APPRAISAL OF RENEWABLE ENERGY RESOURCES FOR SUSTAINABLE RURAL ECONOMIC DEVELOPMENT IN NIGERIA

[1]Bello, M. A. and [2]Oladimeji, S. R.

Corresponding author-engrbellomoruff@gmail.com **+2348034738235, 08051234171**

Department of Technical Education,
Osun State College of Education, Ila-Orangun

Abstract

It is high time Nigeria capitalized on its abundant renewable energy resources to meet the growing needs of its population while simultaneously addressing socio-economic challenges. Achieving this requires a broad and comprehensive set of procedures for all the sectors of its economy and enabling environment which will facilitate the transition away from fossil fuels to renewable energy with all the economic and health benefits that are intertwined. Thus, this review paper illustrated how renewable energy technologies will be significant tools in achieving a sustainable energy mix and meeting the growing needs of the Nigerian populations particularly the rural communities. In the paper, five renewable energy resources - solar, wind, hydro, biomass and geothermal energy resources and their renewable technology potentials were discussed. Thereafter, the indispensable roles of the organizations/institutions and the various policies responsible for governing the development of renewable energy resources in Nigeria were expatiated. Also, as a result of their immense contributions in promoting sustainable energy development for economic growth of the rural dwellers, various barriers facing renewable energy resources were discussed. The paper concluded that Renewable energy is a viable solution to the energy challenges of developing countries in which Nigeria is inclusive because of the numerous benefits they have over the non-renewable fossils source of energy. Finally, owing to these challenges, some recommendations were proposed to the Nigerian government to provide adequate policy framework and enabling environment for renewable energy to flourish in the country. Also, in order to ensure long term development of renewable energy and energy efficiency, the government must partner with philanthropists, local and foreign investors as well as non-governmental organizations.

Keywords: renewable energy resources, solar energy, wind energy, biomass energy, hydro energy, geothermal energy, rural dwellers/communities, sustainable economic growth

Introduction

The recent sharp and incessant increase in the prices of oil, natural gas, uranium and coal underline the importance for all countries to focus on development of alternative energy resources. This is because the significance of energy stability and efficiency cannot be overemphasized for socio-economic advancement and development of any nation across the world. Its use is very crucial to all sectors of the economy and as such, it is trite that all countries have uninterrupted energy supply for proper functioning. In line with the above and for many

other inevitable reasons, renewable energy resources need to be prioritized to mitigate the effects of economic recessions already caused by the epileptic power supply in Nigeria.

Appreciatively, the world already is responding to these imperatives. Virtually all those who have addressed the energy aspects of sustainable development have concluded that renewable resources should play a major role. Thus, in the latest international pronouncement of the Plan of Implementation of The World Summit on Sustainable Development, held in Rio de Janeiro in 2001, Article 20 (e)states: "…with a sense of urgency, substantially increase the global share of renewable energy sources with the objective of increasing its contribution to total energy supply, recognizing the role of national and voluntary regional targets as well as initiatives, where they exist, and ensuring that energy policies are supportive to developing countries' efforts to eradicate poverty, and regularly evaluate available data to review progress to this end;" Similarly, in September 2011, the UN Secretary General launched the Sustainable Energy for All (SE4All) initiative with the aim of achieving three goals by 2030: Ensuring universal access to modern energy services; doubling the global rate of improvement in energy efficiency; and doubling the share of renewable energy in the global mix" (SE4All). Despite the fact that Nigeria has infinite natural renewable energy resources which will be essential for the sustainable development of the country, these resources are very much underexploited.

Renewable energy resources hold great promise for meeting the energy and development needs of all countries throughout the world, but particularly for developing countries where in many areas commitment has not been made to fossil fuel dominance and where rural areas may be served more economically than with traditional resources like kerosene and diesel fuel. Today we primarily depend on fossil fuels to heat and power our homes and fuel our cars. It's convenient to use coal, oil, and natural gas for meeting our energy needs, but we have a limited supply of these fuels on the Earth. We are using them much more rapidly than they are being created. Eventually, they will run out, besides, their uses are not environmentally sustainable. In the meantime, the nation's energy needs are expected to grow by 33 percent during the next 20 years (ECN 2013). Renewable energy can help fill the gap. Even if we had an unlimited supply of fossil fuels, using renewable energy is better for the environment. We often call renewable energy technologies "clean" or "green" because they produce less pollutants. Burning fossil fuels send greenhouse gases into the atmosphere, traps the sun's heat and contributes to global warming. Climate scientists generally agree that the Earth's average temperature has risen in the past century. If this trend continues, sea levels will rise, and scientists predict that floods, heat waves, droughts, and other extreme weather conditions could occur more often. Thus, there are two main solutions to reducing carbon emissions and to overcoming the climate change problem: replacing fossil fuels with renewable energy sources as much as possible and through enhancing energy efficiency. Renewable energy technologies could reduce carbon dioxide emissions by replacing fossil fuels in the power generation industry and transportation sector given the inadequate and epileptic power supply being experienced in the country, using renewable energy conversion system to supplement the energy obtained from the serving hydropower and thermal power plants will be a wonderful initiative. However, given the huge initial investment capital, the government could encourage many individual users to adopt it by giving adequate incentives, such as feed-in tariff (Akorede et al., 2017).

The preset energy crisis mentioned above informed the need to evaluate the expected benefits which can be derived from seeking alternative renewable sources of energy that can ensure sustainable growth and development; thus the objective of this study. Thus, the information presented in this article will serve as an essential tool to sensitize individuals,

relevant government agencies and non-governmental organizations towards fully tapping these abundant energy resources to practically contribute to the energy production for sustainable rural economic development in Nigeria.

What is Renewable Energy?

While there is a broad consensus among scholars, international organizations, government institutions, and regional commissions on what constitutes renewable energy, these groups employ legal or formal definitions that vary slightly in the types of resources and sustainability of the concept. For example, the International Renewable Energy Agency (IRENA) has a statutory definition, ratified by 108 members (107 states and the European Union) as of February 2013: "renewable energy includes all forms of energy produced from renewable sources in a sustainable manner, including bioenergy, geothermal energy, hydropower, ocean energy, solar energy and wind energy" (IRENA, 2017). Similarly, the International Energy Agency (IEA) defines renewable energy resources as those "derived from natural processes" and "replenished at a faster rate than they are consumed" (IEA 2002, OECD, IEA and Eurostat, 2005). The IEA definition of renewable energy includes the following sources: "electricity and heat derived from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources" (IEA 2002).

