1. INTRODUCTION

Most industrially developed countries have been making efforts to change the balance of their energy consumption. They are mainly doing this in order to decrease oil and gas consumption for heat and electricity generation and to conserve their resources for non-power applications and motor fuel production. However, some countries have recently been moving towards increased use of gas for electricity generation, because of its short-term economic advantages and the widespread perception that, it is environmentally friendly.

It should also be noted that, the use of any fossil fuel raises an environmental problem that cannot be solved by any cleaning technology. Atmospheric releases of CO_2 which is a product of combustion result in the so-called green-house effect that at present is of particular concern since it will affect the global climate. The problem can only be solved by limiting the use of fossil fuel.

At present nuclear power is the only alternative to coal for large electricity generation for the majority of regions in the world. Its economic competitiveness has been demonstrated by the experience of many countries.

This manual gives an overview of nuclear electricity generation and also provides some information on Ghana's interest in developing a civil nuclear power capacity for electricity generation.

2. ENERGY RESOURCES

At present, the available energy resources are, fossil fuels, nuclear power and renewable sources including hydro, tidal, biomass, geothermal, solar and wind power. They all have characteristics which affect human health and the natural and social environments.

The use of renewable energy sources, with the exception of hydropower is developing slowly, partly because of their non-uniform geographic distribution, low energy concentration and interruptible nature. For example, in Central Europe, the average solar radiation energy on the earth surface is 160 watts per square metre in clear sunny weather for about 2200 hours per year. At the present technological state of-the-art, a surface area of about 90 square kilometres is required to construct mirrors for a solar plant producing 1000 megawatts of electricity. Very high capital investment are needed for construction of power plants based on renewable energy sources. Until investments can be decreased and new methods of collecting primary energy developed, we can hardly expect that, renewable sources will become suitable to satisfy the energy requirements of densely populated areas. There are few available hydro resources left

Additional hydropower development is limited to geographic regions suitable for creation of large water reservoirs. Such reservoirs can create a lot of damage to the environment, including flooding large land areas and changing regional climatic conditions. In addition, there is a danger of severe accident as a result of a dam break.

In the early 1990's, the share of hydropower in the total world primary energy production was about 5%. The share of the other renewable sources was smaller. Even assuming that the use of renewable sources will grow in the near future, their share of primary energy is not predicted to exceed 6% in the first decade of the 21^{st} century.

Oil is a convenient energy source and has been the main source of primary energy in many countries. However, there is a clear tendency to limit the use of oil for electricity generation since its supply is limited and it is necessary to conserve it as raw material for the chemical industry and for liquid motor fuel production. The potential effects of oil extraction, transportation and utilization include leaks of oil from tankers and ocean oil rigs, atmospheric releases of oil residues, sulphur compounds and other impurities, occupational disabilities and fatalities during production, storage and transportation, and accidents caused by fires at oil storage facilities and refineries.

Natural gas can be much less environmentally damaging than oil, but only if significant leakage from pipelines is prevented. There are also ecological risks from its extraction and accident risks from extraction and transport.

Coal is the only organic fuel whose resources can ensure large-scale availability of electricity in the future. However, its utilization leads to potentially serious ecological an health consequences. They include,

1. Occupational risk of underground coal-mining
2. Hydrological and surface changes related to open cast mining

3. Combustion product releases to the atmosphere
4. Atmospheric emissions of fly ash, sulphur dioxide, toxic metals, organic carcinogenic substances and radioactivity

3. ELECTRICITY GENERATION BY THERMAL POWER PLANTS

The word "thermal" comes from the Greek word "Thermos" which means hot. Thermal power plants are therefore electricity producing power stations that generate electricity using heat. At every Thermal power station, heat energy is converted into electrical energy in accordance with the law of conservation of energy which states that "Energy can neither be created nor destroyed but can be transformed from one form to the other". For a typical thermal power plant, heat is generated from the combustion or burning of one of the following; coal, crude oil and natural gas depending on the design of the plant. The coal, crude oil and gas are referred to as the heat sources or fuels. The heat generated is made to heat water and in the process the water gets converted into steam or water vapour. The steam or water vapour produced is made to spin turbines that are connected to electromechanical generators. As the turbines spin, they drive thea generators and electricity is produced. After passing over and spinning the turbines, the steam is condensed in a condenser and the water is recycled to where it was heated. This is known as Rankine Cycle.

4. NUCLEAR ENERGY

Every substance or object in the Universe is made up of very tiny particles called atoms. An Atom contains protons and neutrons in a nucleus which is the central core and electrons surrounding the nucleus. An atom is the smallest particle of an element that takes part in a chemical reaction and exhibits the properties of the element. There are different types of atoms with different properties depending on the number of protons neutrons and electrons. As a result different substances or objects have different properties depending on the types and the proportion of atoms that they are made up of. An element is a pure substance made up of atoms of the same kind. Some naturally occurring elements are Hydrogen, Oxygen, Nitrogen, Iron, manganese, lead, Aluminium, Zinc, Silver, Gold, and Uranium etc. A vast majority of the substances or objects in the universe are made up of atoms of different elements and this happens through chemical reactions. For example water is made up of hydrogen and oxygen. This is a chemical reaction because the oxygen and hydrogen use only their electrons in the reaction.

