

Adoption of Energy Mix Research and its Applications for Addressing the Current Energy Crisis in Nigeria

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Abstract

Application of outputs from energy mix research is the way forward for national economic growth and sustainable energy in Nigeria. This paper examines the applications of energy mix research as a special tool for addressing the present energy crisis in Nigeria. The methodology used includes secondary data, opinions from experts, personal observations and previous records. Issues linked present system, appraisal of benefits and strategies for the way forward were highlighted. Energy demand is far more than the supply of energy in Nigeria. Findings reveal that there is a need for strategic synergy between industries and academia to solve the current energy crisis in Nigeria. Multidisciplinary research on energy mix with adequate collaboration from industries and academics has not been fully adopted and integrated into the energy sector. It has been concluded that the current energy crisis can be tackled through energy mix research and its applications. This will bring industrialization, job creation, wealth to the nation, employment opportunities and capacity building in the energy sector. Periodic retraining for engineers in the energy sector, adequate financing, capability building, support efforts, and effective application of policies and regulations will yield great benefits.

Keywords: Energy mix research, Applications, Economic growth, Technological innovations, Energy crisis

INTRODUCTION

Energy mix research and its applications must be adopted for addressing the current energy crisis in Nigeria. The industrial productivities and technological advancement of our nation Nigeria has been grossly affected by severe energy crisis for decades. This has affected its economic, social and political developments traceable to ever-changing energy conditions, as well as recent advancements in renewable energy sources in Nigeria.

There are copious benefits of the energy mix. The right amount of energy can promote a healthy and sustainable lifestyle for the masses, install a secure energy vision in the minds of the masses, enhance limited possibilities of waste in energy export and import, reduce conflict of environmental and social interests in energy and reframe energy transactions models and create new carbon mitigation policies [1]. The concept of developing robust, productive, and efficient energy sectors in a given country or region without jeopardizing current and future socio-environmental security is known as sustainable energy transition. Nigeria is one of Africa's top emitters of greenhouse gases. The practice of flaring gas by Nigerian oil companies has been a major source of greenhouse gas emissions into the atmosphere.

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The energy mix refers to all direct uses of energy, such as transportation and housing, so it is not to be confused with power generation mix, which refers only to the generation of electricity. The energy mix is the range of energy sources of a region. It is the integration of multiple basic energy sources. Sources are used to meet energy needs in a given geographic region for generating power and other activities. China is the world's greatest primary energy consumer, consuming 145.46 [quintillion (10¹⁸) joules] in 2020. This is significantly more than the second-largest consumer, the United States. The majority of primary energy fuels, such as oil, are still sourced from fossil fuels and coal. The energy mix reflects the fact that it has a strong economy and so needs a variety of energy sources for industrial production, electrical production, transport, and domestic use. Figure 1 described the basic benefits of the energy mix in terms of policy, security, access and environment.

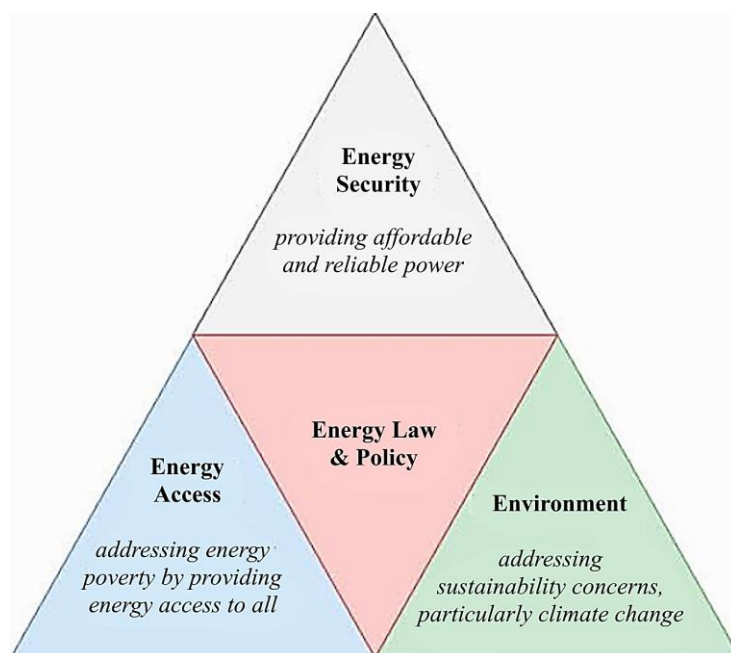


Figure 1. Benefits from energy mix in terms of policy, security, access and environment.

