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Nigeria's Nuclear Power Generation Project: Current State and Future Prospects

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Abstract
The industrialization programme of any nation is driven by its power sector so that the industrialization process becomes epileptic when the power sector becomes epileptic. This has been the challenge facing Nigeria. The national grid has an installed capacity of 6,000 MW, but only about 4,000 MW is obtainable. Also, pipeline vandalisation disrupts the supply lines to the few functional plants, while water shortage and irregular supply incapacitate the effective functioning of the nation's hydroelectric power plants. These factors along with the increasing national energy demand for both domestic and industrial purposes made the nuclear power option attractive to Nigeria and informed the nation's pursuit of the nuclear power option. Nuclear power has not only been adjudged economically competitive and environmentally friendly, but is also a viable alternative for long-term energy security. Nuclear power plants have low operational costs and the added advantage of long life spans. This paper examines Nigeria's nuclear power generation programme with emphasis on how far Nigeria has gone, the successes recorded, the problems encountered and the plans to be implemented for the first nuclear power plant to become functional. The various issues of concern in deploying nuclear power plants for electricity generation are also discussed.
Keywords: Nigeria atomic energy commission, nuclear power plants, nuclear reactors, energy

Introduction

Current population estimates puts Nigeria as the most populous black nation in the world with over 160 million people. It has the second largest economy in Africa [Lowbeer-Lewis, 2010]. The Nigerian economy relies heavily on earnings from crude oil for revenue generation and expenditures. Electricity generation has been mainly from hydro, oil and gas. Being a developing country, the need for energy is high and this need has not been met by the current output because of inadequate and epileptic supply and the fact that developing these sources to full capacity will not suffice. There are also problems inherent in deploying them for power generation. Pipelines supplying gas to thermal plants are at the mercy of vandalisation. Seasonal nature of rainfall and climate change makes hydropower susceptible to drought [Niger Power Review, 1989]. And because much of its power derives from flowing rivers, the water level may be affected [Ohunakin, 2010]. For example in Chile where a major part of their hydropower potential has been developed, a drought reduced the hydropower output at the same time that the importation of natural gas was interrupted [IAEA, 2010a]. The country is now beginning to consider the possibility of the nuclear option [IAEA, 2010a]. A report according to a study group of experts concluded that Chile cannot afford to leave out the possibility of the nuclear power option [IAEA, 2010a].

Only about 40% of Nigerians have access to electricity [ECN and UNDP, 2005]. With an installed grid capacity of 6,000MW, less than 4,000MW of electricity is generated presently, which is even lower than what India generates from nuclear power plants alone [IAEA, 2009a]. This is grossly insufficient for Nigeria's growing population where the per capita electricity consumption is 4 times less than the average in Africa and about 19 times less than the average in the world [Sambo, 2009].

Industries are shutting down in Nigeria. The manufacturing sector is suffering from acute shortage in power supply. This has reduced their contributions to government revenues, GDP and export earnings. Some manufacturing industries have relocated to neighbouring countries where the cost of running their business is low compared to Nigeria. Some have shut down operations and some are operating at less than optimal capacity. The result of these has been massive unemployment and drastic reduction in productivity from all other sectors like education, small scale and medium enterprises. The United Nations Human Development Index in 2011 ranks Nigeria 156 out of 187 countries [UNDP, 2011].

Frequent power outage has necessitated the widespread use of electricity generators in the country with attendant noise pollution. Furthermore, fossil fuels power these generators and the burning of these fuels is known to release greenhouse gases like CO_2. These gases are responsible for climate change with effects seen in global warming, melting of the polar ice caps, rising sea levels and flooding [CIPEC, 2002]. On the other hand, oil exploration in the nation's oil rich region has caused untold environmental pollution in the land, air and water. No thanks to oil spillage and gas flaring. Fossil fuels such as coal, oil and gas are therefore not environmentally

friendly.

Fossil fuels cannot give the assurance of long term energy security. They are nonrenewable and deplete with usage. For instance, Bangladesh anticipates exhausting its natural gas deposit within the next decade with only few options left to meets its base load energy generation [IAEA, 2010a].

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. A major cause of this energy crisis in Nigeria is the absence of a robust and comprehensive energy basket. It has become necessary to include nuclear power in the current power mix as provision is made for it in the National Energy Policy [Energy Commission of Nigeria, 2003]. The nuclear industry is an established industry, being over fifty years old. And has accumulated years of experience in nuclear power plant design and technology, making it safe for peaceful use. At present, nuclear power provides approximately 14% of the world's electricity and 2.1% of Africa's electricity [IAEA, 2010b] as shown below in Table 1.

Table1. Use and Percentage Contribution of Different Types of Fuel for Electricity Generation in 2008 [IAEA, 2010b].