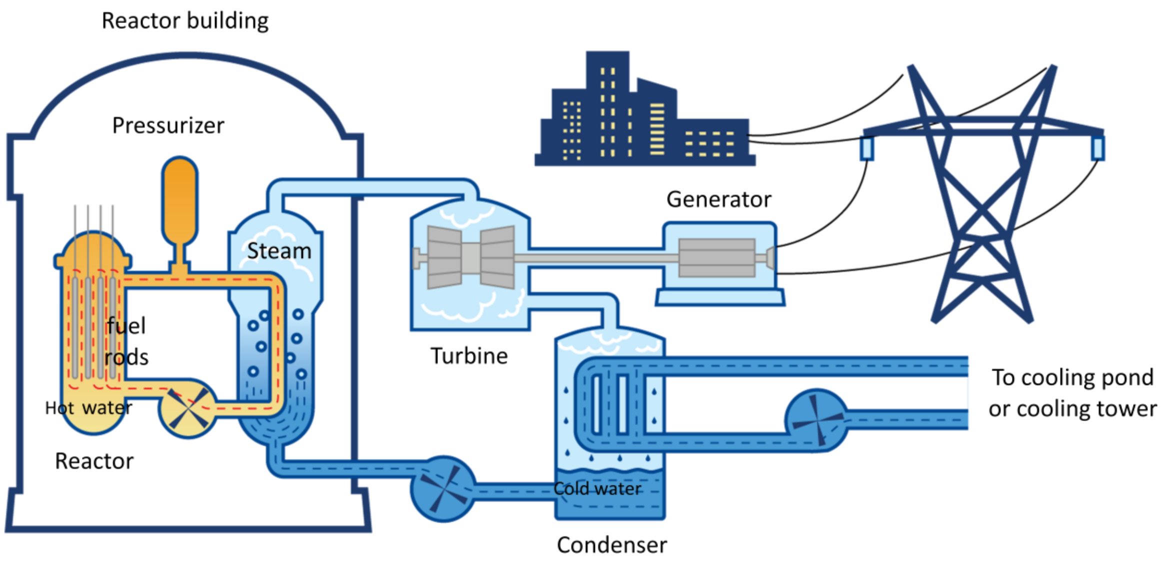
Apart from chemical reactions in which only electrons are involved, there are also reactions that involve the nucleus. These reactions are called nuclear reactions. There are two types of nuclear reactions namely nuclear fusion and nuclear fission.

In nuclear fusion the nuclei of two smaller atoms combine or fuse to form a bigger nucleus with the release of heat energy. This is how the sun produces the heat that is felt on earth. Nuclear Fission on the other hand is the splitting of a large nucleus into smaller nuclei with the release of heat energy. In both cases the heat energy released is known as nuclear energy and can be used to generate electricity.

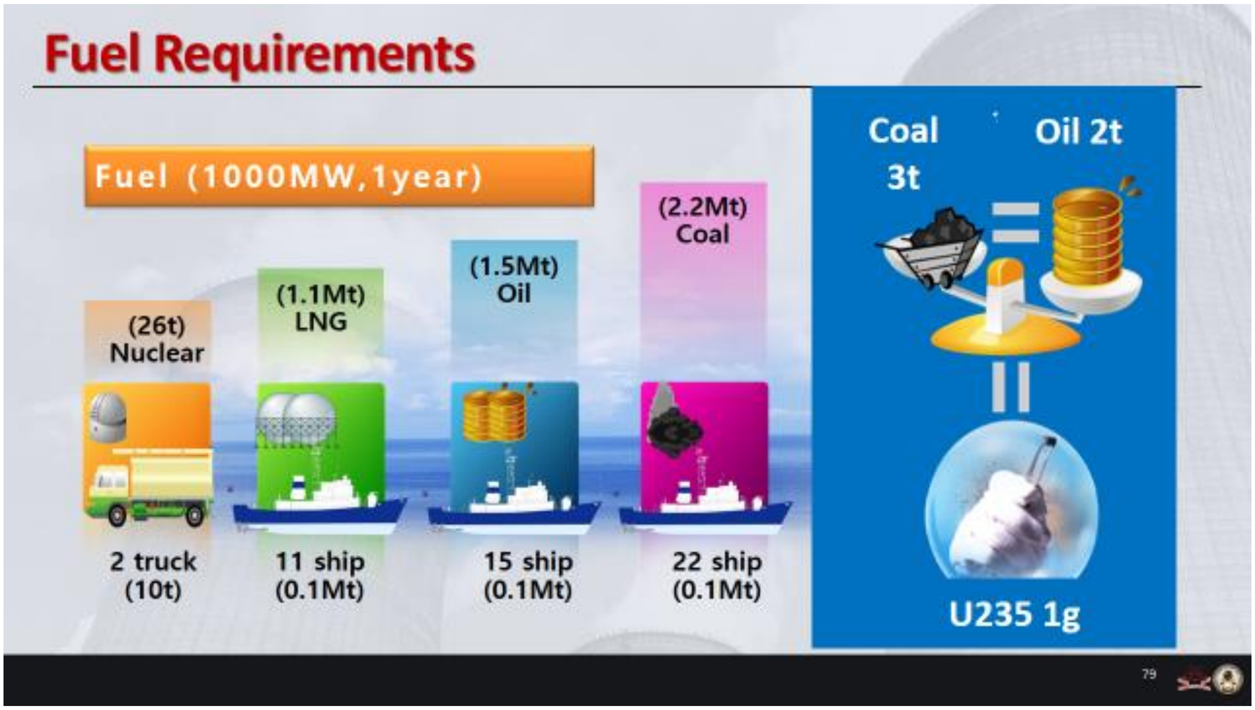
5. ELECTRICITY GENERATION BY NUCLEAR POWER PLANTS

A nuclear power plant also known as a nuclear power reactor, produces electricity by nuclear fission. The process involves the splitting of uranium atoms in the reactor to produce large amount of heat. Like other thermal power plants the heat generated is used to convert water to steam. The steam is made to spin a turbine which is connected to a generator and as the turbine spins it drives the generator and electricity is produced. After passing over and spinning the turbine, the steam is condensed in a condenser and the water is recycled to where it was heated. A nuclear power plant can therefore be said to be a thermal power plant whose fuel is Uranium. Uranium is a naturally occurring element in the earth's crust that is mined like any other mineral and it is processed and fabricated as fuel for nuclear reactors.

The diagram below shows a schematic of the principle of operation of a nuclear power plant.



FUEL REQUIREMENT FOR ELECTRICITY GENERATION



The fuel requirement per energy resource is as shown in the figure above. The figure shows that, a 1000 megawatt nuclear power plant operating for a year will need 26 tonnes of nuclear fuel which could be transported by 2 trucks transporting 10 tonnes per trip.

For the same capacity power plant using Liquified Natural Gas (LNG), there will be the need to supply 1.1 megatonnes of LNG per year to be transported by 11 ships. If the fuel source is Oil, then there is need to procure per year, 1.5 megatonnes of Oil which will be transported by 15 ships.

A coal power plant of the same capacity operating for a year will also require 2.2 megatonnes of Coal to be supplied by 22 ships. This will demand huge storage space to hold such an amount of fuel for smooth operation.

It could therefore be summarized that, for the operation of a 1000 megawatt power plant in a year, the ratio of fuel demand for nuclear, oil and coal is 1gram : 2tonnes : 3tonnes.

Nuclear fuels are only used in nuclear power reactors. However Oil and LNG have applications in other fields aside power generation. This makes the cost of Oil and LNG very volatile and expensive. The high and unpredictable cost of these fuels makes power produced using them expensive.

