

NUCLEAR ENERGY: THE BEST ENERGY MIX FOR SUSTAINABLE INDUSTRIAL DEVELOPMENT AND ECONOMIC GROWTH OF NIGERIA

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Abstract

The need for industrialization in developing countries has been a way of improving the quality of life of the populace by providing the basic amenities to support their life. One of the factors that favor industrialization is the steady and adequate supply of electricity, which could be generated from oil, gas water, wind, and nuclear. In Nigeria, electricity is being generated from hydro and thermal stations which could not meet the demand needed by Nigerians. To meet this demand of electricity needed by Nigerians, more power generating plants are needed. This paper assessed the energy demand, available energy sources, potential energy sources in Nigeria and the needs to add nuclear energy to her energy mix. Among the various energy sources for electricity generation, nuclear energy has proven to be the best alternative energy source. The use of nuclear energy in place of other energy source produces large amount of electricity in a small space, helps to keep air clean, preserves the earth's climate, avoids ground- level ozone formation and prevents acid rain which creates anxieties among the public. Other peaceful uses of nuclear energy that will accelerate industrial development and promote economic growth in Nigeria were also addressed.

Keywords: Development, Economic, Electricity, Energy-Mix, Industrialization, Nuclear-Power

1. Introduction

Industrialization has been a veritable way of attaining the lofty and desirable conception and goal of improved quality of life for the populace. This is because industrial development involves extensive technology-based development of productive (manufacturing) system of the economy. In other words, it could be seen as a deliberate and sustained application of suitable technology, management techniques and other resources to move the economy from the traditional low level of production to a more automated and efficient system of mass production of goods and services¹. On this note, industrialization is central to economic growth and development; this justifies the reason successive governments in developing countries such as Nigeria emphasize industrialization as a way of transforming the economy. Economic growth occurs in a nation when her production capacity increases. In other words, the country's producers of goods and services can make more materials that results to an increase in gross domestic product (GDP), which in turn leads to job creation and more employment. Today, poverty remains the central challenge of underdeveloped and developing nations, but there are effective means to eradicate it within the next generation. Industry continues to be a proven and crucially important source of employment, accounting for millions of jobs worldwide. Industrial development and trade in industrial goods have a proven record in effectively reducing poverty. The recent examples are the role played by industrial development and manufacturing, in countries like in China and the Republic of Korea.

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¹ Umar S A. "A Descriptive Analyses of the Challenges and Prospects of Industrialization: An impediment to Economic Development in Nigeria." *International Journal of Economics and Management Studies (SSRG-IJEMS)*, 2016; 3: 16-23.

These success stories represent models for many developing countries like Nigeria for drafting policies to effectively lift large numbers of people out of poverty². Industrialization is concerned with the expansion of a country's manufacturing activities, including the generation of electricity and the growth of its communications network, it is also a process of reducing the relative importance of extractive industries and of increasing that of secondary and the tertiary sectors³. Out of all the resources required for industrial development of a nation, steady and available energy source (electricity) is the major one that determines the sustainability of industrial sector of a nation. Electrical energy is used to power industrial machines, vehicles, to heat and cool homes and offices, and to provide light and other domestic services⁴.

This paper aims at assessing the energy demand, available energy sources, potential energy sources in Nigeria and the needs to add nuclear energy to her energy mix.

2. Materials and Methods

2.1. The Demand and Supply of Electricity in Nigeria

The demand for energy across the world is constantly rising. This increased demand is caused in part by the increase in population, and by economic development. The amount of energy a country uses is widely used to indicate or measure the level of development. As a country develops, energy-consuming activities, such as manufacturing, provision of services and transport increase in scale and importance. This rising demand for energy results in a country generating more of its own energy from various sources. Nigeria is the largest economy in sub-Saharan Africa, but limitations in the power sector has constrained her growth. The estimated demand for power in 2005 was about 9780MW, requiring a generating capacity of about 12700MW (with hydro accounting for about 31.30% while natural gas accounted for the balance of 68.70%), but most days were only able to generate about 4,000 MW which is insufficient for the Nigerian use⁵.

As of July 2019, the Independent System Operator indicated that the demand for electricity in Nigeria was estimated at 25,770 MW, with supply at about 4,500 MW for a country of over 200 million meaning that demand far outstrips supply leading to widespread self-generation of about 2400MW from small diesel and petrol generating sets. Currently, the combined installed generating capacity is 12,500MW with about 74% contribution from the gas-powered plants⁶.