With an annual average daily solar radiation of roughly 5.25 kW h/m²/day, Nigeria receives a lot of solar energy that can be usefully utilized. This ranges from 3.5 kW h/m²/day along the coast to 7 kW h/m²/day near the northern border. The country's average sunlight hours are estimated to be around 6.5 hours. This results in an average yearly solar energy intensity of 1,934.5 kW h/m²/year; hence, an average of 6,372,613 PJ/year (about 1,770 TW h/year) of solar energy falls on Nigeria's whole geographical area during a year. This is around 120,000 times the Power Holding Company of Nigeria's total yearly average electrical energy production (PHCN). The accessible solar energy resource is nearly 23 times the Energy Commission of Nigeria's (ECN) prediction of total final energy demand for Nigeria in 2030, assuming a 10% conservative conversion efficiency. To boost the country's development, it's critical to supplement the country's current inconsistent energy supply with a long-term renewable energy source like solar energy. Inefficiency and insufficient infrastructure to improve electricity supply have also been important contributors to the growing gap between demand and supply of electricity. This may be because Nigeria only has 14 generating stations (3 hydro and 11 thermal stations).

Only about 4,500 MW of Nigeria's installed capacity is ever used. This is due to a lack of maintenance, fluctuations in the water levels that power the hydro plants, and transmission losses. Figure 2 presented the map of Nigeria showing energy resources distribution and socio-economic zones while Figure 3 gave Sustainable development goals at a glance [2, 3].

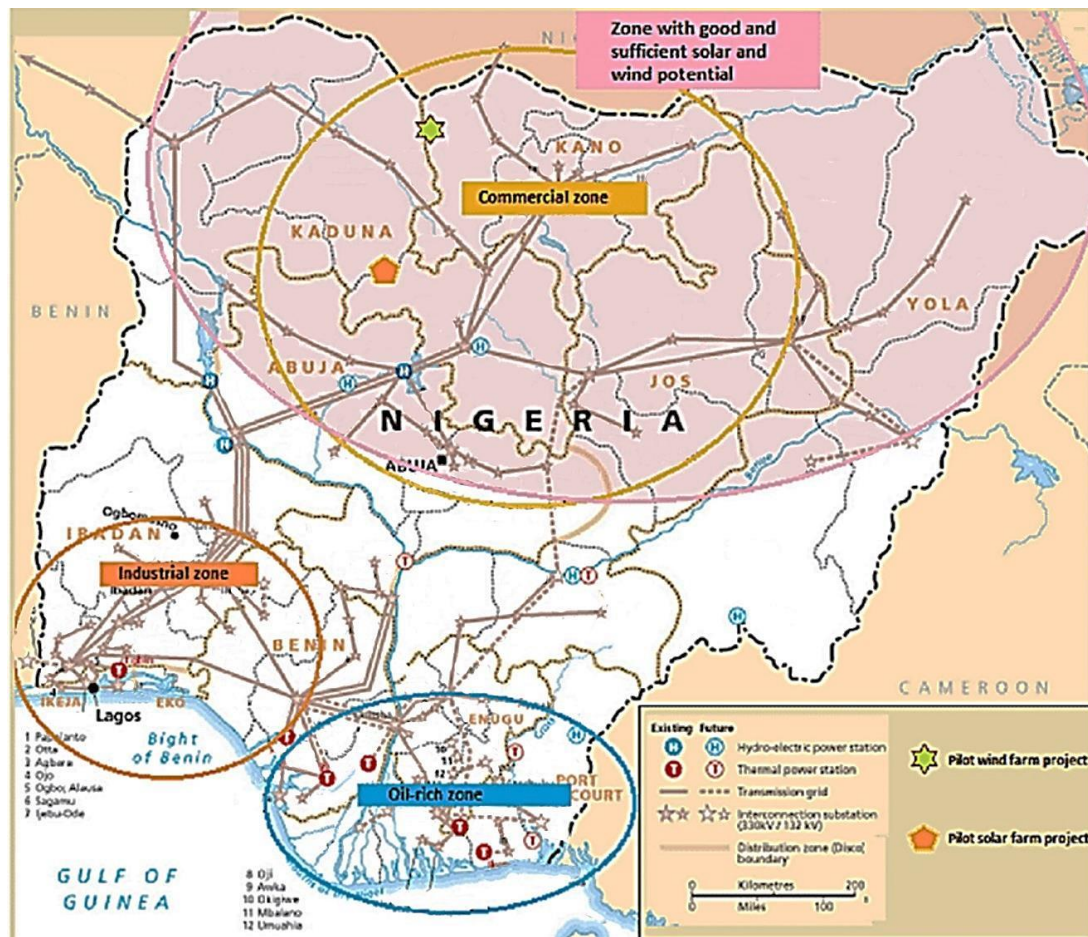


Figure 2. Map of Nigeria showing energy resources distribution and socio-economic zones.