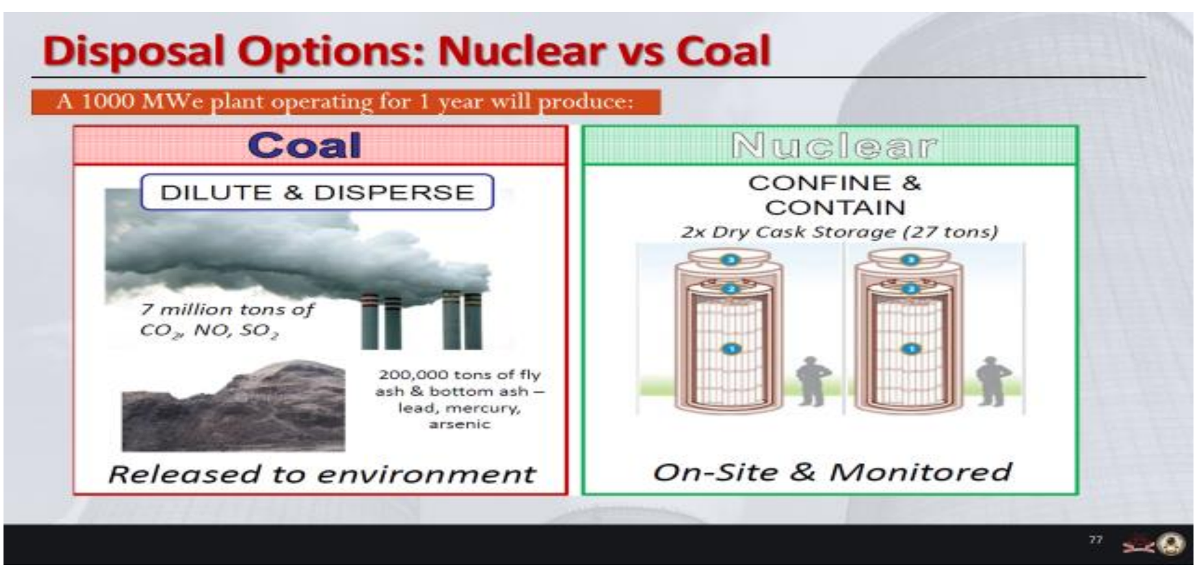
The material used as the fuel in current nuclear power stations is usually uranium. However, other possible fuels such as thorium have been considered. Uranium ore occurs naturally in the earth’s crust and is mined by conventional mining techniques. It is then processed into a form suitable for use as fuel in a nuclear reactor. Natural uranium contains two main isotopes. These are uranium-238 and uranium-235 which is so small and account for only 0.7% of the natural uranium. Uranium- 235 is however the one that can cause the fission reaction in nuclear power reactors for the generation of heat and then electricity. To therefore increase the concentration of the needed uranium isotope, which is uranium-235, the uranium ore or natural uranium must go through a process called enrichment and then become enriched. Although some reactors use natural uranium (uranium ore which is not enriched in uranium -235) as their fuel, most reactors use slightly enriched uranium in which the proportion of uranium-235 atoms has been artificially increased.

6. FABRICATION OF URANIUM FUEL

After the mineral containing the uranium (uranium ore) are mined by the use of conventional methods, the uranium in the crushed ore is extracted in processing plants or mills using very specific chemical methods. The chemical methods used usually extract 85% to 95% of uranium present in the ore. The uranium concentrate produced in the processing plant is known as yellowcake. The yellowcake usually contains 60% to 85% uranium by weight. The yellowcake goes through a series of process to be made into pure uranium dioxide powder which is then pressed into pellets and fired in a kiln to produce a dense ceramic fuel. The ceramic fuel produced is capable of withstanding very high temperatures and also retaining gaseous wastes products. The ceramic fuel pellets are put in tubes of zirconium alloy by stacking them together to form fuel pin. A number of fuel pins are put together in a specific arrangement to form a fuel assembly. A number of fuel assemblies are put in the reactor core as the unique source of heat for steam production and hence power generation.

Uranium in its natural form is only weakly radioactive. However, thorium-230, radium-226 and radon-222 are more radioactive that natural uranium. Radon-222 has become a matter of concern in highly insulated conventional buildings. In these buildings, there is reduction in the levels of ventilation which results in the accumulation of radon in them.

7. NUCLEAR VERSUS COAL : WASTE GENERATION



A 1000 megawatt capacity electricity plant, operating with a load factor of 75% will produce 6.6 terawatt-hours of electricity per year, which is approximately the electricity demand of Paris.

The figure above shows that, if such a plant is a nuclear power plant, it will produce a high level waste of spent fuel of 27 tonnes in addition to 310 tonnes of intermediate waste, 460 tonnes of low level waste, low level radioactive gas that has no public health significance and tailings from uranium mines and ore processing plants.

However if such a plant is a coal power plant, it will produce 7 million tonnes of CO_2, NO_X and SO_2 in addition to 200,000 tonnes of fly ash containing toxic heavy metals such as arsenic, cadmium mercury and lead. Smaller volume of tailings are produced in uranium mines than in coal mines per unit of electricity produced.

Fresh uranium fuels that are brought to the nuclear power plant site are put in storage facilities on site. From storage, the fuel assemblies are transferred to the reactor and placed in the core where they remain for specific time period. As the reactor continues to produce power over this duration, the uranium-235 isotopes become used up. This results in poor power generation and hence they must be replaced periodically to sustain power generation. Uranium fuels that are removed from the reactor after they have been used for some duration are no longer fresh. They are called spent fuels. Spent fuels removed from the reactor core gives off considerable amount of heat and radiations. They are therefore kept in a storage pond immediately after removal from the reactor core for one to two years or longer. The water in the storage pond cools down the spent fuel and also prevent the escape of radiation into the environment.