2.1.1. Status of Electricity Supply Infrastructure in Nigeria

The operation of the power generation sector is driven by the privatized generation companies (GenCos), Independent Power Producers (IPP), and the generation stations under National Integrated Power Project (NIPP). The electricity generated are transmitted through transmission lines that use three phases namely alternating current (AC), single-phase AC current and high-

² Yong L. "Introduction to UNIDO Inclusive and Sustainable Industrial Development". *United Nations Industrial Development Organization*, January 2015; Vienna. p. 1-58. www.unido.org

³ Mandara B, Ali M B. (2018) "Appraisal of the Impact of Industrialization on Economic Growth in Nigeria". *Journal of Business and Management*, 2018; 20:1–10. www.iosrjournals.org

⁴ Bennet D J, and Thomson J R. "The Elements of Nuclear Power", 3rd Edition, New York: John Wiley and Son Inc.; 1988. p. 1-293.

⁵ Oruonye E D. "Politics of Hydroelectric Power Development in Nigeria: A Case Study of the Mambilla Hydroelectric Power Project". *Global Journal of Interdisciplinary Social Sciences*, 2015; 4: 19–25.

⁶ Kehinde O, Babaremu K O, Akpanyung K V, et al. "Renewable Energy in Nigeria - A Review". *International Journal of Mechanical Engineering and Technology (IJMET)*, 2018; 9: 1085-1094.

voltage direct current system. However, transmission of electricity using high voltage (110 KVA or 330 KVA used in Nigeria) aids in the reduction losses⁷.

The annual electricity demand growth is projected to be 7% - 13% depending on economic growth scenarios. There is about 80% demand/supply gap in Nigeria coupled with overloaded and poor voltage profile in most parts of the transmission network resulting to frequent system collapses and exceedingly high transmission losses, often in the region of 30-35%⁸. It is obvious that electricity demand is far above its supply, the inefficient generation as well as inadequate transmission facilities to boost electricity supply has also been a major cause of the increasing gap between demand and supply of electricity⁹. Thus, it is necessary to fully rehabilitate the existing power stations, rehabilitate some critical transmission, distribution lines and their associated substations and adds new generating, transmitting, and distributing capacity to the grid, in the immediate and near future.

2.1.2. The Nuclear Energy

Electricity demand is on the increase, and it is strongly evident that the present energy mix is grossly inadequate to meet the needs of the current population and keep the economy moving on the path of progress. Greater use of nuclear power to produce electrical energy would save greater amounts of fossil fuels for such uses as are of vital importance to our modern civilization and style of life and where no viable substitutes are available. Estimates of the available resources of such fuels have always caused concern about their adequacy to meet the increasing energy requirements in the future. Fossil fuels are needed as vital raw materials in chemical industries to produce many industrial products such as ammonia for fertilizers, synthetics, plastics, pharmaceutical products, and many other commodities for everyday needs. Therefore, fossil fuels could be more effectively and economically used for such applications, rather than by being burned as fuel for energy production¹⁰. The need for energy supply diversity with efforts to reduce global carbon emissions have set nuclear power to become a genuine energy alternative. Nuclear power is created through controlled nuclear reactions that release heat, which is then used to boil water and release steam. The steam is used to power a turbine within the power plant which is connected to a generator that produces electricity. Many countries developed nuclear power stations that generate huge amount of energy from lesser amounts of fuel. In the 1997 report of the International Atomic Energy Agency (IAEA) Power Reactor Information System (PRIS), it was stated that 31 countries were operating a total of 437 nuclear power stations. The countries with the highest reliance on nuclear power in 1997 were: Lithuania, 81.5%; France, 78.2%; Belgium, 60.1%; Ukraine, 46.8%; Sweden, 46.2%; Bulgaria, 45.4%; Slovak Republic, 44%; Switzerland, 40.6%; Slovenia 39.9% and Hungary, 39.9%. In 2018, there are 450 nuclear reactors in operation in some 30 countries around the world. One of the largest plants is situated in France, where about 70 percent of total electricity generation was derived from nuclear sources. There are currently 440 reactors supplying about