Figure 3. Sustainable development goals at a glance.
 Source: (Essex et al., 2020).

It would be difficult for Nigeria to realize any of the numerous objectives of the Sustainable Development Goals (SDGs) significant improvement in the availability of electricity to the populace' an expert in the power industry.

These goals are all direct to the need for investment for future survival Infrastructure investment and innovation are critical drivers of economic growth and development. With over half the world population now was living in cities, mass transport and renewable energy [4]. Infrastructure investment and innovation are critical drivers of economic development, growth of new industries and information and communication technologies. With over half of the world's population now residing in cities, public transportation and renewable energy are becoming increasingly important.

LITERATURE REVIEW

Factors such as delayed and overpriced hydroelectric projects, outdated and insufficient energy infrastructure, transmission and distribution losses, energy theft and poor energy management, a lack of energy conservation, low equipment efficiency, unsustainable energy pricing strategies, and unsatisfactory energy market regulations. Other important elements contributing to the deepening of the energy crisis include unique regional and geopolitical issues, the strong dependence on energy imports, and inadequate exploitation of the vast amounts of renewable energy resources [5, 6].

Nigeria is suffering from a long-term electrical shortage that has paralyzed the economy. Only 40% of Nigerians are expected to be linked to the national grid, and those who are subjected to regular power disruptions. The electricity grid in Nigeria is primarily powered by large hydropower and depleting hydrocarbon resources. Fossil-based electricity generation contributes not only to an increase in carbon footprints but also exposes the country to changes in the price of petroleum resources and political instability in the oil-producing region of the country [7].

Nigeria is a country on Africa's western coast. With almost 150 million inhabitants, it is the continent's most populous country. According to a 2003 analysis of Nigerian energy policy, almost 60% of the population linked to the grid is without power. Furthermore, only about 40% of the population has access to electricity. On a basic level, there is not enough electricity generated to meet the needs of the entire population [8].

Many people and businesses supplement the electricity supplied by the grid system with their generators due to a shortage of reliable electricity. A generator is owned by almost everyone who can buy one. Over 90% of businesses, on average, have generators, according to one estimate. The energy industry in Nigeria has severe environmental ramifications, mostly in the form of both pollution and deforestation [9].

Addressing Africa's impending energy crisis is critical to the continent's long-term development success. Africa has all of the potential to address its energy challenges if it can get the necessary infrastructure in place to tap into the rich renewable resources in the continent, and if skills are pooled together and experiences shared in addressing the key issues [8].

Energy is essential for socio-economic growth and poverty eradication, so access to clean, modern energy services is a huge concern for the African continent. Currently, 60 to 70 percent of the Nigerian population lacks access to electricity [10, 11].

Sustainable building is the through better siting, design, and construction, the practise of increasing the efficiency with which buildings and their sites use energy, water, and materials, as well as reducing building impacts on human health and the environment operation, maintenance, and demolition; the complete building life cycle. Sustainable or "green building" design and construction allows using our resources more efficiently while creating healthier and more energy-efficient homes These buildings reduce their environmental impact by conserving resources, while also balancing energy-efficient, cost-effective, low-maintenance products for our construction needs [12].

Sustainable engineering is the process of building or running systems in such a way that they use energy and resources in a way that is neither harmful to the natural environment nor future generations' ability to meet their requirements. Eco-effective strategies pursue absolute goals in terms of reducing environmental pollution, as achieved through the use of renewable energy sources, recirculation of products, by-products, and materials into product lifecycles or natural systems, and pollution limitation

Nigeria has significant conventional and renewable energy resources that could provide the country with enough capacity to meet the ambitions of both urban and rural Nigerians for full, nationwide electrification. Despite this, Nigeria has one of the lowest per capita energy consumption rates in Africa. Dissemination of decentralised renewable energy resources will not only benefit rural Nigerian communities but will also improve Nigeria's energy and economic prospects for potential global investment [13].