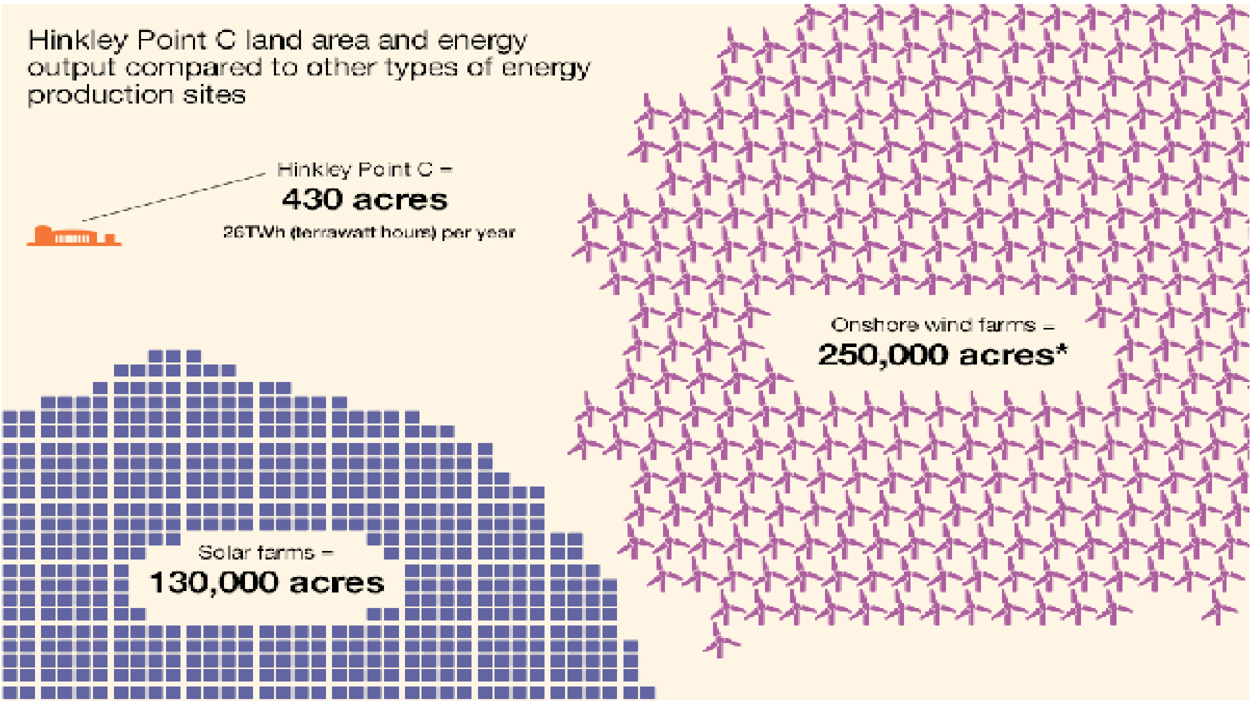
It is noteworthy that, the storage pond is just a temporal place keep the spent fuel. After spending more than one year at the storage pond and after ensuring that the spent fuels are considerably cooled in the storage pond, they are transferred to an interim storage facility and then finally moved to a repository. A repository is a facility that is safely designed as the final resting place of the spent fuel. In the repository, the radiation level of the spent fuel gradually reduces in a process called natural transmutation.

8. SITING OF A NUCLEAR POWER PLANT

Siting of a nuclear power plant is a thorough process that evaluates a number of parameters that ensure safe operation of the reactor as well as enhances the application of emergency actions. The adequacy of the location of a nuclear power plant is an issue of concern to the public and must be addressed. When selecting a site to house a nuclear power plant, some of the factors that are taken into serious consideration include, location of the site, geology of the area, hydrology, meteorology and climatology, local activities such as agriculture and food production, the nuclear power plant characteristics and environmental factors.

The performance of these parameters on the integrity of the nuclear power plant as well as safety and preservation of life in the neighbourhood of the nuclear power plant in the event of any incident are considered in greater details when selecting a site for the construction of a nuclear power plant.

The figure below shows the land use for a nuclear, wind and solar facility all producing the same amount of power (26 terawatt-hour) for a year. It shows that, while nuclear power facility require just 430 acres of land, solar and wind facilities require large amount of space of 130,000acres and 250,000 acres respectively.



9. NUCLEAR POWER PLANT SAFETY

The fundamental safety objective is to protect people and the environment from harmful effects of radiation. There are many basic approach to ensure safety in all nuclear reactors. These include ensuring, system redundancy, diversity, physical separation, multiple barrier concept and defense in-depth.

System Redundancy: In this approach, more components performing the same safety function are connected in such a way that when one fails, the other immediately comes online to sustain safe operation.

Diversity: In this approach also, two or more safety systems based on different designs or functional principles are used to perform the same safety function. This is to balance effectiveness of both designs using their individually unique characteristics.

Physical Separation: This refers to the approach which ensures that components or safety systems that are intended to perform the same function are separated physically from each other. This is to ensure that, the failure of one does not inhibit the action of the other.

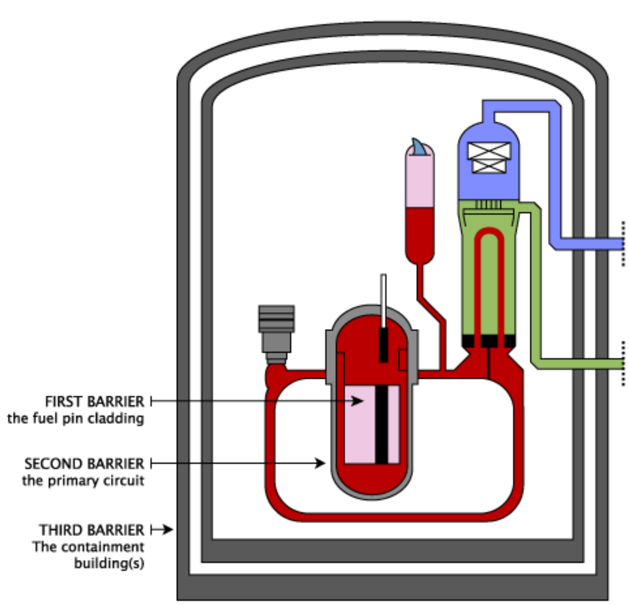
Fail-Safe Principle: With this principle, components or safety systems used in the nuclear power plant are designed to fail automatically into their safest condition.

The basic aim of nuclear power plant safety is to ensure that the integrity of the protective multiple barriers are not compromised and that, the protective barriers working individually and collectively will not at any time allow the escape of harmful radiation to the public. In order word, the harmful radiations that are produced when the plant is operating must always be contained within the reactor through the effective action of these multiple barriers. This is mostly done by an approach called defense in-depth. In the defense in-depth approach, there are three (3) levels of safety measures. These are, preventive, protective and mitigative measures.