⁷ Emodi N V, Yusuf S D. "Addressing Climate Change Impact on the Energy System View project Improving Electricity Access in Nigeria: Obstacles and the Way Forward". *International Journal of Energy Economics and Policy*, 2015;5:335–351. www.econjournals.com

⁸ Paul O U, Aliu S, Albert O, et al. "Electricity Crisis in Nigeria: The Way Forward". *American Journal of Renewable and Sustainable Energy*, 2015; 1: 180-186. <http://www.aiscience.org/journal/ajrse>

⁹ Abanihi V K, Ikheloa S O, and Okodede F. "Overview of the Nigerian Power Sector". *American Journal of Engineering Research, AJER*, 2018; 7: 253–263. www.ajer.org

¹⁰ IAEA. "Guidebook on the Introduction of Nuclear Power". *International Atomic Energy Agency*, July 1982; Vienna. p.1-368.

10% of the world's energy. The United States has the most operational nuclear reactors ninety-five (95) on the planet, together they have a capacity of 97,565 MW, and last year nuclear energy made up about 20% of the country's electricity generation. France, which produce about 75% of the country's electricity, China 47 nuclear reactors, Japan 33 nuclear reactors and Russia 38 nuclear reactors¹¹. Nuclear energy is the world's largest source of emission free energy. Nuclear power plants produce no controlled air pollutants, such as sulfur and particulates, or greenhouse gases. The use of nuclear energy in place of other energy sources helps to keep the air clean, preserve the earth's climate, avoid ground-level ozone formation, and prevent acid rain. Nuclear energy is the most eco-efficient of all energy sources because it produces the most electricity relative to its environment impact. Water discharged from a nuclear power plant contains no harmful pollutants and meets regulatory standards for temperature designed to protect aquatic life. This water used for cooling, never meets radioactive materials. If the water from the plant is so warm that it may harm marine life, it is cooled before it is discharged to its source river, lake, or bay as it is either mixed with water in a cooling pond or pumped through a cooling tower.

2.1.3. The Nigerian Nuclear Power Plants

The major cause of this energy crisis in Nigeria is the absence of a robust and comprehensive energy basket. The former Honorable minister of Environment, John Odey said, use of nuclear energy for electricity generation is no longer an option but a necessity if Nigeria is to meet her energy needs. The grid capacity built around oil, natural gas, and hydro is not only grossly inadequate but cannot meet the country's current and future energy demands¹².

The column bus study submitted to the Federal Government in 1978 showed that nuclear power will play a significant role when the country demand reaches a minimum of 20,000MW of electricity based on projection. The Federal Government of Nigeria have activated a Nuclear power program (NPP) and has approved the road map for its implementation, as the national strategy for the implementation of the approved program has been finalized with assistance of the International Atomic Energy Agency (IAEA). With the setting up of near term targets of nuclear contribution of national electricity generation, Nigeria is to achieve a minimum of 1000 MW online electricity by 2010 to 2022 with upgrade to a minimum of 4000MW in 2030, said by Senior Special Assistant to the President on Media and Publicity, Garba Shehu. In November 2019, the Senate of Nigeria called on the government to consider the inclusion of nuclear power in the country's energy mix. It has therefore become necessary to include nuclear power in the current power mix as provision is made for it in the National Energy Policy¹³. To implement this policy, the size and configuration of the national power grid are needed. Thus, improvement of the national grid and increased generating capacity are imperative for the development of a nuclear program in Nigeria¹⁴.

2.1.4. Economic Analysis of Nuclear Power Plants

¹¹ Agneta R. "World Nuclear Performance Report", *World Nuclear Association*, August 2020; London. p. 1-68.

¹² John O. "Nuclear Electricity A necessity in Nigeria", *Stakeholders Workshop*, 26th-30th October 2009, Nigerian Nuclear Regulatory Authority, Abuja. The Guardian Newspaper.

¹³ Musbaudeen O B, Abdallah D, Adetunji A, et al. "A Review of Nigerian Energy Policy Implementation and Impact". *Energy Commission of Nigeria*, April 2019; Nigeria. p.1-32
<http://dx.doi.org/10.13140/RG.2.2.10422.14408>.

