. It covers consumption of the energy sector itself, losses during transformation (for example, from oil or gas into electricity), distribution of energy, and the final consumption by end users. It excludes energy carriers used for non-energy purposes (such as petroleum not used not for combustion but for producing plastics) (IEA, 2013).

According to IEA (2013), energy consumption is calculated using the following steps. First, historical and forecast levels of real GDP for as many countries as possible from around the world are gathered. These data series are measured in local currencies and may have different base years. To make them consistent, the GDP index for each country is created, where the base year/quarter value is set to 100.

The next step in calculating energy consumption is to gather historical energy consumption volumes for each of those countries for which we have GDP estimates. Energy consumption data can change significantly from year to year in some countries, and to minimize the effect of this volatility on the weighted index, a base year is chosen to calculate each country's shares of total consumption for that specific year. Currently, the base year is 2010 (IEA, 2013). For a world GDP growth rate, each country's energy consumption is calculated as a share of the total for all countries. Similarly, we can calculate an OECD or non-OECD GDP growth rate using each OECD or non-OECD country's consumption as a share of OECD or non-OECD total consumption respectively.

The final step is to combine all the information [oil-consumption shares and GDP indices] to calculate an overall GDP index for the world, Organization for Economic Co-operation and Development (OECD) countries, and non-OECD countries. We do this using a weighted geometric mean, where the final value of the weighted index for a given year is proportional to the product of each country's GDP index raised to the power of its share.

For example, to get a value for the world index in 2015, take each country’s calculated GDP index value in 2015 and raise it to a power equal to its respective share of world energy consumption in 2010.

Then, multiply these weighted indices to get a value for world energy consumption weighted GDP in 2015. By this definition, therefore, the data for energy consumption are in their net values. Why use a geometric mean instead of a standard arithmetic one? Primarily because such averages are less sensitive to outliers, GDP data at the country level are notoriously volatile yearly. The geometric mean, in effect, "normalizes" the various indices so that the values for a larger country do not dominate the weighting over smaller ones or so that outliers have less of an impact on the final values (Lawrence & Marc, 2008).

Theories

Energy consumption is a complex topic; theories and models help us understand and analyze it. Here are some key theories and concepts related to energy consumption:

Energy Efficiency: According to this hypothesis, reducing energy consumption can be achieved by increasing energy efficiency. Its foundation is that reducing energy use while maintaining or improving performance can help reduce energy demand. This hypothesis encompasses tactics like process optimisation, improved insulation, and technology upgrades.

Jevons Dilemma: This paradox, which economist William Stanley Jevons first put forth in the 19th century, contends that improvements in energy efficiency may inadvertently result in increasing energy consumption. Higher usage may offset the initial energy savings from energy-efficient devices due their greater affordability and accessibility.

Rebound Effect: The Jevons Paradox and the rebound effect are connected. It argues that when people or organisations become more efficient and save money on energy, they can utilise those savings to increase their energy use in other areas. People who drive fuel-efficient cars, for instance, can travel more, which would essentially offset their energy savings.

Kaya Identity: Four elements determine a population's total carbon dioxide emissions: population, GDP per capita, energy intensity of GDP (energy utilised per unit of GDP), and carbon intensity of energy (carbon

emissions per unit of energy). This equation is known as the Kaya Identity. It is employed to comprehend the factors that influence emissions and energy utilisation.

Peak Energy hypothesis: According to this hypothesis, as resources become scarcer or technology advances, energy use will eventually peak and then begin to drop. It is frequently used about fossil fuels, with the idea that energy consumption will move towards alternate sources when these resources get more scarce or unappealing due to environmental concerns.

Energy Transition Theory: The transition from one major energy source to another, such as the switch from fossil fuels to renewable energy sources like solar and wind, is the subject of the energy transition theory. It considers the policy, technological, and economic aspects that propel this shift.

Energy Demand-Side Management (DSM): DSM theory focuses on strategies to manage and reduce energy consumption on the demand side. This includes techniques like demand response, energy conservation, and load shifting, which aim to influence when and how energy is consumed to optimize efficiency.