According to Dawn, (2019) cited in Nathan et al., (2024), renewable energy refers to power that comes from non-stop, endless sources including the sun, wind, rain, tides, waves, and geothermal heat which are reliable and environmentally friendly. He further explained that renewable energy sources will always be available, regardless of how much we use them. Also, Umar (2023) defined renewable energy as an increasingly popular form of energy that is replenished naturally at a rate that is comparable to or faster than the rate of human consumption. The differences in the above definitions illustrate the fact that there is no common or global definition of renewable energy. However, all the definitions are simple and comprehensible. In the definitions, it is clear that energy use must not only support development overtime; it must also be secure and reliable, as well as environmentally friendly. Energy must be available from generation to generation to be regarded as sustainable. Thus, three elements can be distilled from the definitions of sustainable energy: energy security, energy equity and environmental sustainability

Why Choosing Renewable Energies Over Non-Renewable Fossil Fuels?

It is a well-known fact that the need for sustainable energy is rapidly increasing globally. To this end, renewable energy has been identified as a veritable alternative to fossil fuels in a sustainable and environmentally-friendly manner. The development and utilization of renewable energy should be accorded a high priority, especially in the light of increased awareness of the adverse environmental impact of fossil-based generation. A widespread use of renewable energy is important for achieving sustainability in the energy sectors in both developed and developing countries. Renewable energy is, undoubtedly, a promising solution to Nigeria's energy challenges. Apart from being sustainable and inexhaustible, it can be established in smaller units, thus, suitable for rural community management and ownership, and could be pivotal to economic development (Chukwueyem et al., 2014).

Other advantages of renewable energy over fossil fuels include: security of supply because of its constantly replenished from natural sources, promoting decentralization of energy management, easy generation due to its well-distribution globally, suitability for

rural/community development since they can be set up in small units for ownership and management; and its ability to address the environmental concerns that emerge due to greenhouse gas emissions caused by power generation from oil, natural gas, and coal.

Current Accessibility of Electricity in Nigeria

According to Nigerian electricity regulatory commission (2018), currently Nigeria's electricity production ranges between 3500-4000 Megawatts which is far less than the current demand of 10,000 Megawatts in the whole country. Electricity generated is from thermal and hydro power which constitutes of 66.7% and 33.3% of total power production respectively in the country (NERC, 2014). As of 2020, 55% of Nigeria's population had access to electricity and are on-grid while the remaining 45% have no access and are off-grid. In urban areas, 84% had access compared to 25% in rural areas (Sustainable Energy for All). By virtue of electrification rate per geopolitical zone, North-Central (48%), North-West (40%) and North-East (27%) have the least electrified population in the country compared to South-East (78%), South-South (81%) and South-West (85%) (ECN, 2012). The three technologies used for the generation and distribution of electricity are the national grid powered by thermal and hydro plants, mini-grids and standalone systems which are mainly solar or solar hybrids. Fuel generators are widely used across both urban and rural communities for lack of grid power availability. In terms of total installed PV capacity, Nigeria has 8.25MWp large scale, 89.34MWp C&I, 7.33MWp mini-grids and 24.3MWp SHS and residential systems (ECN, 2013)

Presently, the Federal Government of Nigeria is targeting 100% electrification by 2030 using a least-cost technology mix approach. This approach consists of a mix of 28% grid, 46% mini-grids, and 26% Solar Home System (SHS) connections. Mini-Grids are shown to be the least cost option for most new connections in densely populated rural settlements by 2030, estimated to reach 51 million people, mostly in rural off-grid locations (SE4all, 2022). This has been orchestrated in the latest Energy Transition Plan which is the most recent policy driving the energy sector (Rural Electrification Agency 2023). The renewable energy resources available in Nigeria are diverse and enormous. A summary of the Nigeria's renewable energy potentials is shown in Table 1 below. At present, there are no installed geothermal plants in Nigeria. However, the Renewable Energy Master Plan (REMP) in its second draft of November 2012 as prepared by the Energy Commission of Nigeria (ECN) sought to increase the supply of renewable electricity from 13% of total electricity generation in 2015 to 23% in 2025 and 36% by 2030. Renewable electricity would then account for 10% of Nigerian total energy consumption by 2025 ECN (2012).

Table 1: Renewable energy potential with current utilization capacities in Nigeria.

S/N	Energy resource	Potential	Current Utilization and Further Remarks
1	Large Hydropower	11,250 MW	1,900 MW exploited
2	small Hydropower	3,500 MW	64.2 MW exploited
3	Solar	4.0 kWh/m2/day - 6.5 kWh/m2/day	15 MW dispersed solar PV installations (estimated)
4	Wind	2 - 4 m/s 10 m height mainland	Electronic Wind Information System (WIS) available
5	Biomass (non-fossil		18.5 million tonnes produced in 2005

	organic matter)		and now estimated at 0.5 kg/capita/day
	Municipal solid waste		
	Fuel wood	13,071,464 hectares	43.4 million tonnes/yr. fuel wood consumption
	Animal waste	61 million tonnes/yr	245 million assorted animals in 2001
	Energy crops and Agricultural residues	83 million tonnes/yr	91.4 million tonnes/yr. produced
			28.2 million hectares of arable land; 8.5% cultivated

Source: ECN (2013)

Table 2 displays a breakdown of the renewable energy potentials with current utilization information according to Energy Commission of Nigeria (ECN) (2013).

Table 2: Estimates of Renewable Energy Potentials in Nigeria (MW)

Energy Source	**Power (Megawatt)**
Small and Large Hydro	64,000
Geothermal	500
Onshore Wind	1,600
Onshore Wind	800
Solar PV Panels	7,000
Biomass	50
Nuclear Power	20,000
Total	93,950

Source: ECN 2013

Methodology and Materials

The aim of this study is to gain a deeper understanding about the potentials of renewable energy and investigate how to support, promote and encourage its growth in order to derive its maximum benefits for sustainable economic development. Five renewable energy resources and their renewable technologies potentials have been selected for this study. These include; solar, wind, hydropower, biomass and geothermal. They are the most advantageous and widely used renewable resources for energy in developing countries today and are particularly relevant to rural areas and have both a track record and scope to develop further. Information was collected from secondary data (print and online) such as researched journals and books with respect to energy resources in Nigeria.