The fundamental principle behind defense in-depth is to include multiple, successive barriers to prevent the release of radioactive material to the environment. The primary (first) barrier are the fuel and the fuel cladding. By their design, they contain radioactive material under extreme conditions inside the reactor core.

The secondary barrier is the primary system, which contains the coolant use to carry away the heat which is used to produce steam for the generation of electricity. The final barrier is the containment building which is also designed to mitigate the release of radioactive material in the event that both the primary and secondary barriers are damaged. The figure shown below depicts the three (3) barriers discussed.

The Three Barriers



An inherent safety characteristic found in most power reactors is the movement of the cooling materials (eg. water) in the reactor by natural process called natural convection. This natural process takes over when the pumps which are supposed to move the cooling material get damaged during operation. Also, the force of gravity can be used to drop control rods that are used to shut the reactor down into the reactor. This is passive safety system since it does not need power supply or human interference for the reactor to shut down by this method.

No operating commercial power plant uses inherent and passive systems alone to control operation of the reactor. They all need active safety systems as well. Active safety systems need a power supply as well as an activating signal to work. A good combination of all three systems (inherent, passive and active) rather than a choice between them ensures the safety of nuclear power plants. Most recent nuclear reactor designs make extensive use of passive safety features. This is in an effort to limit errors resulting from human interferences during reactor operation.

10. WHY GHANA MUST GO NUCLEAR

Ghana's electricity generation mix is mainly made up of thermal power (about 68%) and hydro power (about 32%). Ghana's thermal generation at present is mainly from crude oil and natural gas. There is the need for Ghana to introduce other sources of power such as coal, Nuclear etc into the generation mix for the following reasons.

i. Ghana has only about 840 megawatts of untapped hydro potential that can be achieved through the damming of twenty one (21) rivers. The construction of a dam on each of these rivers comes along with such issues as destruction of vegetation and the displacement of settlements along the river banks.

   One unit of a Nuclear power plant can deliver about 1000 -1200MW of power and it is even possible to have two or more units at one site which covers an area far less than the area required for the construction of twenty one (21) dams.

ii. Ghana recently discovered some oil reserves suggesting the promise for a sustainable supply of fuel for thermal power production. However the gas reserves will start dwindling at about 2030 making it imperative to start planning for other sources of power such as Nuclear that require a long term planning and implementation.

Also coal, crude oil and natural gas that are the fuels for thermal plants have other uses apart from their use in power production causing them to have price changes every now and then. Uranium, the fuel for nuclear power plant on the other hand is only used in Nuclear reactors making it a very cheap fuel.

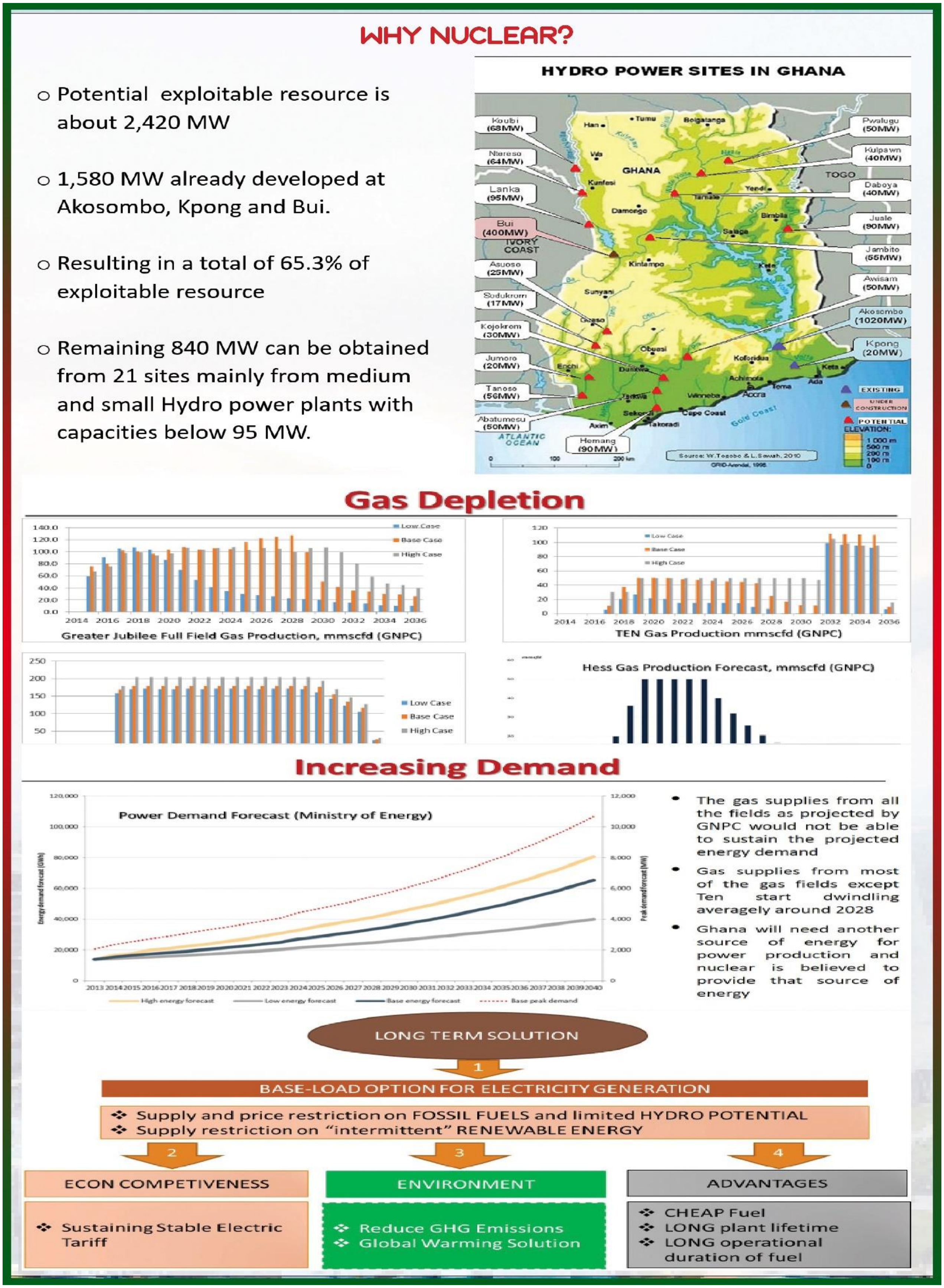
iii. The combustion of fossil fuels (coal, crude oil and gas) in thermal plants causes large amounts of greenhouse gases to be released into the atmosphere posing a threat to the ozone layer and causing global warming. The use of uranium in nuclear power plants releases no green house gases and is said to be very environmental friendly.

iv. Renewable sources of power (wind and solar) are unstable and intermittent and have the tendency to cause disturbances to the grid. Nuclear power plant is very reliable and has long and stable operational life.