¹⁴ Nathaniel L L. "Nigeria And Nuclear Energy: Plans And Prospects". *The Centre for International Governance Innovation*, January 2010; Ontario. p.1-16. www.cigionline.org

Nuclear energy is a secure energy source that a nation can depend on, unlike some other energy sources; it is not subject to unreliable weather or climatic conditions, unpredictable cost fluctuations, or dependency on foreign supplies. Nuclear power plants typically have high capital costs for building the plant, but low direct fuel cost (with much of the costs of fuel extraction, processing, use and long-term storage).

In a typical reactor, which produces 3000 MW of thermal power, the U-235 fuel consumption is approximately 4 kg/day. To produce the same energy using fossil fuels such as coal, oil, or gas, millions of times as much weight would be required¹⁵. The economics analysis of nuclear power plants must consider security and safety costs that bears the risks of future uncertainties. Unlike other power plants, nuclear plants must be carefully guarded against both attempted sabotage and theft of nuclear material. Thus, security costs of both protecting the physical plant and the screening of workers must be considered. Since nuclear reactors contain a core of highly radioactive fuel and around that core a complex cooling system which is also significantly contaminated, nuclear power plant operators need to invest considerable resources in keeping these structures intact, functioning, and isolated from the environment¹⁶. Whereas a conventional power plant can break down without large environmental effects, this must be prevented at a nuclear power plant at all costs. If the cost of producing electricity using nuclear power is expected to be lower than the risk adjusted costs associated with alternative electric generation technologies, then investments on commercial nuclear generating facilities would be embarked upon by investors. It is obvious that nuclear power plants have high capital costs and extremely low marginal operating costs, therefore, nuclear energy will compete with alternative electricity generation sources for high load factor operation¹⁷.

2.1.5. Prospects of Additive Manufacturing and 3D Printing on Nuclear Power Plants

Additive manufacturing is the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining. It can deliver parts of very intricate and complex geometries with a minimum need for post-processing. Additive manufacturing (AM) allows for layer-by-layer fabrication of complex metallic parts with features typically unobtainable via conventional manufacturing processes. Additive manufacturing techniques can fabricate a wide variety of materials, including ceramic, glass, metals, polymers, and composite materials. Direct energy deposition (laser, electron beam, plasma-arc, and electric-arc) where focused thermal energy is used to fuse powders or wires by melting as they are deposited on the substrate are normally employed for the production and repair of parts¹⁸. To fabricate nuclear fuel, additive manufacturing was successfully applied to nuclear fuel material using a consumer-grade 3D printer and commercially available photocurable resin. Thorium dioxide was printed and sintered to densities of ~90% of theoretical density without addition of impurities from the resin used in the stereolithography process¹⁹. This is a promising technology for quick and economical replacement of faulty components of nuclear power plant.

¹⁵ Murray R L. "Nuclear Energy : An Introduction to the Concepts, Systems, and Applications of Nuclear Processes". Oxford : Butterworth-Heinemann/Elsevier; 2009. p. 1-519

¹⁶ Pedersen E S. "Nuclear Power Project Management", Michigan: Ann Arbor Science Publisher, 1978. p. 1- 267.

¹⁷ Eric S B. "The Future of Nuclear Power". Cambridge: MIT; 2003.p. 1-180.

¹⁸ Sun C, Wang Y, McMurtrey M D, et al. "Additive Manufacturing for Energy: A Review." *Applied Energy*, 2021; 282:1-18.<https://doi.org/10.1016/j.apenergy.2020.116041>

¹⁹ Bergeron A, and Crigger J B. "Early Progress on Additive Manufacturing of Nuclear Fuel Materials". *Journal of Nuclear Materials*, 2018; 508:344–347. <https://doi.org/10.1016/j.jnucmat.2018.05.058>.

2.1.6 Non-Electric Power Applications of Nuclear Energy

The practical contributions of nuclear energy and the IAEA's activities to enhance environmentally sound and sustainable international development have gained wide recognition in the global community. Compared to other electricity technologies, nuclear technology has unique features that create additional opportunities and challenges for sustainable development. Nuclear technology also plays a role in sustainable development outside the energy domain, notably in Agriculture, Environmental Pollution, Wastewater Treatment, Manufacturing Industry, Health, Oil & Gas Production, and research supports environment objectives²⁰. The following are some examples of non-electric power applications of nuclear energy technology.