Worldwide population growth, growing demand, and continuous reliance on fossil-based fuels for generation are all contributing to a global energy catastrophe. Increases in greenhouse gas concentration levels, if not reversed, will result in significant changes in global climate, with consequences for our society and economy [14].

There is a great need to overcome barriers to the development of the technologies, such as the lack of understanding of solar thermal systems, people are doubting the viability of renewable electricity due to a lack of incentives for renewable technology and recent experience with as solar photovoltaic systems failure. Lack of technical competence, lack of project funding, and lack of enabling policies to drive the technologies and high technology were also viewed as impediments. Widespread application of these clean energy technologies can help mitigate climate change [3]. The National Energy Policy (NEP) was created by ECN and approved by the government in 2003. The document launched in 2005 is the origin of the various master plans, such as the Renewable Energy Master Plan (REMP), and National Energy Master Plan (NEMP) in 2007 drafted subsequently. The NEMP contains action plans that guide its implementation to ensure the development of the nation's energy resources with diverse energy resources alternative for increased national energy security [15].

METHODOLOGY

The methodology used includes secondary data, opinions from experts, personal observations and previous records. Issues linked present system, appraisal of benefits and strategies for the way forward were highlighted. Figure 4 depicts Nigeria's power-producing plants and their use capacity, while Table 1 showed numerous sources of energy with utilization categorization.