The fuel source also has a long life and can stay in the reactor and generate electricity between 18 – 24 months unlike the other sources that require fuel on a daily basis

The figure below shows that, limited hydro potential, gas depletion and increasing energy demand for various application in Ghana support the efforts to include a more resilient and reliable base load energy generation option into Ghana's electricity generation mix.

This option offers economic competitiveness which sustains stable electricity tariff as a result of the use of cheap fuel and provides a solution to global warming by reducing emission of green-house gases. Most industrialized countries developed their industrial capacities around their nuclear power programme. Hence a nuclear power programme is a huge undertaken that builds the international competitiveness of local industries and as well generate substantial business for local industry. Once local industry become viable, it translates into creation of new job opportunities, improvement of overall national economy, reduction of foreign exchange expenditures and increase of national self-sufficiency.



Why Ghana must Include Nuclear Power in its Electricity Generation Mix

11. GHANA'S NUCLEAR POWER PROGRAMME; THE JOURNEY SO FAR

Ghana's nuclear journey begun in 1963 with the establishment of the Ghana Atomic Energy commission (GAEC) by Osagyefo Dr. Kwame Nkrumah; the first president of Ghana. In the same year he launched Ghana's first reactor project for the construction of a 2MW soviet reactor for the training of nuclear scientists for the country. Dr. Kwame Nkrumah also launched the "Energy for accelerated national development plan" in 1964. However on 24th February 1966 there was a revolution and Dr. Nkrumah was overthrown. After the revolution, the National Liberation council (NLC) led by General Ankrah took over as the Government of Ghana. The NLC approached the International Atomic Energy Agency (IAEA) and one British Scientist Sir Cockcroft to offer advice on the Nuclear Programme. The view of the IAEA was that "the advice sought was political in nature, and must therefore remain the prerogative of the Government to take a decision." In November 1966, Sir Cockcroft's report indicated that "In View of the capacity of the Volta hydroelectric project, for some twenty years to come, a reactor is unlikely to be necessary for the purposes of producing power". Following this statement the reactor project was abandoned and GAEC was closed down from 1967 to 1974. It is worthy of note that approximately twenty years after Cockcroft's statement, Ghana started experiencing power crisis (Dumsor-Dumsor). There were three major crises in 1984, 1998, 2000/2007 and a minor crisis in 1993. In December 2007 a presidential committee chaired by Professor Adjei-Bekoe was set up by the ex-president John Agyekum kuffour to report on a feasibility study of introducing Nuclear power into Ghana's energy mix. Following the committee's report, cabinet took a decision in 2008 to include Nuclear power into Ghana's Energy mix and in 2010 nuclear energy was included in the national energy policy and strategy. The government of Ghana declared its intention to pursue a nuclear power programme for peaceful purposes through a letter submitted to the International Atomic Energy Agency in 2012. The Ghana Nuclear Power Programme Organization (GNPPO) was also established in September 2012 to oversee the implementation of the programme and the development of the necessary nuclear infrastructure for successful introduction of nuclear energy into the energy mix. To accelerate the development of the necessary nuclear infrastructure, the Ghana Atomic

Energy Commission, acting on behalf of the government of Ghana and the GNPPO, established the Nuclear Power Centre (NPC) in February 2014 to provide technical support to the GNPPO. The Nuclear Power Centre was upgraded to the Nuclear Power Institute in September 2016. In August 2015 the nuclear regulatory Authority Act 2015 (Act 895) was passed leading to the establishment of an independent Nuclear Regulatory Authority (NRA). The NRA regulates activities involving the use of nuclear materials in Ghana. In December 2015 Ghana applied to the IAEA for an integrated nuclear infrastructure review (INIR) mission which was actually conducted in January 2017. The mission was conducted to assess the status of the nuclear power program and to make recommendations and suggestions. The reviewers made twelve (12) recommendations, eight (8) suggestions and also found three (3) good practices with Ghana's programme that they encouraged other countries to learn from. The INIR mission report was submitted to the Government of Ghana in May 2017.

Presently the recommendations of the review mission are being addressed so as to move the programme into its second phase. Many national institutions are involved in providing expertise for the nation's nuclear power programme. Among these are, the Volta River Authority, Environmental Protection Agency, Ghana Grid Company, Geological Survey Department, Ghana Statistical Service, Association of Ghana Industries, Ghana Institution of Engineers, National Development Planning Commission, Ghana Atomic Energy Commission, Council for Technical and Vocational Education and Training and National Council for Tertiary Education.