2.1.7. Soil Fertility and Crop Production

The traditional method for subsistence farmers in Nigeria is multiple cropping where Nitrogen fertilizers are used widely to increase agricultural production. Many fertilizers, however, can harm the environment. Nuclear techniques (Isotope-labeled Nitrogen and Phosphorous fertilizers) are used to determine the best form, timing, and placement to avoid waste and to reduce its movement into the environment²¹. Measurements of the radiation at various times and locations in the plant by a detector or photographic film provides accurate information on the rate of phosphorus intake and deposition. This application of nuclear technology in agriculture improves crop yields.

2.1.8. Irrigation

Agricultural production requires an adequate supply of water in soils. In the northern part of Nigeria, farmers adopt and use efficient irrigation systems to maximize farm-level profitability, through improved crop yields and decreased costs and other inputs. Efficient use of irrigation scheduling such as using data from soil moisture sensors to schedule irrigation can reduce the amount of water applied to the field, resulting in less water withdrawn from a source such as groundwater or river basin²². Different practices to increase water conservation in rain-fed areas have been evaluated and have resulted in immediate practical application. Neutron moisture gauges (nuclear energy techniques), which measure the spectrum shift resulting from the impingent of energetic neutrons upon protons, can measure the hydrogen component of water in both the plant and the surrounding soil. As such, they are ideal instruments to help farmers make the best use of limited water supplies.

2.1.9. Environmental Pollution

Pollution of the air, land, and rivers has become a serious global problem threatening public health and the environment. The indiscriminate release into the environment of chemicals can also adversely modify the uptake by living organisms of trace elements, some of which are necessary for life only when present in small, controlled amounts²³.

²⁰ IAEA. "Nuclear Power for Sustainable Development". *International Atomic Energy Agency (Department of Nuclear Energy)*, November 2017; Vienna. p.1-10.

²¹ Bole J B. "Nuclear Techniques in the Development of Fertilizer Practices for Multiple Cropping Systems". *International Atomic Energy Agency*, December 1986; Vienna. p. 1-63.

²² Timothy M P, and Steve D M. "Irrigated Agriculture Technologies, Practices, and Implications for Water Scarcity", *United States Department of Agriculture*, 12th November 2019; Washington DC. p.1-129.

²³ Pier R D. "Nuclear Techniques for Sustainable Development: Water Resources and Monitoring Environmental Pollution" *International Atomic Energy Agency*, January 1993; Vienna. p. 1-7.

The use of isotopes and the development of analytical tools for the study, and detection of environmental pollutants such as pesticides and toxic metals have helped to solve pollution problems. The emission of toxic gases, SO_x and NO_x, into the atmosphere from coal and oil-fired boilers in power plants and industrial installations has long ago been recognized as the main source of environmental pollution on a large geographical scale. Reactions in the atmosphere result in an "acid rain" effect, with devastating consequences to earth flora. The International Atomic Energy Agency supports research and development activities in the use of electron beam irradiation to clean flue gases originating from the combustion of fossil fuels. The electron beam processing of combustion flue gases is a technology which has proved its potential for improving air quality, by reducing SO₂ and NO_x emission in a single stage dry process; converting toxic components in flue gases into a byproduct usable as agricultural fertilizer or soil conditioner; reducing "acid rain" by providing the controls above. Electron Beam processing is a safe technology and simple to control.

2.1.10. Wastewater Treatment

Potable water is the cornerstone of development and essential for sustainable growth. The first consideration for drinking water is to produce water that has been disinfected. Chlorine, the most widely accepted disinfectant in drinking water treatment, is known to have some disadvantages, namely in the formation of by-products that have adverse health effects, and the fact that it is less effective with some of the new, emerging organisms of public health concern. The ionizing radiation (gamma rays and electron beams) process has been shown to be extremely effective in killing bacteria of widely differing genera, inactivating viruses of many diverse kinds, and more recently, in water of differing quality (particularly those high in suspended material), in killing cryptosporidium²⁴.

2.1.11. Manufacturing Industry

Radioisotopes are used by manufacturers as tracers to monitor fluid flow and filtration, detect leaks, and gauge engine wear and corrosion of process equipment. Small concentrations of short-lived isotopes can be detected whilst no residues remain in the environment. By adding lesser amounts of radioactive substances to materials used in various processes it is possible to study the mixing and flow rates of a wide range of materials, including liquids, powders and gases, and to locate leaks. The ability to use radioisotopes to accurately measure thickness is widely utilized in the production of sheet materials, including metal, textiles, paper, plastics, and others. Density gauges are used where automatic control of a liquid, powder, or solid is important, for example in detergent manufacture.