Renewable Energy Resources and Potentials in Nigeria

Solar Source of Energy

In 2003, the Federal Government of Nigeria approved a national energy policy, which encourages the effective utilization of the country's renewable energy resources. This has

positioned her for the integration of solar energy into the nation's energy mix. During the two last decades, the economic feasibility of solar power for residential, commercial and industrial consumption has been investigated by researchers. According to Shahrouz & Heshmati (2014), it is estimated that solar energy equivalent to over 15,000 times the world's annual commercial energy consumption reaches the earth every year. It is as a result of this enormous sustainable and free clean energy source that (Chilakpu, 2015) emphasized that this nation can achieve enough in the areas of agricultural product drying, cooking/boilers and generation of electricity for domestic and industrial uses.

Solar energy presents great development opportunities in developing countries, particularly since most of them are in the Sun Belt. Solar energy is dependent on weather conditions. Therefore, solar power generation varies by season, location and daytime. Studies have shown that Nigeria receives an average solar radiation of 3.5 kWh/m^2 a day at coastal latitude and 7 kWh/m^2 a day at the far north (Fadare, 2009; Oyedepo, 2012 and ECN, 2013). Therefore, if the right technology is put in place, solar radiation in almost every location in Nigeria is viable for electricity generation. The rise of solar as a renewable energy source and the various technological advances to improve battery technology and photovoltaic capacity is changing the lives of millions of people in rural communities and even in cities where grid power is insufficient. In Nigeria, the Energy Commission of Nigeria, with its two renewable energy centres, namely, the National Center for Energy Research and Development, NCERD, at the University of Nigeria, Nsukka and the Sokoto Energy Research Center, SERC, at Usmanu Danfodiyo University, Sokoto, has developed or adapted a variety of renewable energy technologies and capacities, including solar dyers, solar water heaters, solar cookers and solar chick brooders.

Application benefits of solar energy technologies

Some of the application benefits of solar energy technologies include;

- Photovoltaic (PV) System: Coverts solar energy into electricity using solar panels
- Solar Water Heater: Uses solar energy to heat water for house and industrial uses.
- Solar Space Heating and Cooling: Uses solar energy for space heating, cooling and ventilation.
- Solar Lighting: Uses solar energy for lighting, both indoor and outdoor.
- Solar Power Generator: Portable generators that use Solar Energy to charge batteries.
- Solar Power Pumps: Uses solar energy to pump water for irrigation, drinking and industrial use.
- Agricultural Applications: Uses solar energy for irrigation, crop drying and livestock management.
- Electric Vehicle Charging: Uses solar energy to charge electric vehicles.
- Solar Energy Storage Systems: Stores excess energy generated by solar panels for later use.
- Concentrated Solar Power (CSP) Systems: Uses mirrors or lenses to focus sunlight, generating heat for electricity production.

Fig. 1: Solar Thermal Energy Application. Source: Rural Electrification Agency (REA, 2023)

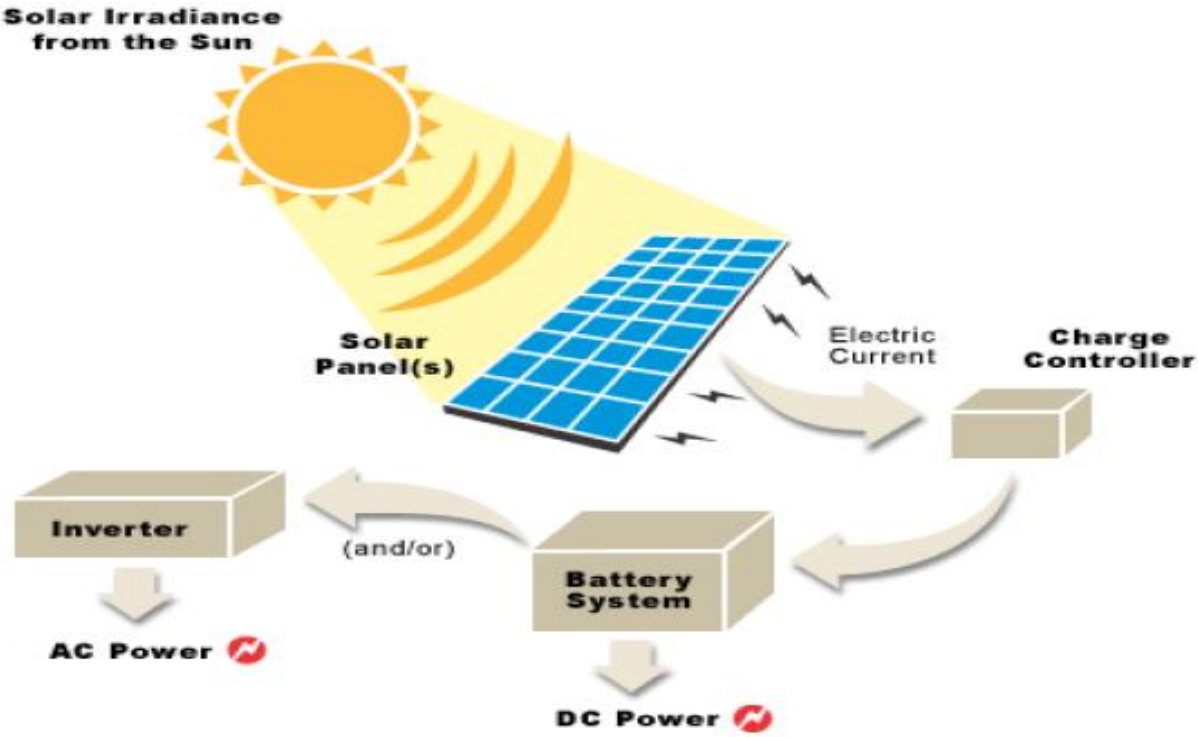

Fig. 2: Harnessing the Solar Energy for Domestic Use. Source: Anowor & Achukwu (2014).

Wind Source of Energy

When solar radiation enters the earth's atmosphere, different regions of the atmosphere are heated to different degrees because of earth curvature. This heating is higher at the equator and lowest at the poles. Since air tends to flow from warmer to cooler regions, this causes what we call winds, and it is these airflows that are harnessed in windmills and wind turbines to produce power (Anowor & Achukwu, 2014).). Wind power is not a new development as this power, in the form of traditional windmills -for grinding corn, pumping water, sailing ships -

have been used for centuries. Now wind power is harnessed to generate electricity in a larger scale with better technology. Wind energy for electricity production today is a mature, competitive and virtually pollution-free technology widely used in many areas of the world.