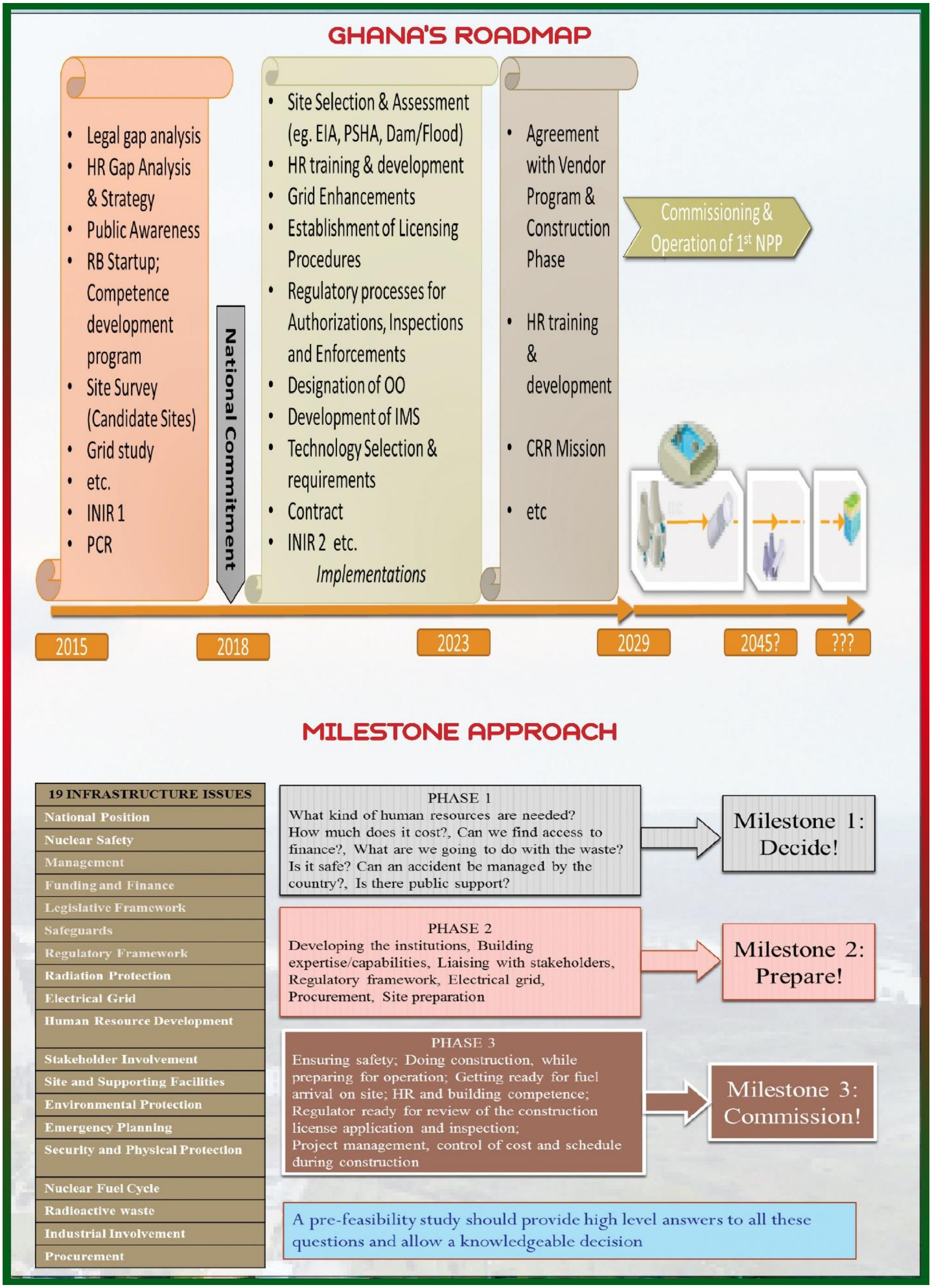
GHANA'S NUCLEAR JOURNEY

DATE	ACTIVITIES
1963	Ghana's 1st Reactor Project launched: Construction of 2 MW Soviet reactor
1963	Establishment of Ghana Atomic Energy Commission (GAEC)
1964	Energy for accelerated national development plan – Dr Kwame Nkrumah
Feb. 1966	Revolution - Gov. invitation to Sir Cockcroft and IAEA on Reactor Project. View of IAEA was that "... the advice sought was political in nature, and must therefore remain the prerogative of the Government to take a decision."
Nov. 1966	Sir Cockcroft Report (to NLC); "In view of the capacity of the Volta hydroelectric project, for some twenty years to come, a Reactor is unlikely to be necessary for the purposes of producing power."
Between 1967 - 1974	Reactor Project disbanded and GAEC shut down. GAEC later revived but not with a strong mandate for energy development.
Between 1984 - 2007	3 major power crises (1984, 1998, 2000/2007). A minor crisis in 1993
Dec. 2007	Presidential Committee to report on a feasibility study of introducing nuclear into country's energy mix (Adjei-Bekoe Committee)
2008	Cabinet decision to include nuclear into energy mix based on the Committee's Report
2010	Nuclear Energy included in National Energy Policy and Strategy
Sept. 2012	Ghana Nuclear Power Programme Organization (GNPPO) established
Feb. 2014	Establishment of Nuclear Power Centre at GAEC as the technical driving force for GNPPO. Upgraded to an Institute in September 2016.
Jan. 2015	IAEA Experts visit Ghana to develop a better understanding of the for nuclear power infrastructure development
March 2015	Draft of Roadmap for NPP development in Ghana. Document reviewed by IAEA in Nov 2015, and subsequently approved by GNPPO
Aug. 2015	Nuclear Regulatory Authority Act 2015 (Act 895) for the establishment of an effectively independent Nuclear Regulatory Body passed.
Dec. 2015	Ghana applied for IAEA Integrated Nuclear Infrastructure Review Mission for Phase 1 of the Programme developments
Apr.– Dec 2016	Ghana develops Phase 1 INIR Mission Self Evaluation Report
Jan 2017	Phase 1 INIR Mission conducted by IAEA
May 2017	Submission of Phase 1 INIR Mission Report to Government

<u>Ghana's Nuclear Journey so far</u>

12. GHANA’S NUCLEAR POWER PROGRAMME: THE ROADMAP

Ghana’s nuclear power programme roadmap spans from the period of 2015 to 2029 within which all the infrastructure issues concerned with developing a new nuclear power programme will be delivered. Provided that all resources are timely provided for the execution of the roadmap, Ghanaian will see their first nuclear power plant become operational from 2029 providing electric power through the national grid. The programme period is divided into three (3) major phases within which 19 infrastructural issues will be developed. The required 19 infrastructural issues and the target for each of the 3 phases are provided in the figure below.



<u>Ghana's Nuclear Power Programme Roadmap</u>

STATUS OF GHANA NUCLEAR POWER PROGRAMME

INTRODUCTION

The Ghana Nuclear Power Programme Organization (GNPPO) is the organization mandated to see to the development of Ghana's nuclear power programme. The GNPPO in collaboration with the International Atomic Energy Agency (IAEA) in January 2017 conducted an international peer review of the country's nuclear power programme.

The review noted that Ghana had made considerable progress in the development of Phase 1 nuclear power infrastructure, and had established effective mechanisms to involve a wide and comprehensive range of national stakeholders in relevant activities.

The went further to state that Ghana had already completed or initiated a significant number of studies, but some key studies still remained to be completed in order for the government to make a knowledgeable commitment to a nuclear power programme

The following sections provide a summary of the status of the nineteen IAEA nuclear infrastructure issues that are considered in the development of any country's nuclear infrastructure.

1. National Position

The GNPPO has established an effective Technical Body with a strong programme management function and mechanisms to involve a wide and comprehensive range of national stakeholders. This ensures an inclusive process in the studies required for the government to make a knowledgeable commitment to a nuclear power programme.