2.1.12. Health/Medicine

There are several ways of using radioactivity in medicine. These include diagnosis of disease, external source cancer treatment and internal source cancer treatment. Radiation and radioisotopes are widely used in medicine particularly for diagnosis (identification) and therapy (treatment) of various medical conditions. Radioisotopes carried in the blood allow doctors to detect clogged arteries or check the functioning of the circulatory system. To evaluate the presence of heart disease, a radioisotope is injected into a patient's bloodstream while he or she is exercising on a treadmill. The radioisotope travels toward the heart, allowing doctors to follow the blood flow on

²⁴ IAEA. "Radiation Treatment of Polluted Water and Wastewater". *International Atomic Energy Agency*, September 2008; Vienna. p.1-222

a screen. While looking at the image, doctors can check for reduced blood flow through the arteries, a signal of heart diseases.

2.1.13. Processing of Heavy Crude Oil and Tar Sand

An oil refinery typically breaks down the residual heavy or long-chain hydrocarbons in a catalytic cracker by hydrogenation. The hydrogen is produced from natural gas, and it breaks down the long-chain hydrocarbons to yield synthetic crude oil, (about 5 kg is used per barrel). This hydrogenation of heavy crude oil is a major use of hydrogen today. This means about 15-20% of the energy value of the crude oil is used in producing refined products. The main difference between natural gas and nuclear steam generation is that a fuel-intensive process is replaced by a capital-intensive one, with no carbon emissions.

Tar sands also known as oil sands are a mixture of mostly sand, clay, water, and a thick, molasses-like substance called bitumen. Bitumen is made of hydrocarbon of the same molecules in liquid oil and is used to produce gasoline and other petroleum products. If the locations of tar sands are too deep to dig up, the bitumen can be extracted by injecting hot steam or solvents to loosen up the bitumen and allow it to flow through a well to the surface. To do this, nuclear steam generation would be more suitable to get more quantities of refined products from the bitumen extracted which could be used in areas other than steam generation by natural gas or oil.

3. Results and Discussion

Table 1: Existing Power Generation Capacity in Nigeria

Plant	Age (Years)	No. of Units	Installed Capacity (MW)	No. of Units Available	Capacity Available (MW)	Operational Capability (MW)
Egbin	23	6	1320	4	880	600
Egbin AES	7	9	270	9	270	220
Sapele	26-30	10	1020	1	90	65
Okapi	3	3	480	3	480	400
Afam	26	20	702	3	350	300
Delta	18	18	840	12	540	330
Omoku	3	6	150	4	100	70
Ajaokuta		2	110	2	100	80
Geregu	2	3	414	3	414	414
Omotosho	1	8	335	2	80	75
Olorunsogo	1	8	335	2	80	35
Kainji	38-40	8	760	6	440	400
Jebba	25	6	578.4	4	385.6	300
Shiroro	22	4	600	4	600	300
Total		111	7914.4	59	4809.6	3589