In terms of required wealth, technical potential for world development, wind power exceeds global electricity demand. This in line with Douglas, (2012) who stated that technically wind is of higher projected potential than hydro power. Nigeria with about 924,000 KM^2 of land mass including desert and semi-arid areas has enough un-obstructed spaces to install wind power plants that can serve its energy needs (Chilakpu, 2015). Study has shown that total exploitable wind energy reserve at 10 m height may vary from 8MWh/yr in Yola, Adamawa State to 51MWh/yr in the mountainous areas of Jos, Plateau State and it is as high as 97MWh/yr in Sokoto, Sokoto State (Nadabo, 2010). These are few among the enormous wind energy potentials in Northern Nigeria which when harnessed properly will improve the erratic power problem being experienced in Nigeria. However, wind energy exploration in Nigeria has not been significant as most of the existing wind energy systems are abandoned due to inappropriate evaluation of its potentials, operations and management (Oyedepo, 2012). Given the inadequate and epileptic power supply being experienced in the country, using wind energy conversion system to supplement the energy obtained from the serving hydropower and thermal power plants will be a wonderful initiative.

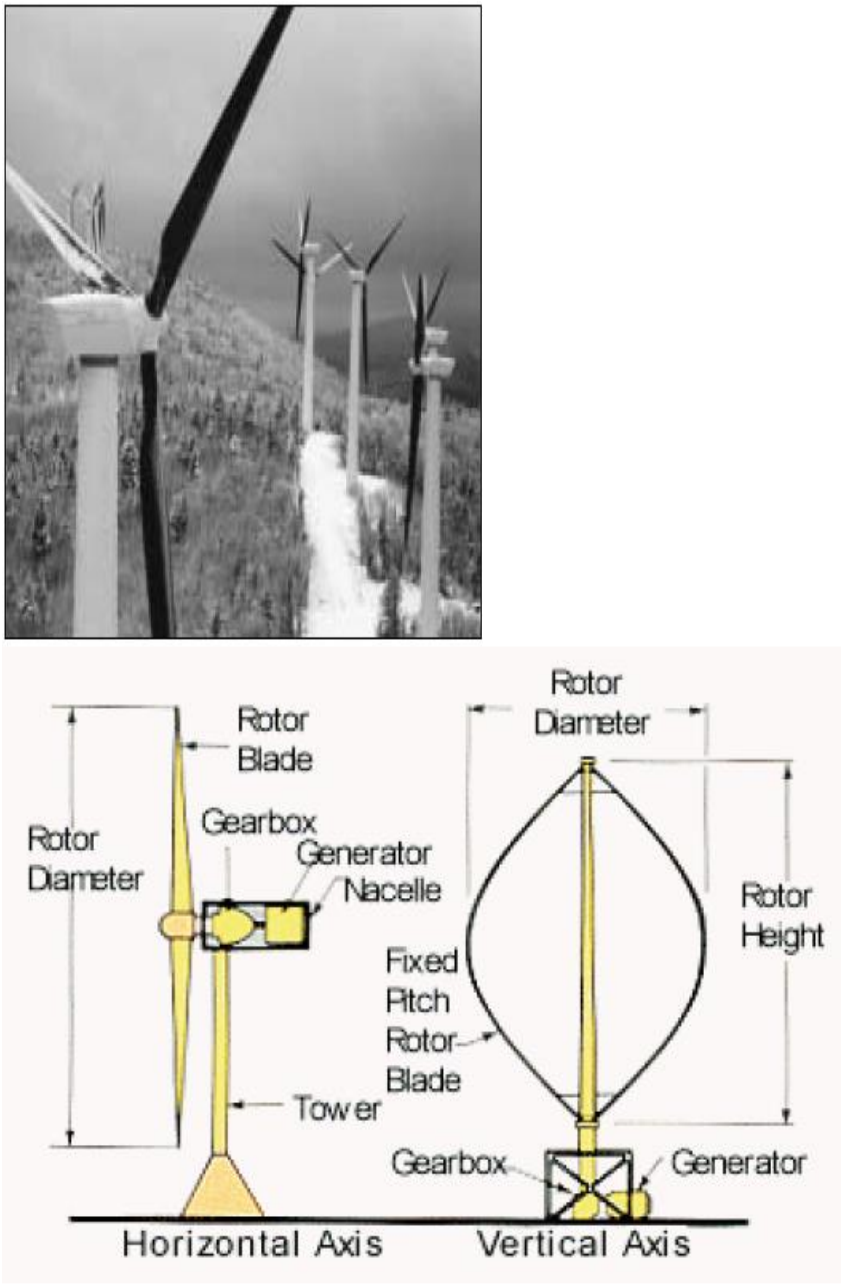

Fig. 3: Wind Turbine, Configuration and its Application. Source: Anowor & Achukwu (2014).

Application benefits of wind energy technologies

These include;

- Wind Turbines: Converts wind kinetic energy into electricity using lades attached to a rotor.
- Wind Farms: Large collections of wind turbines generating electricity on a utility scale.
- Distributed Wind: Small scale wind energy systems for homes, farms, or businesses.
- Wind-Powered Electric Vehicle Charging: Uses wind energy to charge electric vehicles.
- Wind-Powered Agriculture: Uses wind energy for irrigation, crop drying, and livestock management.

- Wind Powered Hydrogen Production: Uses wind energy to generate hydrogen fuel for transportation and power generation.
- Wind-Powered Water Pumping: Uses wind energy to pump water for irrigation, drinking water, and industrial applications.
- Wind-Solar Hayride Systems. Combine wind and solar energy to generate electricity and optimize energy production.
- Wind Electric Generators: Wind electric generator converts kinetic energy available in wind to electrical energy by using rotor, gear box and generator.

Hydro Source of Energy

Hydropower is a renewable energy source because it is replenished constantly by the fall and flow of snow and rainfall in the water cycle. As water flows through devices such as a water wheel or turbine, the kinetic (motion) energy of the water is converted to mechanical energy, which can be used to grind grain, drive a sawmill, pump water, or produce electricity. Hydropower is currently the largest renewable energy source for power generation around the world. Thus, hydro electricity generation has had a strong increase over the past 50 years (Shahrouz, 2014). According to Aliyu and Elegba 1990 cited in Yakubu et al. (2014) Nigeria possesses potential renewable source of energy along her numerous river systems, a total of 70 micro dams, 126 mini dam and 86 small sites have been identified. Policies are also in place allowing private sector participation in hydro power generation. Also, A 2013 study by the United Nations Industrial Development Organisation (UNIDO) showed that six hydro power sites including: Ikere Gorge Dam, Oyan Dam, Bakalori Dam, Tiga Dam, Challawa Dam, Doma Dam have huge hydro power potentials. These hydro projects lying idle around the country can be revamped to deliver huge Megawatts of hydro power which can serve about millions of people. The total potential of hydro power in Nigeria is about 14,750 MW. Approximately 14 % of the hydro power potentials, that is, 1930 MW which is currently being generated at Shiroro, Kainji and Jebba representing 30 % of gross installed grid –connected electricity generation capacity of Nigeria (Shaaban & Petinrin, 2014). Similarly, in 2015, Nigeria had about 1.9 GW installed capacity of large hydro and about 60 megawatts of small hydro (ECN, 2018).