Region	Thermal (a)		Hydro		Nuclear		Renewables (b)		Total	
	Use (EJ)	%	Use (EJ)	%	Use (EJ)	%	Use (EJ)	%	Use (EJ)	%
North America	25.13	66.15	2.32	13.72	9.76	19.04	0.76	1.09	37.98	100
Latin America	5.14	39.15	2.56	57.54	0.32	2.38	0.39	0.93	8.41	100
Western Europe	16.06	52.45	1.89	17.06	8.97	26.68	0.72	3.81	27.64	100
Eastern Europe	18.18	64.59	1.12	17.04	3.64	18.30	0.03	0.07	22.96	100
Africa	5.73	80.51	0.37	16.95	0.14	2.11	0.05	0.43	6.29	100
Middle East and South Asia	19.09	87.54	0.62	11.47	0.16	0.99	0	0.00	19.87	100
Southeast Asia and the Pacific	6.78	88.92	0.25	9.29			0.39	1.79	7.41	100
Far East	43.46	74.27	2.65	15.23	5.35	10.15	0.49	0.35	51.95	100
World total	139.57	67.15	11.77	17.66	28.34	14.03	2.83	1.16	182.51	100

(a) The column headed 'Thermal' is the total for solids, liquids, gases, biomass and waste.

(b) The column headed 'Renewables' includes geothermal, wind, solar and tide energy.

As at August 2010, there were 441 nuclear power plants in 29 countries producing 375 GW of electricity [IAEA, 2010b].

Nigeria is one of the 65 countries referred to as nuclear newcomers. 21 of these countries are in Africa. An example is Egypt [IAEA, 2010b]. These countries are expressing interest and considering nuclear power so that they can adequately plan for it. 25 nuclear newcomers have said they would begin their first operation before 2030 while 14 choose between 2015 and 2020 [IAEA, 2010b]. With 24 having one or more research reactors [IAEA, 2010a]. Table 2 shows the different stages that the nuclear power programme has reached in these countries.

Table2. Positions of Countries without Operating Nuclear Power Plants [IAEA, 2010b].

Description of group	Number of countries
Not planning to introduce nuclear power plants, but interested in considering the issues associated with a nuclear power programme	31
Considering a nuclear programme to meet identified energy needs with a strong indication of intention to proceed	14
Active preparation for a possible nuclear power programme with no final decision	7
Decided to introduce nuclear power and started preparing the appropriate infrastructure	10
Invitation to bid to supply a nuclear power plant prepared	—
New nuclear power plant ordered	2
New nuclear power plant under construction	1

In order to solve the nation's current power problem, the nuclear option has been introduced. This work reviews the current status of Nigeria's nuclear power programme with emphasis on the current status, future plans and the prospects for goal realization.

The Nigeria Atomic Energy Commission

Nigeria's nuclear technology history started after her independence when the Federal Radiation Protection Service was established in 1964 and at the same time the country joined the International Atomic Energy Agency (IAEA) [Mundu and Umar, 2004].

The Nigeria Atomic Energy Commission (NAEC) came into existence through the enactment of Decree 46 (now Act 46) in August 1976 and the launching of the national nuclear programme. NAEC was dormant for thirty years until 2006 when it was activated by the same Head of State that had originally created it 30 years earlier. NAEC's board was formally inaugurated in July 2006. It is a 10-man board with the President as its head [Osaisai, 2011a]. The implementation of the nation's nuclear energy program was also revitalized.

Goals and Objectives of NAEC

Until recently, NAEC is a federal government agency operating under the Ministry of Science and Technology. However, by March 2011, it was reconstituted as a full-fledged commission. The new NAEC board was formally inaugurated on September 15, 2011 [Osaisai, 2011b].

NAEC's primary goal entails the provision of the pathway to explore, exploit and harness atomic energy for peaceful applications in the quest for the socio-economic development of Nigeria. This, expectedly, would be done in conformity with the economic policies of the Federal Government. Those objectives that are relevant to the attainment of this goal are listed as follows [NAEC, 2011]:

1. To streamline, harmonise, promote and coordinate research and development activities for capacity building and infrastructure development in nuclear technology.
2. To fast-track and catalyse the process of development and deployment of nuclear power plants for electricity generation in Nigeria, in partnership with the private sector.
3. To put in place a comprehensive manpower development programme. This includes:

(a) Development and introduction of core training programmes in nuclear science and engineering in selected institutions of higher learning in Nigeria to generate the critical mass of the needed manpower for the nuclear industry.

(b) Development, networking and creating opportunities for fellowships and advanced training in nuclear science and technology in international organisations and institutions with advanced facilities in other countries with similar objectives to use nuclear technology for peaceful applications only.

4. To develop the requisite legal framework for the use of nuclear power plants in Nigeria within a strict regulatory regime as specified by the Nigerian Nuclear Regulatory Authority (NNRA), and in due compliance with the three universal cardinal planks of safety, security and safeguards of the IAEA and the nuclear Non Proliferation Treaty (NPT).
5. To liaise with the International Atomic Energy Agency (IAEA), the Preparatory Commission to the Comprehensive Nuclear Test Ban Treaty Organisation (CTBO), other international organisations and countries with similar vision for the implementation of the national programmes.

In other words, the Nigeria Atomic Energy Commission is the focal national agency with the mandate to formulate and implement the nation's atomic energy programme for the socioeconomic development of the country; to develop technical framework to harness and apply nuclear energy for peaceful uses; to prospect for and mine radioactive materials; to construct and maintain nuclear installations for the purpose of generating electricity; to produce, use and dispose of atomic energy and carry out research into matters connected with the peaceful uses of atomic energy; to manufacture or otherwise produce, buy or otherwise acquire, treat, store, transport, and dispose of any radioactive substances; to make arrangements with universities and other institutions or persons in Nigeria to conduct research into matters connected with atomic energy or radioactive substances; to educate and train persons in matters connected with atomic energy and radioactive substances; and to advice the federal government on questions relating to atomic energy [Agu and Balogun, 2010]. Figure 1 shows the organization chart of NAEC.