Table 2: List of Power Stations in Nigeria²⁵

S/N	Power Station	Type	Location	Capacity (MW)	Status
1	Egbin	Thermal	Lagos	1320	Existing
2	Afam	Thermal	Rivers	969	Existing
3	Sapele	Thermal	Delta	1020	Existing
4	Ijora	Thermal	Lagos	40	Existing
5	Kanji	Hydro	Niger	760	Existing
6	Jebba	Hydro	Niger	578.40	Existing
7	Shiroro	Hydro	Niger	600	Existing
8	Ughelli	Thermal	Delta	912	Existing
9	Orji	Coal	Rivers	20	Existing
10	Geregu	Thermal	Kogi	414	Ongoing
11	Omotosho	Thermal	Ondo	335	Ongoing
12	Papalanto	Thermal	Ogun	335	Ongoing
13	Alaoji	Thermal	Abia	504	Ongoing
14	Omoku	Thermal	Rivers	230	New IPP
15	Rain/Ube	Thermal	Bayelsa	225	New IPP
16	Sapele	Thermal	Delta	451	New IPP
17	Ihorbor	Thermal	Edo	451	New IPP
18	Egbema	Thermal	Imo	338	New IPP
19	Calabar	Thermal	C/River	561	New IPP
20	Mambilla	Hydro	Taraba	3050	New
21	Zungeru	Hydro	Niger	700	New
22	AES	Thermal	Lagos	300	Commissioned
23	AGIP Okpai	Thermal	Delta	480	Commissioned
24	Omoku	Thermal	Rivers	150	IPP
25	Obajana	Thermal	Kogi	350	Approved IPP
26	Ibom Power	Thermal	A/Ibom	188	Approved IPP
27	Ethiope Energy Ltd			2800	Approved
28	Farm Electric Supply Ltd			150	Licenses IPP
29	ICS Power			624	Licenses IPP
30	Supertek Ltd			624.00	Licenses IPP
31	Mabon Ltd			39.00	Approved
32	Geometric Ltd			140.00	Licenses IPP
33	Aba Power Ltd			0.00	Licensed
34	Westcom Tech & Energy Service Ltd			1000.00	License IPP
35	Lotus and Bresson Nig. Ltd			60.00	License IPP
36	First Independent Power Co			95.00	License
37	First Independent Power Co			150.00	License
38	Hudson Power Station Ltd			200.00	License
39	Ibafo Power Station Ltd			640.00	License
40	Shell Distribution Coy Ltd			100.00	License
41	Agbara Shoreline Power Co			1800.00	License
42	Index Thermal Power Ltd			1800.00	License
	TOTAL			24,106.00	

²⁵ Mary Utuk. 38 Power Stations in Nigeria, Locations and their Capacities [internet]. Mary Utuk; c2021[cited 15th December 2021]. Available from: <https://infoguidenigeria.com/power-stations-nigeria>)

Table 3: Potential Energy Sources

Resources	Potentials
Small Hydropower	3,500 MW
Large Hydropower	11,250 MW
Wind	2 - 4 m/s @ 10m height (main land)
Solar Radiation	3.5 – 7.0 or 7.5 kWh/m ² /day
Municipal Solid Waste	17451000 tons per day
Animal Waste	211 million assorted animals (285.065 million tons/yr of production) 61 million tons/yr
Energy crops and Agric Residue	28.2 (30% of total land) Million hectares of arable land
Crop Residue	83 million tons/yr
Fuel Wood	11million hectares of forest and wood land
Wave and tidal energy	150,000 TJ (1759.6 toe/yr)

3.1. Discussion

From table 1, between 2008 and 2009, the installed, available and operational power generation capacity of all existing power plants (hydro and thermal) are 7914.4; 4809.6 and 3589MW, respectively. This means 45.4% of installed power generation capacity are in operation when the estimated demand for power was about 10,000MW which require a generating capacity of about 12700MW. From table 2, between 2012 and 2015, the estimated total power generation capacity for the existing, ongoing, New IPP, commissioned, approved and licensed power plants was 24,106MW. In 2020, the demand for electricity in Nigeria was an estimated at 30,000 MW while the combined installed generating capacity was 12,500MW. This can be translated that, to meet the estimated power demand, it requires to have at least three times of currently installed generating capacity. Even, with full utilization of estimates from potential energy sources in table 3, the demand for electrical energy (electricity) in Nigeria cannot be met.

4. Conclusion and Recommendation

From the discussion of results, it shows that reliable and sustainable energy mix is needed to cope with the demand for electricity in Nigeria. The analysis of nuclear energy applications (electrical and non-electrical) is evident that nuclear energy is the best alternative energy source among others for generating electricity and other applications for industrialization. Thus, utilization of nuclear energy will bring about industrial development and economic growth in Nigeria. It is therefore recommended that stakeholders such as Nigerian Nuclear Regulatory Authority, Energy Commission of Nigeria, International Atomic Energy Agency in Nigeria, Ministry of Environment, Electricity Generating Companies and Federal Government of Nigeria to work together to see that generation of electricity from nuclear energy in Nigeria comes to reality, and to encourage peaceful application of nuclear energy in conformity with international policy.

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Author Contributions

Emmanuel Ayobami Adedoye reviewed relevant literatures to this work, while Rasaq Ibrahim, gathered data, prepared and revised the manuscript.