Table 3: Major Hydro Power Plants in Nigeria.

S/N	Name of Hydro Power Plant	Year Established	Installed capacity (MW)	Availability as of June 2010 (MW)
1	Kainji	1968	760	465
2	Jebba	1968	578	482
3	Shiroro	1990	600	450
	TOTAL		**1,938MW**	**1,397MW**

Source: Sambo (2008)

Application benefits of hydropower technologies

These include;

- Hydroelectric Energy Storage: Stores excess energy generated by hydropower plants for later use.
- Hydroelectric-Powered Irrigation: Hydroelectric-powered to pump water for agricultural irrigation.

- Hydropower Plant: Generates electivity from the moving water energy, using turbine and generator.
- Pumped Storage Hydroelectricity: Stores excess energy by pumping water between two reservoirs, releasing through a turbine during peak demand.
- Hydroelectric Power Transmission: Efficient transmission systems to transport hydropower-generated electricity over long distance.
- Hydroelectric-Powered Industrial Processes. Uses Hydroelectric-powered to power industrial processes such as paper mills or food processing.
- Hydroelectric-powered Electric vehicle charging. Use Hydroelectric-powered energy to charge electric vehicles.
- Hydroelectric-Powered Water Supply: Uses Hydroelectric-powered energy to pump and treat water for municipal or industrial use.

Biomass Source of Energy

Biomass energy is a term that includes all energy materials derived from biological sources, including wood wastes, agricultural residues, food industry wastes, sewage, municipal solid waste (MSW), and dedicated herbaceous or woody energy crops. The biomass resources of Nigeria consist of wood, forage grasses and shrubs, animal wastes arising from forestry, agricultural, municipal and industrial activities as well as aquatic biomass (REMP, 2012). Biomass as organic substance has been used for thousands of years and is the oldest known energy source. It is a renewable energy source because its supply is unlimited; that is more can always be grown or generated in a relatively short time. The total land available in Nigeria for agriculture and under vegetation is a measure of biomass potential (Rahman et al., 2011). The biomass energy resources of the nation have been estimated to be 144 million tones / year. Burning wood is the oldest form of energy production. It is only very recently that other fuels have supplanted wood as the world's principal fuel. Indeed, in many regions wood-burning technology has remained the sole source of energy generation with little or no technological improvements.

Consequently, it is estimated that Nigeria consumes about 43.4 × 109 kg of fuel wood annually. Over 60% of Nigeria's population depends on fuel wood for cooking and other domestic uses. This traditional method is not sustainable as the rate of consumption of fuel wood far exceeds the replenishing rate thus resulting in desert encroachment, soil erosion and loss of soil fertility (National Bureau of Statistics, 2016).

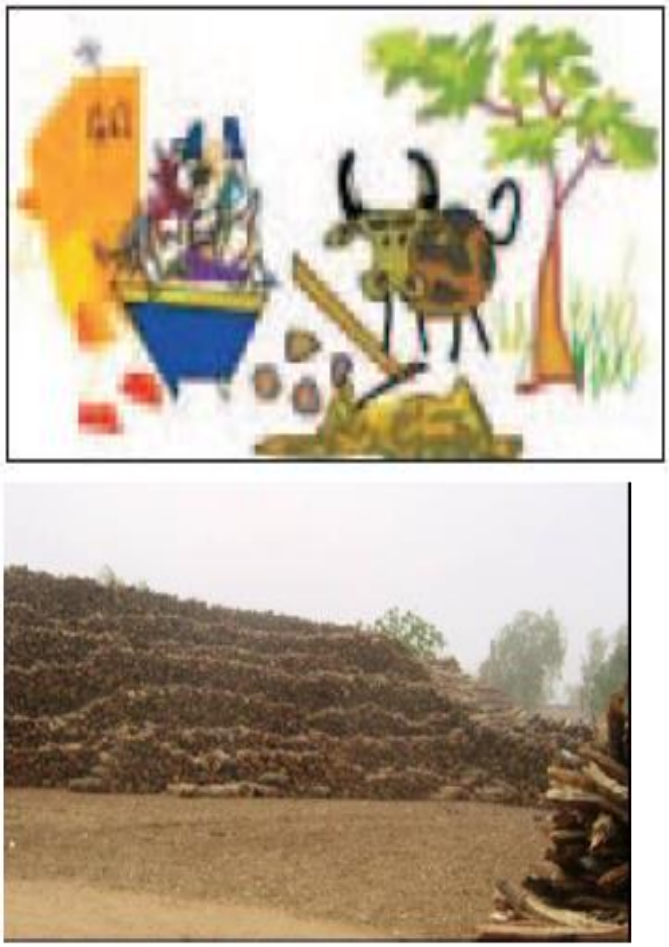

Fig. 4: Biomass Energy Resources (wood wastes, agricultural residues, municipal solid waste and so on)

The rural dwellers should be enlightened so as to use an improved wood-burning stove which could reduce fuel wood consumption for a particular process by 50% (Ademiloye et al., 2020). Biomass fuels are overwhelmingly the most important energy source for rural households, agricultural production and rural industries particularly in developing countries. Utilization of biomass is a very attractive energy resource, particularly for developing countries since biomass uses local feedstocks and labor. Biomass is then a heterogeneous energy source and may be used to meet a variety of energy needs, including generating electricity, heating homes, fuelling vehicles and providing process heat for industrial facilities.

Fig. 5: The Traditional Three-Stone Cooking Stove and Highly Improved Wood Saving Stoves

Application benefits of biomass technologies

These include;

- Electricity Generation: Biomass energy can be harnessed to generate electricity. Biomass plants are often called combined heat and power (CHP) plants, as they create both heat and electricity.
- Transportation Fuels: Biomass energy can be used to produce biofuels such as ethanol and biodiesel which can be blended with gasoline and diesel to power vehicles.
- Heating and Cooking Processes: Biomass energy can be used for heating purposes in homes. It is harnessed for home heating and cooking, with wood and wood pellets serving as standard fuels for stoves and oilers as an alternative to traditional natural gas and oil sources.
- Agriculture: Biomass energy can be used in agriculture to produce fertilizers and animal feeds.