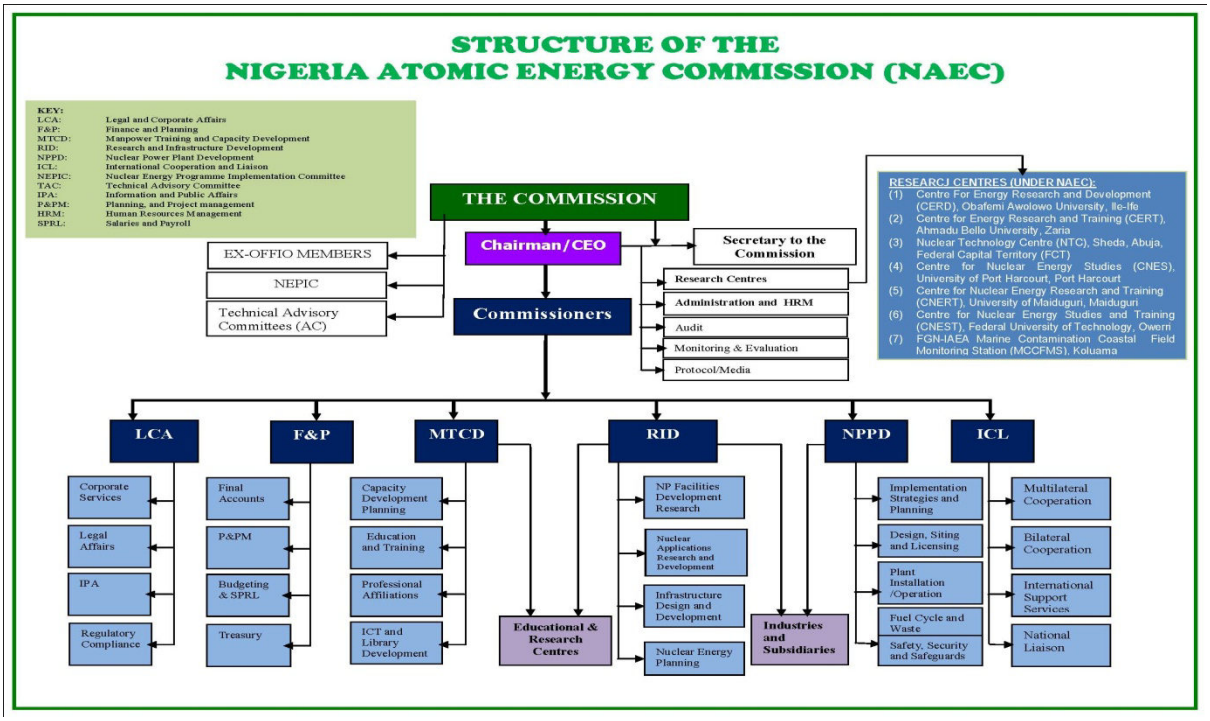

Figure 1. Organogram of the Nigeria Atomic Energy Commission [Osaisai, 2011b].

The Nuclear Road Map

Within the first year of its operation, the Nigeria Atomic Energy Commission developed a road map to achieve its goals and objectives. The nuclear road map is a three-phase technical frame work which involves the generation of 1,000 Megawatts of electricity using nuclear power plant by 2020. The capacity is to be increased to 4,000 M We by 2030 [Obioh and Agu, 2011]. The three phases are:

a. Manpower and infrastructure development
b. Design certification, regulatory and licensing approvals and
c. Construction and start up.

The gestation period for the implementation of a nuclear power programme is at least 10 years. An example is Iran where their first nuclear power plant was finally connected to the grid on September 4, 2011 and a ceremony to mark its commissioning was held on the 12th of September 12, 2011. Meanwhile, work began on this plant since 1975 [World Nuclear News, 2011].

While it takes approximately 10 to 15 years to implement the infrastructural base [IAEA, 2009b], the government of Nigeria has proposed 10 to 12 years to have on-line electricity generation from nuclear.

According to the IAEA Milestone Approach designed for the successful introduction of nuclear power as shown in Figure 2, a country's nuclear programme is said to have attained Milestone 1 when phase 1 of the development of infrastructure is completed. Phase one which is also known as the pre-project phase is the period during which the country looks into what nuclear power entails. At the end of it, the country becomes ready to make commitment based on knowledge [IAEA, 2009b].

During phase 2, preparatory works such as developing the necessary infrastructures are put in place. And at the end of this phase, Milestone 2 is said to have been reached. The country will now be ready to invite bids. Just as the United Arab Emirates that selected a bid at the end of 2009 from a consortium led by the Korea Electric Power Corporation. Turkey cancelled its bidding process in the same year [IAEA, 2010a].

Milestone 3 is attained at the end of phase three. Phase three entails construction activities. When milestone three is reached, the country is then ready to commission and operate its nuclear power plant [IAEA, 2009b]. Nigeria nuclear power programme is currently at the level of Milestone 1.