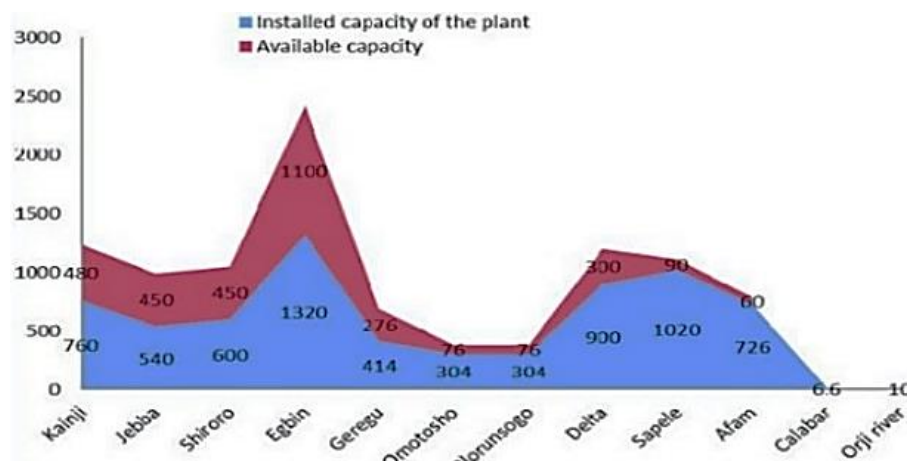


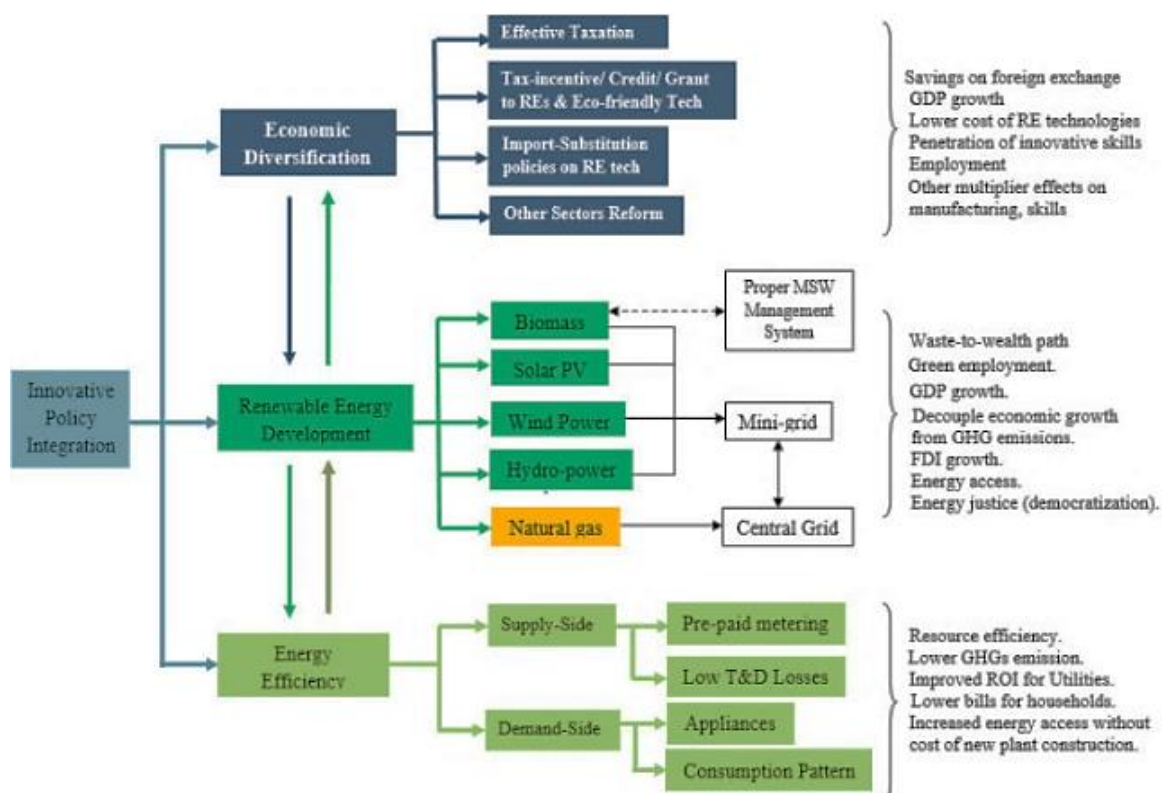
Figure 4. Nigeria power generation plant and their utilization capacity.
 Source:[16].

Table 1. Various sources of energy with utilization characterization.

Resources	Quantification	Utilization characterization
Crude oil	37.062 billion barrels	22% utilization of refineries
Natural gas	182.3 trillion standard cubic foot	18% indiscriminately flared
Coal and lignite	2.7 billion tonnes	7% contribution to net GDP
Tar sands	31 billion barrels of oil equivalent	Negligible usage
Large Hydro	11,250 MW	1938 MW (17% utilized)
Small Hydro	3,500 MW	64 MW (2% utilized)
Solar	3.5-7.0 kWh/m ² /day	27% capacity factor; negligible utilization
Wind	2.0-4.0 m/s at 10 m height	Negligible utilization
Fuel wood	11 million hectares of forest	43.4 million tonnes/yr of consumption
Municipal waste	30 million tonnes/year	0.5 kg/capita/day
Animal waste	1.05 tonnes/ day	Negligible utilization
Agricultural residues	91.4 million tonnes/yr. produced	Negligible utilization
Energy crop	28.2 million hectares of arable land	8.5% cultivated

Source: [17].

Recognizing that gas will play a role at least in the near foreseeable future [18] especially in developing countries such as Nigeria, where adoption of renewable energy is very sluggish [19] energy efficiency is critical to mitigating emissions and promoting sustainability in Nigeria energy sector. Energy efficiency and renewable energy are two fundamental cornerstones of the current energy shift. Five critical factors that affect the success or cost-competitiveness of Nigeria's businesses are inadequate access to funding, macroeconomic situations and economic volatility, poor electricity supply, political instability and high operating overheads. Nigeria exports most of the petroleum products it produced. Domestic consumption, on the other hand, is increasing. The increase in domestic production is related to population growth, urbanization and economic growth [20].

**Figure 5.** Integration of economy, RE and energy-efficiency.

Source: [10]

Table 2. Renewable energy potential and their current utilization in Nigeria.

Resources	Amount	Current Use
Large hydropower	11,250 MW	1930 MW (17.1%) used
Small hydropower	3,500 MW	64.2 MW (1.83%) used
Solar	4.0–6.5 kWh/m ² /day	27% Capacity Factor (Negligible)
Wind:	2–4 m/s @ 10 m hub height	
- Onshore wind	1,600 MW	Negligible use
- Offshore wind	800 MW	Negligible use
Geothermal	500 MW	Negligible use
Biomass (Non-fossil fuel):		
Municipal waste	30 million tonnes/year	0.5 kg/capita/day
Fuel wood	11 million hectares of forest	43.4 million/tonnes/yr consumed
Animal waste	1.05 tonnes/day	Negligible use
Agricultural residues	91.4 million tonnes/yr produced	Negligible use
Energy crops	28.2 million hectares of arable land	8.5% cultivated

Source:[1].