Geothermal Source of Energy

Geothermal is a type of thermal energy generated and stored within the Earth. It has been used throughout history for bathing, heating and cooking. According to Ngô & Natowitz, (2009) cited in Rahman et al. (2011), geothermal energy is created by radioactive decay, with temperatures reaching 4,000˚C at the core of the Earth A more experimental pollution-free geothermal energy resource, requiring further research to become economic. Hot rock energy is obtained by drilling intersecting holes deep into the center of the earth, pouring water down one

of the holes and obtaining steam to drive a turbine up the other hole (Richard, 2005). When the steam cools, it condenses to water and is injected back into the ground to recharge the reservoir and complete the renewable energy cycle. There are most likely just three geothermal energy locations in Nigeria. The Ikogosi warm spring (37°c) placed in south-western piece of the nation, in Ekiti state, the Wikki warm spring (39°c) spotted in Bauchi (North-eastern) a piece of Nigeria and the RafinRewa spring (42°c) found in Plateau (North-focal) condition of Nigeria (Ikechukwu et al., 2015).

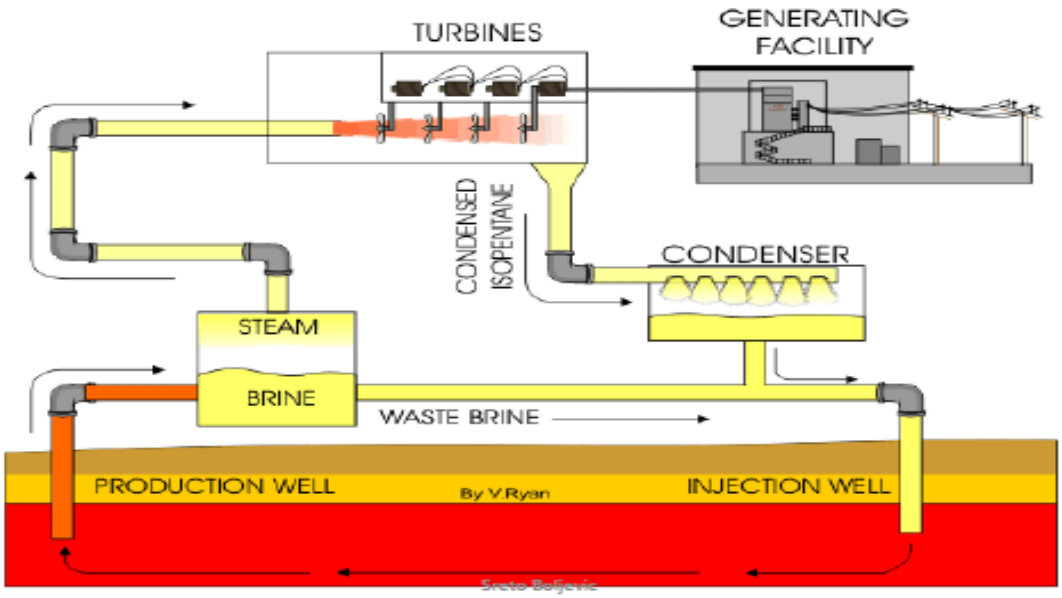

Fig. 6: Flash Steam Power Plant for Driving Turbines for electricity generation. Source: Raluca et al. (2023)

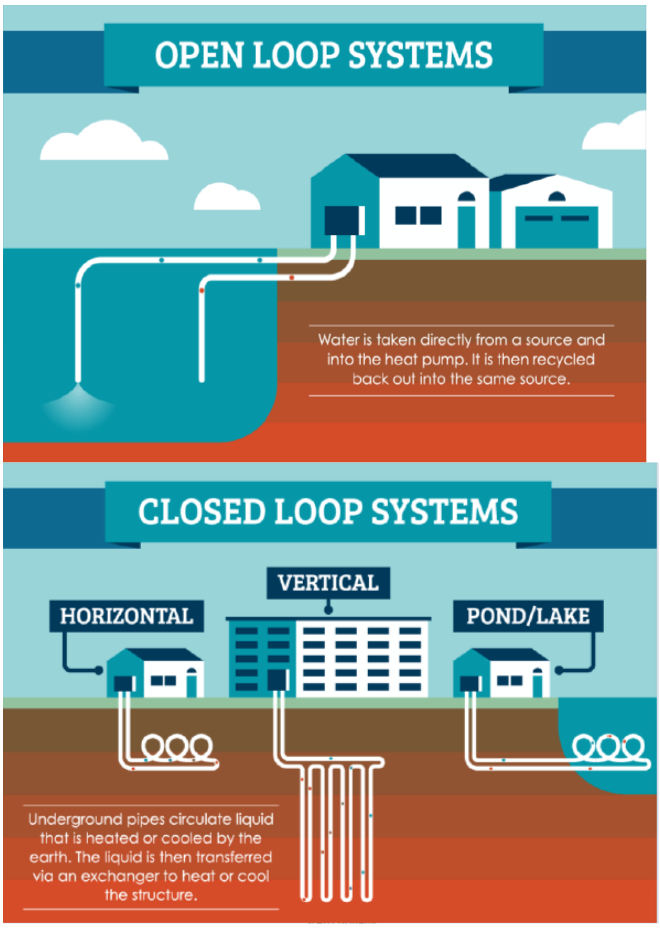

Fig. 7: Direct Use of Geothermal Energy for heating and cooling buildings. Source: Raluca et al. (2023).

Application benefits of geothermal technologies

These include;

- Electricity Generation: Geothermal power plants use steam from underground reservoirs to drive turbine, generating electricity.
- Direct Use: Geothermal energy is used for heating buildings, greenhouses and water, as well as for industrial processes like paper mills and food processing.
- Geothermal Heat Pump: A heat pump is a device that extracts heat from one place and transfers it to another. This system harnesses geothermal energy for heating and cooling buildings, using underground pipes and a heat exchanger.
- Dry Steam Power Plants: Steam from underground reservoirs is used directly to power turbines, generating electricity.
- Geothermal Energy Storage: Excess energy is stored in underground reservoirs for later use, stabilizing the grid and ensuring a reliable supply.
- Geothermal-Powered Aquaculture: Geothermal energy is used for aquaculture, providing optimal water temperature and conditions for fish and shellfish farming.
- Hybrid Geothermal-Fossil Power: Geothermal energy is combined with fossil fuels to generate electricity, increasing efficiency and reducing emissions.

- Flash Steam Power Plants: High-pressure geothermal water can be flashed into steam, driving turbines for electricity generation.