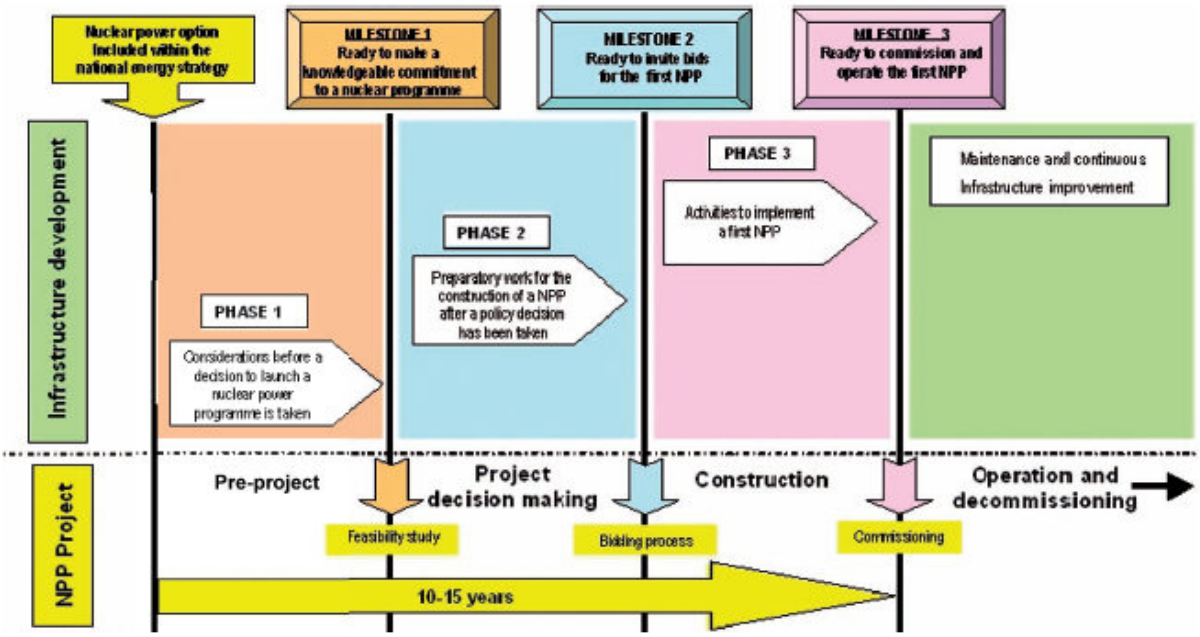

Figure 2. The Three Phases in the Development of a Nuclear Power Programme [IAEA, 2009b].

Current State and Future Prospects of Nigeria's Nuclear Power Generation Programme

Nigeria has made progress over the years towards its goal by developing the supporting institutions and infrastructure required for its nuclear power programme. The nuclear roadmap developed by NAEC is expected to drive the national nuclear programme. A near term target has been set for the contribution of nuclear power to national electricity generation. The first nuclear power plant is expected to be connected to the national grid by 2020, the same year Turkey also expects to bring its first nuclear power plant online [Tongal, 2011].

Government Commitments

The commitment of the federal government has been made known at various stages of the implementation of the nuclear power programme with successive administrations considering it as a viable alternative to traditional energy resources and a way out of the nation's power problem. The federal government has also promised NAEC will be given necessary funding to fulfil its mandate. Also, the programme is to be executed in partnership with the private sector where the government's major focus would be directed at developing the manpower and infrastructure base required to create an enabling environment for the successful implementation of the programme in the country. In February 2006, commitment was shown by the government of Nigeria when it endorsed the NAEC national nuclear road map. And in 2007, the government approved the Strategic Plan for the Implementation of National Nuclear Power Programme also developed by NAEC [Osaisai, 2011a]. The IAEA then endorsed it in December 2009 when it was finalised and publicly presented.

Educational Infrastructure and Manpower Development

Since the nuclear professionals available in the country are few, it then becomes imperative to generate the critical mass of manpower needed to drive the nuclear power programme. It is estimated that about 800 – 1000 persons are needed for the operation of a 1,000 MWe nuclear power plant [Balogun and Ume, 2009]. Technology has not reached a point where human effort would not be required.

The first phase of the NAEC roadmap is manpower and infrastructure development. After the enactment of the NAEC Act in 1976, the Federal Government, in 1978 established two university based research and training centres: Centre for Energy Research and Development (CERD) at the Obafemi Awolowo University, then University of Ife, Ile-Ife and Centre for Energy Research and Training (CERT) at the Ahmadu Bello University, Zaria.

These centres are to conduct researches, develop and train manpower in nuclear technology, engineering and science. The Nuclear Technology Centre at the Sheda Science and Technology Complex (SHESTCO), Abuja was established in 1988 as the third training and research centre in nuclear technology [NAEC, 2011]. Two more university based nuclear energy research centres were established in 2009. These are the Centre for Nuclear Energy Studies at the University of Port Harcourt, Port Harcourt and the Centre for Nuclear Energy Research and Training at the University of Maiduguri, Maiduguri [Osaisai, 2011a]. The Centre for Nuclear Energy Studies and Training (CNEST) was also established at the Federal University of Technology, Owerri in 2011 bringing to six the total number of research centres which operate under the coordination and supervision of NAEC [Osaisai, 2011b]. CERD houses a particle accelerator while a research reactor is operational at CERT.