Socioeconomic Factors: Several ideas acknowledge that socioeconomic factors impact energy usage. The degree of income inequality, urbanisation, industrialization, and lifestyle decisions can all affect a society's energy use.

Technological Innovation: According to the notion, the creation and uptake of new technologies can have a greatly impact on how much energy is used. More effective energy use can result from energy generation, storage, and transportation advancements.

Policy and Regulation: How energy consumption patterns are shaped are greatly influenced by government policies and regulations. Carbon pricing, energy efficiency regulations, and incentives for the use of renewable energy sources can all have an impact on consumption.

These theories and concepts are not mutually exclusive and often interact. Understanding the complex interplay of factors that drive energy consumption is essential for developing effective strategies to manage and

reduce it, especially in addressing climate change and sustainability challenges.

Plausible Lessons from Related Studies

Energy consumption is a critical factor for economic development, and it plays a pivotal role in the growth of economies worldwide. Nigeria, as one of the largest economies in Africa, faces a unique set of challenges and opportunities regarding its energy consumption and its impact on economic growth. This literature review aims to provide an overview of empirical studies that have explored the relationship between energy consumption and economic growth in Nigeria. This review is aims to identify some lessons from related studies on energy consumption and national economic activities.

Jia, Fan, and Xia (2023) utilized data from Belt and Road countries to investigate how renewable energy affects economic growth. Based on the paper's findings, the countries along the Belt and Road were advised to enhance international renewable energy cooperation, support international renewable energy project cooperation through national mechanisms, boost international trade exports of renewable energy, and encourage sustainable economic development. Finally, to promote the growth of new energy industries like hydropower, nuclear energy, photovoltaic, wind, and solar energy, as well as to advance domestic capital accumulation and the development of international trade, countries along the Belt and Road can embrace the "investment plus industry plus operation" model. This will ultimately contribute to the promotion of economic growth.

Using panel data analysis on data for 25 EU member states—excluding Malta and Croatia—Andronicеanu and Georgescu (2023) investigated the impact of energy consumption and CO2 emissions on economic growth. Their research findings recognize the environmental impact of energy consumption and CO2 emission on economic growth. As such, to reduce environmental degradation and air pollution, governments should find alternate sources of renewable energy resources, reduce dependence on fossil fuels, and reduce geopolitical risks. Governments should also stimulate businesses to promote renewable energy and install solar power and energy-based constructions. They emphasized the future role of renewable energy sources in households by installing electric heating and solar panels on the roofs of the buildings. Finally, social support policies

that can improve energy efficiency by using green energy should be initiated. The public should become aware of these policies on environmental issues. Other environmental policies include increasing the infrastructure for energy efficiency, reducing unwanted waste, and finding new renewable energy sources to reduce pollutant emissions.

*Umeji, et al. (2023) e*mployed the Toda-Yamatoto Granger Causality Test and the Autoregressive Distributed Lag estimation technique to examine the impact of renewable energy consumption and economic growth in Nigeria. Their research findings confirm the importance of energy consumption on economic growth in Nigeria. Based on the findings, it was recommended that the government of Nigeria should encourage the use of renewable energy to reduce the domestic use of fossil fuels. This will help in the long run and lead to the reduction of CO2 emissions that cause climate change. This will further encourage the economic growth process in Nigeria. Also, the government of Nigeria should support and encourage investments in the renewable energy sector by providing a conducive economic environment that will attract foreign investors in the sector.

To investigate the impact of biomass energy use and economic complexity on environmental sustainability in G7 economies, Shahzad *et al*. (2022) used panel data analysis. Based on their empirical outcomes, their study suggests some policy implications for sustainability in the context of the G7 countries. As much as biomass energy sources are considered cleaner and renewable, the findings of their study are in contrast and novel. The empirical findings suggest that biomass energy sources may not always act as greener energy sources and may depend on the bioenergy generation process. Though biomass is considered a driver for expanding energy use in these countries, it is destroying the environment. As such, these countries urgently need to devise strategies to reduce biomass energy use which will augment the quality of the environment in the long run. The governments in the G7 countries should increasingly focus on research and development towards alternative sources of energy which augment the welfare of the environment based on the use of renewables. Since globalization in the G7 countries is environmental welfare augmenting, these countries can mitigate the problems of carbon emissions by imports instead of relying on biomass for domestic energy uses. Arguably, economic complexity has resulted in environmental degradation for the G7 countries. These countries need to encourage more innovation towards

product specialization and structural transformation that would produce sophisticated products that are environment friendly. Economic complexity helps in product transformation, which is energy efficient and less damaging to the environment. Research and innovation on product transformation to raise the complexity of the production process may accelerate the country's trajectory towards achieving sustainable development goals on clean climate change.