Organizations/Institutions Responsible for Overseeing Renewable Energy in Nigeria

The National Energy Policy developed by the Energy Commission of Nigeria was to serve as a blueprint for the sustainable development, supply and utilization of energy resources within the economy, and for the use of such resources in international trade and co-operation (Sunday, 2014).

The Energy Commission of Nigeria (ECN): An act to establish the Energy Commission of Nigeria (ECN) and to charge it with responsibility for coordinating and general surveillance over the systematic development of the various energy resources in Nigeria was made in 1979. It serves among other functions, as a center for gathering and dissemination of information relating to national policy in the field of energy development. The comprehensive national energy policy was released in April 2003 by the Energy Commission of Nigeria to champion the government's policy on the development and exploitation of all Nigeria's energy resources, addressing environmental issues, energy utilization and efficiency, financing and policy implementation.

Nigerian Electricity Regulatory Commission (NERC): The Nigerian Electricity Regulatory Commission (NERC) is an independent regulatory body with authority for the regulation of the electric power industry in Nigeria. It was established by the electric power sector reform act of 2005 (repealed) now the electric act of 2023 undertaking technical and economic regulation of the Nigeria electricity supplies industry. The Commission is to, among other functions issue operating licenses, granting permits, promoting competition, determining operating codes and standards, establish customer rights and obligations and set cost reflective industry tariffs, protecting grid stability and promoting energy conservation and renewable energy.

Transmission Company of Nigeria (TCN): The Transmission Company of Nigeria (TCN) is a federal government owned electric utility company in Nigeria which was established in November 2005 and given a transmission license by the Nigerian Electricity Regulatory Commission (NERC) in July 2006. It is charged with the responsibility of ensuring better coordination of electricity in Nigeria. As electricity is generated, the company transmits and distributes it to the final consumers in the country. TCN is one of the successor companies that emerged from the unbundling of National Electric Power Authority (NEPA) and Power Holding Company of Nigeria (PHCN) in April 2004 and subsequent privatization of the companies. TCN is charged with the responsibility of wheeling power from power generating companies (GensCos) to distribution companies (DisCos).

National Environmental Standards and Regulations Enforcement Agency (NESREA): National Environmental Standards and Regulations Enforcement Agency (NESREA) is a Nigerian government agency that was established in 2007 to protect and develop the environment. The agency is responsible for enforcing environmental standards and regulations, conducting environmental impact assessments, combating illegal wildlife trade, regulating waste disposal and raising environmental awareness through public information campaigns. The body is also charged with the responsibilities of protection and development of the environment, biodiversity conversation and sustainable development of Nigeria's natural resources in general.

National Environmental Standards and Regulations Enforcement Agency (NESREA): Nigerian Bulk Electricity Trading (NBET) PLC is the government-owned company responsible for managing the electricity pool in the Nigerian electricity supply industry. It was incorporated

on July 29, 2010 and is responsible for purchasing electricity from generating companies through Power Purchase Agreements (PPAS) and selling to distribution companies through vesting contracts. The generating companies include the privatized Power Holding Company of Nigeria (PHCN) successor companies, the Niger Delta Power Holding Companies (NDPHC), the already existing Independent Power Producers (IPPs) and the new IPPs.

Nigerian Electricity Management Services Agency (NEMSA): Nigerian Electricity Management Services Agency (NEMSA) is also known as Nigerian Energy Management Services Agency. It was established by NEMSA act 2015 and is presently known as act 2023. Its functions is to enforce technical standards and regulations, technical inspection, testing and certification of all categories of electrical installation, electric meters and instruments, and to ensure the efficient production and delivery of safe, reliable and sustainable electricity power supply in the country.

Federal Ministry of Power (FMP): Federal Ministry of Power (FMP) is the policy making arm of the federal government of Nigeria with the responsibility of the provision of power in the Country. The ministry in discharging this mandate is guided by the provision of the National Electric Power Policy (NEPP) of 2001 the electric power sector reform (EPSR) act of 2005, the roadmap for power sector reform of August 2010 and the Electricity Act 2023. The major objective of the ministry include; generation, distribution and transmission of power (electricity) nationwide.

Policies and Enabling Environment Regulating Renewable Energy for Sustainable Development

Nigeria is at a key point in time to capitalize on its abundant renewable energy resources to meet the growing needs of its population while simultaneously addressing socio-economic challenges. To do so requires a broad and comprehensive set of policies and enabling environment for all the sectors of its economy which will facilitate the transition away from non-renewable fossil fuels with all the economic and health benefits that would follow.

a) National Electric Power Policy (NEPP), 2001: The Electric Power Implementation Committee introduced the NEPP which served as a foundational outline for the current framework for power sector reforms in Nigeria. It served as a prelude to the Electric Power Sector Reform Act and provided for majority of the changes that came alongside the Act.

b) National Energy Policy (NEP), 2003: National Energy Policy (NEP) is geared towards the optimal utilization of the nation's energy resources for energy security and sustainability. It provides for strategies, objective and plans to harness the abundant sources of renewable energy in Nigeria for access to sustainable energy.

c) Renewable Energy Master Plan (REMP), 2005: The foremost objective of the REMP is to set out a road map for addressing key development challenges facing the electricity market in Nigeria through the utilization and exploitation of renewable energy. It identifies hydropower, solar energy, ocean energy, tidal energy amongst others as relevant to the pursuit of the country's goal in achieving sustainable energy. It also recommends the establishment of a Renewable Energy Fund, to be managed by a new National Renewable Energy Agency (NREA) pending when a full Ministry of Renewable Energy is established to address the lack of adequate institutional leadership for renewable energy in Nigeria. The REMP seeks to increase the share of renewable electricity in Nigeria, from 13% of electricity generation (mainly met by large hydro) in 2015, to 23% in 2025 and 36% by 2030.

d) Renewable Electricity Policy Guidelines (REPG), 2006: Renewable Electricity Policy Guidelines (REPG), expresses the Federal Government's aims and objectives for promoting access to a more viable source of energy. The policy guideline provides a framework to integrate renewable energy sources into the energy technology sphere in improving the reliability of electricity supply through the grid which may in turn, ensure the stability of grid electricity supply.

e) Renewable Electricity Action Program (REAP), 2006: Renewable Electricity Action Program (REAP), primarily, focuses on utilizing all forms of renewable energy sources for electricity generation. It highlights potential gaps, technical assessments and the financial implications of utilizing renewable energy and looks at the general overview of the potential for renewable energy technologies, and potential markets while detailing the development targets per technology, application and strategies for achievement.

f) National Policy on Climate Change (NPCC) 2013: The National Policy on Climate Change (NPCC) sets out Nigeria's response strategy to climate change as well as measures for the adoption of climate smart practices aimed at fostering sustainable development. It describes adaptation and mitigation measures for responding to the threat of climate change in the country.