Training of personnel, developing human capacity and manpower is one of NAEC's core mandates and a principal component of the three-phase technical framework. At present, NAEC is developing training programmes necessary for the successful and sustainable implementation of the national nuclear programme. In May 2007, a technical committee was set up to design training programmes in nuclear science and engineering in tertiary institutions and research centres in the country. The committee's report of July of the same year is what informs most of NAEC's human resource development programmes [Balogun and Ume, 2009]. Furthermore, the training programmes are put together for the work force in order to [Agu and Balogun, 2011]:

1. Understand the technology and project management for the planning, coordination and implementation of the nuclear programme;
2. Obtain the necessary skills for the operation and maintenance of nuclear power plants;
3. Develop local manpower for the nuclear industry;
4. Build capacity for the use of nuclear technology for other peaceful socio-economic uses in health, food and agriculture, water resource management, industry, mineral exploration and environmental monitoring.

These are to be achieved via the following approach [Agu and Balogun, 2011]:

1. Education in universities and polytechnics;
2. Building educational infrastructure in institutions and providing facilities at the five nuclear research centres;
3. Training while on the job;
4. Training provided by reactor vendor organisations for specific facilities;
5. Direct involvement during the implementation of the project, direct partnership with experienced power utility organizations for power plants initial operation.

So far NAEC has taken the following steps [Agu and Balogun, 2011]:

1. Empower educational institutions to train nuclear engineers and scientists through memorandum of understandings entered into with universities and polytechnics to design curriculum and start the programmes;
2. Development and approval of undergraduate programmes in nuclear science and engineering in partnership with eleven institutions of higher learning;
3. Development and approval of postgraduate programmes in nuclear science and engineering in partnership with the four universities housing the nuclear research centres;
4. Cooperate and partner with foreign institutions to train graduate nuclear engineers and scientists as potential faculty in order to implement the training programmes in local institutions
5. Take advantage of the bilateral agreements on peaceful use of nuclear energy to train professionals for Nigeria's nuclear industry.

A three-month bridging training programme in nuclear science and engineering for forty graduates of engineering and physical sciences has been designed and successfully implemented between November 15, 2009 and February 27, 2010. They are to form the first set of graduate students in the master's programme in nuclear science and engineering taking place at the four universities where the nuclear research centres are located. The four designated universities have approved the postgraduate programmes in nuclear science and engineering [Osaisai, 2011a]. The master's programme has been launched on December 15, 2011 [Osaisai, 2011b].

NAEC aims to train 2000 nuclear professionals including scientists, engineers, technicians, technologists, as well as postgraduate nuclear scientists and engineers in the next 8 – 10 years. [Esogbue and Osaisai, 2011].

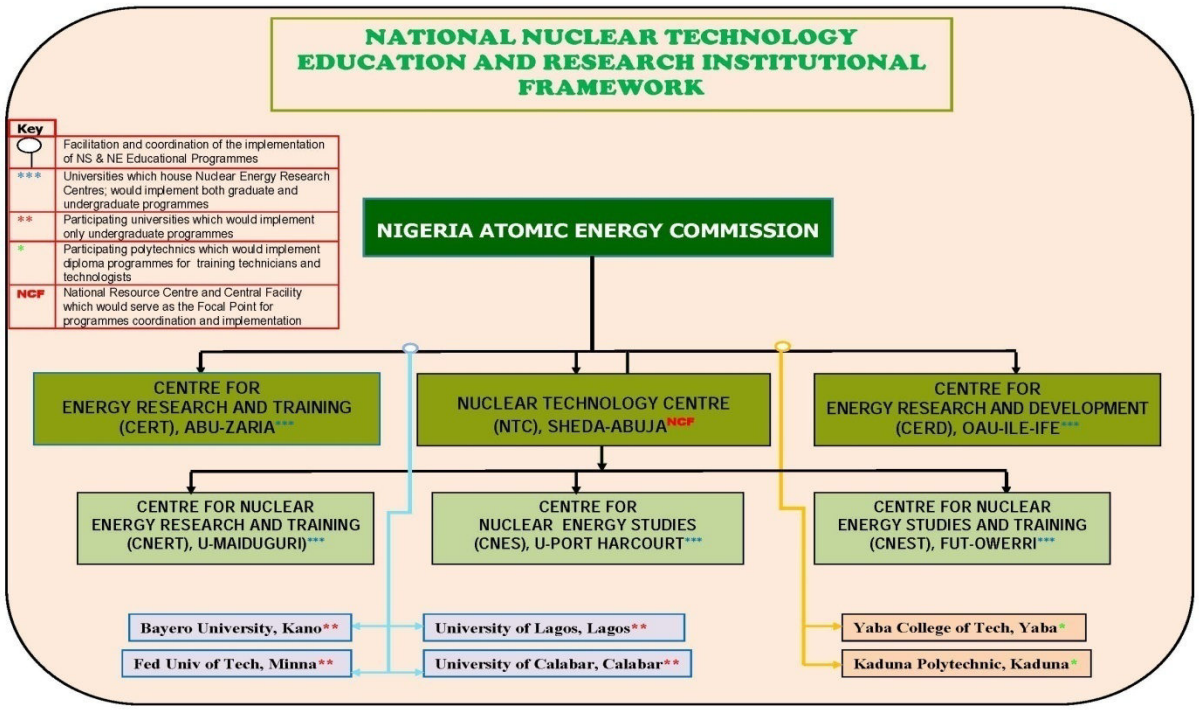

Figure 3. Nuclear Technology Education and Research Institutional Framework [Esogbue and Osaisai, 2011].