Figure 5 gave a vivid conceptualization of the integration of economic diversification, scaled-up Renewable Energy and energy efficiency. Table 2 also presented renewable energy potential and their current utilization in Nigeria.

The major challenges confronting energy mix and power generation in Nigeria are:

1. Government policies are unclear.
2. Inadequate legal instrument for renewable energy development.
3. Effective funding of energy mix related projects and research in all geo-political zones.
4. Poor plant maintenance, outdated/obsolete equipment, and gas pipeline line vandalism, to name a few.

STRATEGIES FOR ENERGY MIX RESEARCH AND ITS APPLICATIONS FOR ADDRESSING CURRENT ENERGY CRISIS IN NIGERIA

Strategies for Energy Mix Research and its Applications for Addressing Current Energy Crisis In Nigeria include the following:

1. Full utilization and promotion of renewable energy resources, as well as energy efficiency measures and energy application of energy as conservation measure in a variety of industries, including the construction of industrial, residential, and office buildings, as well as transportation. The government must accelerate the implementation of renewable energy and energy efficiency programmes to ensure the country's energy supply and, as a result, its economic development.
2. In Nigeria, instead of flaring gas, the gases can be processed to methanol and used as a residential and industrial fuel. The use of fossil fuels for energy will be considerably reduced with good energy efficiency techniques and products.
3. Introduction of principles of environmental sustainability within these processes of re-use, recycling and disposal of e-waste globally and in Nigeria. These principles must be accompanied by state policies and regulatory frameworks that promote sustainable processes.
4. Development of policies on energy efficiency and integration them into the current energy policies. A comprehensive and consistent energy policy is required to guide residents toward the most efficient use of the country's energy resources.
5. Promotion of energy-efficient products and appropriate practices at the side of the end-users and energy generation.
6. Project development, project management, monitoring, and assessment should prioritize human resource development, critical knowledge, and know-how transfer. The preparation of

standards and codes of practices, maintenance manuals, life cycle costing, and cost-benefit analysis tools should be undertaken as an urgent priority.

CONCLUSION

Energy mix research and applications can help address the current energy issue. This will bring industrialization, job creation, wealth to the nation, employment opportunities and capacity building in the energy sector. Governments and all stakeholders have important roles to play in promoting energy efficiency and conservation. Efficiency standards for appliances, equipment and automobiles have proved to be extremely cost-effective in many developed countries and are often relatively easy to implement compared to other policies, particularly if they can be harmonized with the standards adopted in other large markets. Despite their availability in reasonable quantities, renewable energy resources are grossly underutilized in Nigeria. Energy efficiency can be especially important in rapidly industrializing countries as a way to manage rapid demand growth, improve system reliability, ease supply constraints and allow energy the production and distribution infrastructure to 'catch up'. The adoption of energy mix research and its applications is a veritable tool for addressing the current energy crisis in Nigeria. The current power crisis in Nigeria will undoubtedly continue unless the government diversifies energy sources in the home, commercial, and industrial sectors.

RECOMMENDATIONS

Periodic training should be organized for engineers in the energy sector, adequate financing, entrepreneurial training, support initiatives, and proper implementation of strategies and regulations. Government, engineering family and energy experts should work on strategies for the deployment of technological innovations in the promotion of renewable energy systems. To ensure the long term development of renewable energy and energy efficiency, there must be human resource development at a high level and manufacturing capacity building. Critical knowledge and technical know-how transfer should be the focus of project development and management. The energy Commission of Nigeria (ECN) shall keep a close eye on and evaluate the performance of these centers in terms of quality research outputs. The government should be more serious to take a pragmatic step toward realizing the targets set by the ECN for the renewable energy contribution to electricity generation in Nigeria. To lower energy consumption, relevant government agencies and non-governmental groups should encourage energy efficiency and conservation through energy-saving bulbs, improved fuelwood stoves, efficient electrical appliances, and other methods. In addition to these, the existing research and development centers and technology development institutions should be adequately strengthened to support the shift towards the increased use of renewable energy. There is a great need for multi-sectoral cooperation to scale up and deepen the scope of Renewable Energy and energy efficiency in Nigeria. This will assist diversification of our economy and all relevant ministries, agencies, professionals, financial institutions, universities, research and development institutions, entrepreneurs, government, non-governmental organizations and other stakeholders must be involved. To secure additional benefits and ensure that manufacturers continue to innovate, other policies and incentives are needed to generate a demand for products that perform above the minimum standards.

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