g) National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015: The National Renewable Energy and Energy Efficiency Policy (NREEEP) sets out the Nigerian government's blueprint to increasingly harness the country's renewable energy and energy efficiency resources in driving sustainable development across the country. Developed in line with the country's national energy policy, the NREEEP outlines the government's programs and measures for deploying renewable energy and energy efficiency technologies and practices towards facilitating Nigeria's green transition. NREEEP recognizes hydropower, biomass, solar and wind as viable sources of renewable energy and provides strategies to leverage on these sources to achieve stable energy system in the country.

h) Nigeria's Nationally Determined Contributions (NNDC) 2015, updated 2021: Nigeria's Nationally Determined Contribution (NDC) shows its global commitment towards embracing sustainable development measures that limit the rate of global warming and negative impacts of climate change. It shows the country's climate targets and measures to be adopted in actualizing them.

i) Rural Electrification Strategy and Implementation Plan (RESIP) 2016: The Rural Electrification Strategy and Implementation Plan (RESIP) was developed in line with the federal government's plan for rural electrification and provides the implementation framework and measures for driving rural electrification across the country by means of - on and off-grid energy solutions.

j) Sustainable Energy for All Action Agenda (SEAAA), 2016: Nigeria's Sustainable Energy for All Initiative Action Agenda is the country's implementation document for the global Sustainable Energy for All. It shows Nigeria's commitment towards global sustainable development, and links to the country's policy and regulatory documents on sustainable energy such as the National Renewable Energy and Energy Efficiency Policy (NREEEP), the National Renewable Energy Action Plan (NREAP), the National Energy Efficiency Action Plan (NEEAP), and Nigeria's Nationally Determined Contribution (NNDC) to the COP 21 Paris Agreement.

k) National Energy Efficiency Action Plan (NEEAP), 2016 (2015-2030): The NEEAP is a supporting strategy document to the NREEEP and guides its implementation. It currently provides the general framework for Nigeria's energy efficiency strategy with reference to other

specific energy efficiency related documents. The NEEAP includes baseline data and information on energy efficiency in the country as well as suggested achievable energy efficiency targets, including gender disaggregated indicators, based on national potentials and socio-economic assessments.

Overall Benefits of Renewable Energy Technologies to Economic Development

The Following are some of the benefits derived from renewable sources of energy.

- ✓ Renewable energy could stimulate growth in farming, forestry and rural industry leading to overall rural development.
- ✓ Renewable energy could also provide a productive avenue for using household, agricultural and forestry wastes, besides plantations that could be used for bio-fuel production..
- ✓ If appropriately explored, renewable energy resources can provide a reliable and sustainable supply of energy almost indefinitely because they have security of supply.
- ✓ Renewable energy resources are generally well-distributed all over the world, even though wide spatial and temporal variations occur.
- ✓ It contributes to environmental protection by offsetting fossil fuel use and related emissions of nitrogen oxides, sulfur dioxides, and other pollutants.
- ✓ Renewable energy is a source of new revenue since it can increases the tax base for improving service provision in rural communities.
- ✓ It can create some valuable job opportunities for people in communities where there are otherwise limited employment opportunities.

Barriers or Limitations to Development of Renewable Energy Resources in Nigeria

Despite the numerous benefits of renewable energy resources, there are yet many barriers to the wider spread use of the alternative energy resources as noted in Nigeria's Vision 2010 National Energy Plan.

- ➢ High import duties on renewable energy equipment and materials.
- ➢ High Initial Investment Cost for the installation of renewable technology systems.
- ➢ Ineffective implementation of energy policies by the government, commercial and industrial officials.
- ➢ Lack of information or awareness by the public, and even many government, commercial and industrial energy officials, about the availability, costs and benefits of renewable energy technologies.
- ➢ Preference for the existing non-renewable fossil resources over newer renewable resources by government, commercial and industrial officials responsible for making energy decisions.
- ➢ Lack of knowledgeable personnel trained in the installation, operation and maintenance of renewable energy equipment and materials.
- ➢ Poor Research and Development (R&D) efforts and findings being devoted to improving renewable energy technologies.
- ➢ Lack of knowledge by project initiators and managers of the social and energy related needs of rural communities, how to adapt projects to meet these needs, and involvement of the communities in the design of projects may be the most significant barrier.

Conclusion

The paper has obviously reviewed the need to make use of the abundant resources of renewable energy that are inexhaustible and which the menace of climate alteration is reduced,

while they also sustain development over time. The renewable energy resources in Nigeria such as hydropower, biomass, solar, wind geothermal and others are in abundance and should be maximally harnessed to fill the gap created by the conventional power generation which is grossly inadequate for the growing population of the country. Renewable energy sources provide very good sources (opportunities) to increase energy generation in Nigeria. Thus, the main goal in achieving optimal sustainable economic development is to make good use of these opportunities by increasing the use of renewable energy sources and increasing the economic efficiency of their use.

Recommendations

Future studies can improve on this by focusing on the commitments of governance quality in the financial development of renewable energy. It is also imperative to intensify research and development in the renewable energy to increase energy sources and improve energy management systems that will promote sustainable development. Therefore, the following recommendations were made;

(i) Nigeria must improve its records on renewable energy sources and approach the use of available energy potential responsibly and economically. To achieve these goals will require an increased commitment to eliminating the barriers to adoption of sustainable energy measures and creating a climate and legislation to encourage private investment in them.

(ii) The government's existing policies/programmes as discussed in this review are already on the right track but need to be actively implemented for renewable energy to flourish in the country. This can be done through its various organizations/institutions responsible for overseeing renewable energy.

(iii) The federal Government should also improve and expand the regulatory framework for decentralized renewable energy solutions through the implementation of the Electricity Act 2023.

(iv) Private sector should be encouraged by the government to invest and engage in the development of renewable energy.

(v) Universities and other research institutions should be provided with adequate fund to carry out more researches on a suitable conversion technologies for the country.

(vi) Government should also increase the budgetary allocation to the energy sector and release these funds duly. It can also complement its finance source bypartnering with international organizations like International Monetary Fund (IMF) and World Bank to help finance some of the Renewable Energy Projects lying in the country.

(vii) To ensure long term development of renewable energy and energy efficiency, there must be human resource development at high level and manufacturing capacity building.

(viii) Critical knowledge and technical know-how transfer should be the focus for project development and management.

(ix) Energy based economic development in rural community is recommended in order to achieve 100% prospect of renewable energy.

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