Institutional Infrastructure

Although Nigeria is sometime referred to as a nuclear newcomer country, it has developed and put in place the required institutional and regulatory framework for the successful implementation of nuclear power programme as required by the International Atomic Energy Agency (IAEA). The Nigeria Atomic Energy Commission has been established to promote and develop nuclear energy for peaceful uses in Nigeria.

Nigeria Nuclear Regulatory Authority (NNRA)

The Nigeria Nuclear Regulatory Authority (NNRA) was established following the enactment of the Nuclear Safety and Radiation Protection Act of 1995 and began operations in 2001.

It was established as the national regulator and licensing authority saddled with the responsibility of developing and enforcing all regulations that would govern the operations of the nuclear industry [NNRA, 2011]. NNRA is currently developing procedures for the licensing of nuclear power facilities. A draft regulation for the licensing of nuclear power plant site has been developed and is being reviewed.

Other relevant national agencies established include the Energy Commission of Nigeria (ECN) with responsibility for energy policy and planning; National Electricity Regulatory Commission (NERC) for electricity pricing; National Environmental Standards and Regulations Enforcement Agency (NESRA). These agencies and institutions constitute the Nuclear Energy Programme Implementation Committee (NEPIC) [Agu and Balogun, 2011].

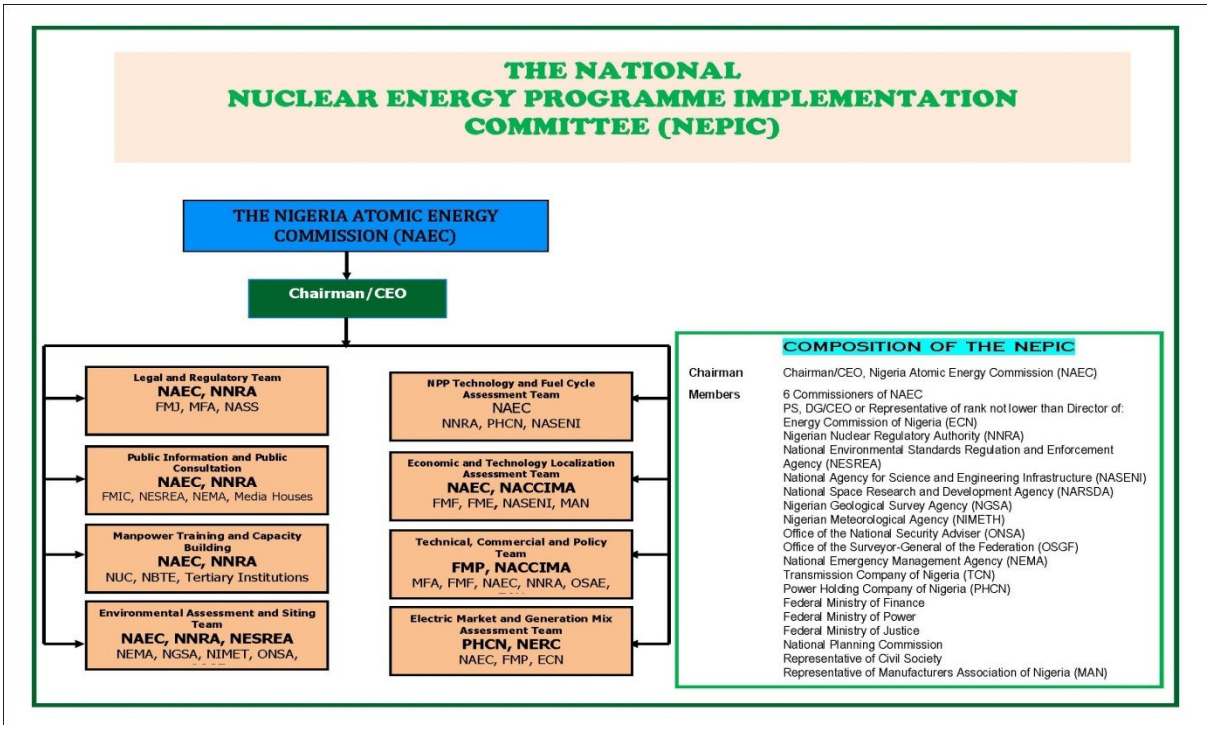

Figure 4. The Nuclear Energy Programme Implementation Committee (NEPIC) [Osaisai, 2011b].

Site Selection

In line with the nuclear roadmap developed by NAEC, a committee was set up in May 2007 to carry out a survey of possible sites for a nuclear power plant. These sites were evaluated using criteria shown in figure 3 [Agu and Balogun 2011].