In their 2022 study, Olanrele and Awode investigate the connection between Sub-Saharan Africa's energy consumption, foreign direct investment, and economic expansion. The Generalized Method of Moments is used in the study to examine the extent of influences on energy consumption, foreign direct investment, and economic growth. Findings from the study show that a percentage increase in energy consumption engenders economic growth by 1.3 per cent. Conversely, economic growth increases energy consumption by 0.004 per cent. Also, a significant one-way causality runs from foreign direct investment (FDI) to economic growth. The link between energy consumption and FDI was not statistically significant. Therefore, this study advocates that the government in Sub-Saharan Africa should ensure more access to energy to enhance economic growth.

Ekeocha, Penzin, and Ogbuabor (2020) examined the impact of energy consumption on economic growth in Nigeria using a test of Alternative Specifications. The findings from their study thus conclude that there is a wake-up call on governments and policymakers in Nigeria and other Sub-Saharan African economies that share structural similarities with it that there is an urgent need to evolve and implement policies that will address the energy challenges of these economies.

Using the Ordinary Least Square estimation technique and the Granger causality test, Ekone & Amaghionyeodiwe (2020) investigated the relationship between renewable energy consumption and economic growth in Nigeria. Based on the empirical results, this study concludes that there is no significant and positive long-run relationship between renewable energy consumption and economic growth in Nigeria. This might be attributed to the fact that Nigeria, though heavily reliant on energy, uses these renewable resources which tend to be negligible, which might be a major factor in the result obtained by the study. Therefore, it is

recommended that policies focus more on increasing the use and efficiency of this renewable energy. Investing in renewable energy should be encouraged and enhanced as this may further reduce domestic fossil fuel consumption, an environmentally friendly economy that can enhance economic growth in Nigeria.

Conclusion

The literature reviewed here indicates a consistent, positive relationship between energy consumption and economic growth in Nigeria. Most studies suggest a bidirectional causality, emphasizing energy consumption and economic growth's mutual influence. While increased energy consumption can drive economic growth, a growing economy, in turn, demands more energy. In addition to recognizing the relevance of renewable energy to economic growth, these findings highlight the importance of a reliable and sustainable energy supply to support Nigeria's economic development and suggest that policies to enhance energy efficiency and infrastructure could have substantial economic benefits for the country. However, the impact of energy consumption on economic growth may vary depending on specific circumstances and policy choices. Further research is needed to delve deeper into this relationship intricacies and guide policymakers in achieving sustainable economic growth through energy management in Nigeria.

Policy Recommendations

Nigeria can benefit from diversifying its energy sources and reducing reliance on one source. This may involve increasing investments in renewable energy, such as solar and wind power, which contribute to sustainable development and enhance energy security.

Implementing energy efficiency measures across various sectors can lead to more sustainable economic growth. Policies promoting energy-efficient technologies and practices can help optimize energy use, positively impacting economic productivity.

Improving energy infrastructure is crucial for ensuring a reliable and consistent energy supply. Power generation, transmission, and distribution infrastructure investments can contribute to economic growth by reducing energy constraints on businesses and households.

Ensuring coherence and consistency in energy policies is vital. The government can play a key role in creating a conducive environment for energy sector investments, providing clear and stable policies that encourage private sector participation.

Considering the global shift towards sustainability, integrating environmentally friendly practices into energy policies can enhance Nigeria's global competitiveness and contribute to long-term economic resilience.

It's important to note that various factors can influence dynamics between energy consumption and economic growth, and policies need to be tailored to country specific context. Additionally, ongoing research and monitoring are crucial to adapting strategies in response to changing economic and environmental conditions.

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