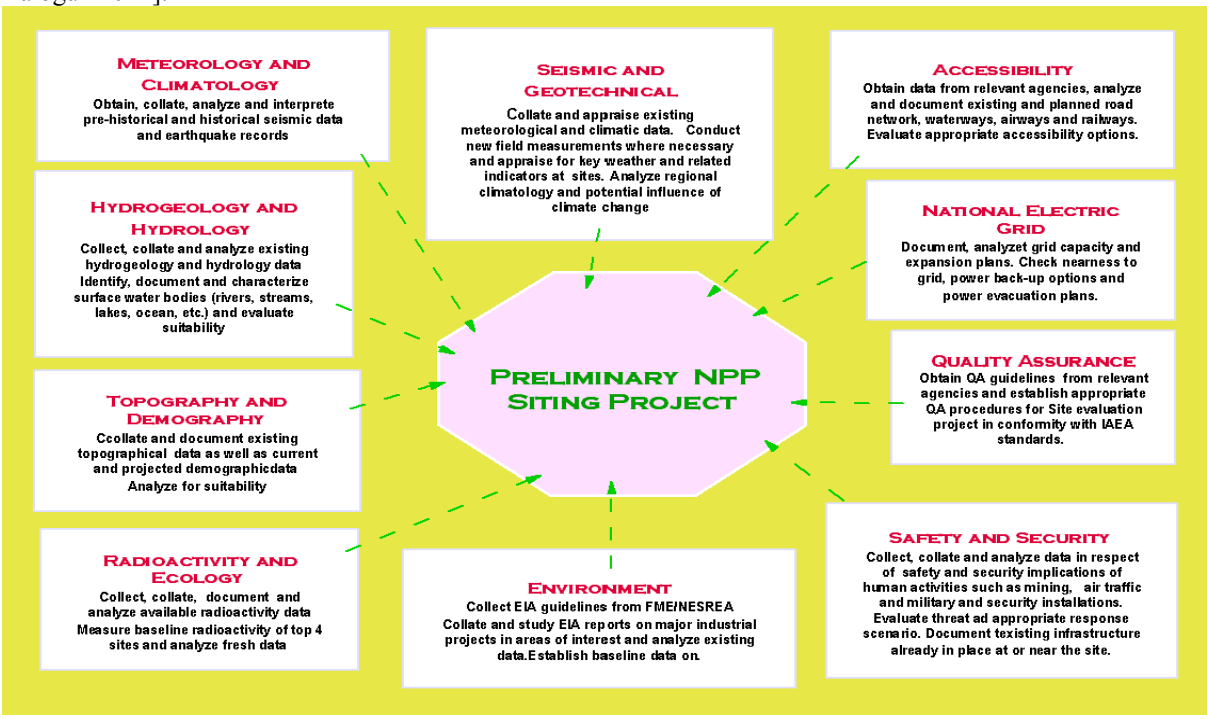

Figure 5. Considerations in Preliminary Site Selection Activities [Agu and Balogun 2011].

Preliminary studies by NAEC have chosen four sites for further detailed characterization and after which recommendations will be made to the government. These sites shown in figure 4 are located around areas in [Osaisai, 2011a]:

a. Geregu/Ajaokuta in Kogi State,
b. Agbaje in Okitipupa Local Government Area in Ondo State,
c. Lau Local Government Area in Taraba State and

d. Itu in Akwa Ibom State.

Licensing of the approved site(s) is expected to be done at the end of year 2012 [Osaisai, 2011a].

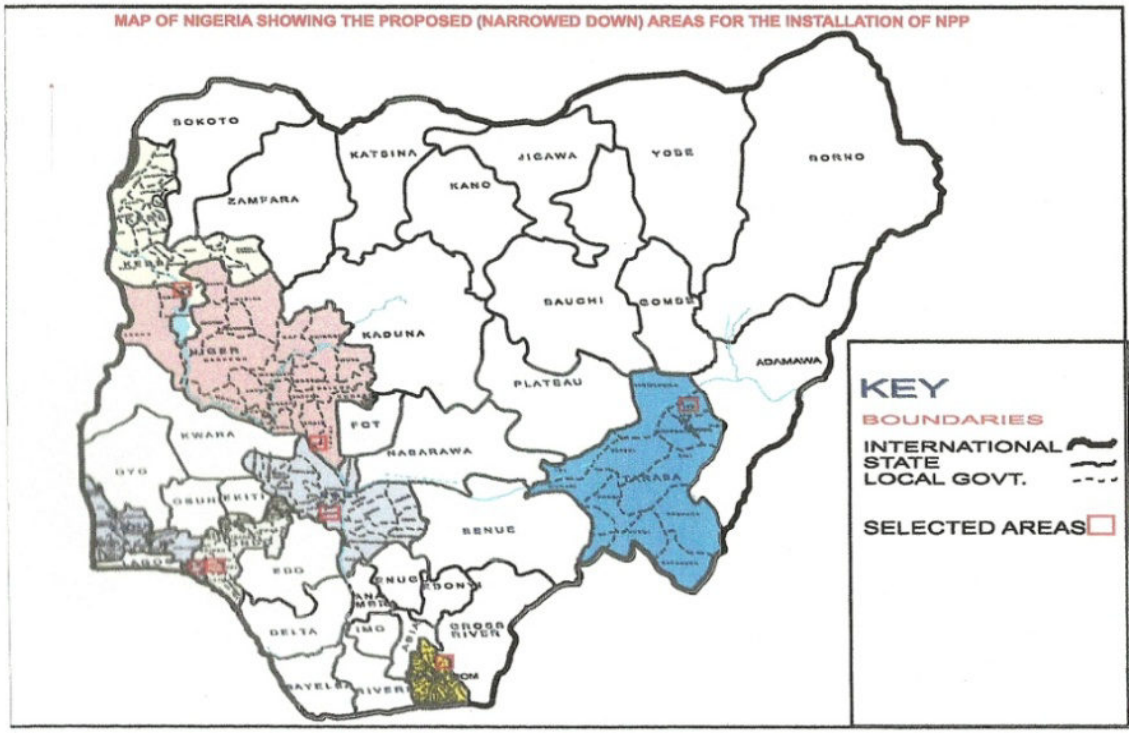

Figure 6. Preliminary sites selected [Osaisai, 2011a].

The Legal Framework

In 2010, NAEC produced a draft Atomic Energy Bill that would constitute the legal framework for the Nigerian nuclear industry. A number of activities have been put in place for the enactment of the Atomic Energy Law in order to successfully implement the nuclear power programme. The legal framework is made up of the following elements [Agu and Balogun, 2011]:

i. Nuclear security,
ii. Radioactive materials and radiation,
iii. Nuclear civil liability,
iv. Radioactive waste management,
v. Spent fuel and decommissioning,
vi. Environmental protection,
vii. Radiological emergency management,
viii. Notification of nuclear accidents,
ix. Foreign investments, and
x. Safety of nuclear installations.

A final draft of the law has been developed in collaboration with all relevant stakeholders. It also contains technical inputs from the IAEA and is to be submitted to the national assembly for passage into law [Osaisai, 2011a].

NAEC is also developing a national policy on radioactive waste management in consultation with the NNRA and other stakeholder institutions.

Meanwhile, the regulatory authority, NNRA is also developing a draft regulation on the safety and regulatory requirements for licensing of sites for nuclear power plants.

A framework to establish a national nuclear insurance policy and a plan to properly deal with the civil liability component of the nuclear power industry is to be put in place together with the Federal Ministries of Finance, Commerce & Industry, and Justice.

International Agreements

NAEC has worked out the signing of international agreements to speed up international nuclear cooperation and develop capacity. Nigeria signed a Memorandum of Cooperation with Iran in 2008. In 2009, two international agreements to assist in the development of nuclear technology and exploitation of uranium resources were signed with Russia (World Nuclear News, 2009). Co operation agreements were also signed with India and South Korea in 2009.

Nigeria was one of the first countries that signed and ratified the 1968 Nuclear Non-Proliferation treaty (NPT). The IAEA Convention on Nuclear safety (IAEA, 2008a) was ratified in 2007. In the same year, the 1997 Joint Convention on Safety of Spent Fuel Management and Safety of Radioactive Waste Management (IAEA, 2009c), the Convention on the Physical Protection of Nuclear Materials (IAEA, 2009d), and the Vienna Convention on Civil liability for Nuclear Damage (IAEA, 2008b) were all signed but are yet to be ratified. The 1986 Convention on Early Notification of a Nuclear Accident has been ratified (IAEA, 2008c), and also the Revised Supplementary Agreement Concerning Provision of Technical Assistance by the IAEA (IAEA, 2007), and the 1968 Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency (IAEA, 2008d). A Comprehensive Safeguards Agreement and Additional Protocol with the IAEA, allowing the agency access to a nation's facilities to ensure that peaceful nuclear technology and materials are not diverted to weapons development has been concluded (IAEA, 2009e). The treaty of Pelindaba, establishing an African nuclear weapon-free zone was ratified in 2001 (Centre for Non-Proliferation Studies, 2009).

Conclusion

Although preparatory works to attain Milestone 2 are being put in place, it is evident that the government has shown some commitment at least to an extent in the actualisation of the nuclear power programme given its short time from 2006 when NAEC became operational. Nigeria is presently in phase two of the development of the infrastructure for a nuclear power programme getting ready to invite bids.

With the signing of international and bilateral agreements with countries like Russia and South Korea and the signing and ratification of treaties, conventions and protocols, it shows that the country means it to use nuclear power for peaceful socio-economic purposes only.

NAEC is also putting in place programmes to relate with the public on its various activities in order to address public perception during the successful implementation of the nuclear power programme. This is to be achieved by making the general public aware of the environmental and economic benefits of nuclear power compared to others, safety and security issues inherent in deploying nuclear power for power generation, and the various ways it intend to manage the risk involved and the waste produced. Poland, for example has its nuclear programme revived after the programme had been stopped when governments and public opinion changed [IAEA, 2010a]. Chile is also involving its general public along as they consider the nuclear power option. It's newly appointed Minister of Energy is laying emphasis on public information. Series of public seminars on nuclear power were conducted with opinion leaders and the general public in attendance [IAEA, 2010a].

It is worthy of note that the nuclear industry has an international body that regulates, approves and monitors its activities worldwide. So that of Nigeria is not an exception.

The industrial and the financial sector together with the business community are to be engaged to take advantage of the opportunities that would be created with the successful implementation of Nigeria's nuclear power programme.

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