2. Nuclear Safety

The GNPPO promotes safety culture and makes significant use of IAEA safety standard documents in the development of the necessary nuclear infrastructure. The Nuclear Regulatory Authority is engaged with a number of international partners to develop competency in safety regulatory infrastructure. The GNPPO has established bilateral cooperation with Russia, China and other international organizations for knowledge sharing on nuclear and radiation safety.

3. Management

The GNPPO has set up the Nuclear Program Management Centre to develop an understanding of management system requirements. The NPMC is involved in the Establishment and implementation of an effective management system to ensure that all nuclear issues especially safety are properly managed. Several processes including processes for document review and management have been developed. Processes developed for GNPPO will serve as the foundation for the management systems of key organizations.

4. Funding and Finance

Discussions have been held with some vendor countries and financing could potentially be based on government-to-government loans. Other local potential investors are also being considered. Further analysis to develop viable financial options and to understand their economic implications and risks is ongoing. A draft document on radioactive waste management, spent nuclear fuel and decommissioning has been developed.

5. Legal Framework

Ghana has enacted the Nuclear Regulatory Authority (NRA) Act (Act 895) which is a comprehensive nuclear law .This act established the NRA. Ghana has adhered to a number of nuclear related international legal instruments. A preliminary assessment of national laws in relation to the introduction of nuclear power has been conducted. From the study, it has been identified that the following laws will need to be amended.

6. Safeguards

Ghana has concluded a comprehensive safeguards agreement (CSA) and an additional protocol to the CSA. It has also rescinded its small quantities protocol. Integrated safeguards have been implemented in Ghana and staff of GAEC and NRA is involved in safeguard inspections.

7. Regulatory Framework

Ghana's Nuclear Regulatory Authority is established, with the powers to authorize, inspect and regulate nuclear activities and has a Board with representation from varied stakeholder institutions. The NRA, through collaboration with the U.S. Nuclear Regulatory Commission, the IAEA and other bodies, is developing regulations, standards and guides for the programme.

8. Radiation Protection

Expertise has been built within the Radiation Protection Institute (RPI) to provide services related to dosimetry, instrument calibration and radiation protection training. To better serve the nuclear power program, the RPI will need to expand their dosimetry service, develop internal dosimetry capability and consider the need for additional instrument calibration services.

9. Electrical Grid

Preliminary grid assessment has been performed. The Terms of reference (TOR) for detail studies that have to be undertaken in order to successfully connect the first nuclear reactor to the national grid has also been developed. Preparations are underway to kickstart this study which will cover both the national and the sub-regional grid network.

10. Human Resource Development

Profiling of manpower requirements for key organizations covering pre-project activities, plant construction and commissioning, plant operation and maintenance have been developed. Analogous industries in Ghana and West Africa as well as Ghanaian expatriates in the nuclear sector have been identified as potential man-power source. Use of existing tertiary, vocational and special training institutions both locally and abroad for education and training to meet local content are planned.

11. Stakeholder Involvement

The GNPPO has involved a wide range of national stakeholders in the nuclear power program and has engaged a wide spectrum of stakeholders including, leadership of the Parliament of Ghana. Surveys aim at continuously evaluating societal inclination throughout the programme has been designed with very instrumental involvement of Ghana Statistical Service and the International Atomic Energy Agency (IAEA)

12. Site and Supporting Facilities

Detailed criteria for site selection and the site selection process have been developed and currently under review by international experts. Two regions of interest (south-western and south-eastern Ghana) have been identified. Nine candidate areas within these regions have been identified and plans are to identify candidate sites by end of 2018.

13. Environmental Protection

Ghana has adhered to several international conventions and has adopted a number of laws and policies that form the framework for environmental protection. Review of these documents as well as environmental and social impact assessment guidelines to ascertain whether any areas related to environmental protection need to be updated to fully cater for the introduction of nuclear power is ongoing with the involvement of Ghana's environmental regulator, the Environmental Protection Agency.

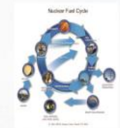
14. Emergency Planning

NADMO and GAEC have developed a National Nuclear and Radiological Emergency Response Plan to specifically address radiological emergencies for various radiation sources in the country. The plan presents a general description of the roles and responsibilities of ministries, organizations and facilities involved in any given emergency response. A procedure has also been developed for responders such as public information officers, radiological assessors, medical teams, law enforcement agencies and fire fighters in the event of Radiological Accident. An international review mission on the Emergency Response plan document was conducted in Ghana, and action plan based on recommendations from the mission is being developed. With regards to nuclear power program, a team is already set up to review the existing plan to ensure that emergency preparedness and security concerns for the operation of nuclear power plant are fully covered.

15. Nuclear Security

A radiation safety, security as well as an international nuclear safety and security advisory services were conducted. An international physical protection advisory service was also conducted. Findings from these missions are being addressed through the implementation of an integrated nuclear security support plan. The national radiological threat assessment is expected to be finalized by the end of 2017 by the National Security Council.

16. Nuclear Fuel Cycle



Draft Nuclear fuel cycle policy and implementation strategy documents have been developed. These documents define Ghana's short, medium and long term approaches to the nuclear fuel cycle. Among the short term considerations are; buying complete fuel assemblies and adopting a take-back policy with reprocessing of spent fuel in vendor country and return of high level waste or storage of spent fuel locally. Prospecting and developing capacities for uranium mining and yellow cake production is to be considered in the medium term.

17. Radioactive Waste Management

The NRA has prepared a Draft Regulation for the Management of Nuclear and Radioactive Waste. The responsibility for radioactive waste management would rest with the owner/ operator of the plant, while the NRA and EPA would be responsible for regulatory control. Draft Waste management policy and implementation strategy of radioactive waste, spent nuclear fuel and decommissioning documents have been developed.

18. Industrial Involvement

Local industry involvement study with a focus on appraising local industry capability to participate in Ghana's nuclear power program sub-contract has been planned. The outcome of this study will inform the development of a policy document regarding local industry involvement in the NPP project. The policy is expected to be completed by 2018 by stakeholders drawn from MOTI, NDPC, VRA, GhIE, GNPPO and AGI.

19. Procurement

Procurement process for both goods and services are to be guided by the Public Procurement Act 2003 (Act 663), with is relevant amendment.

CONCLUSION

Ghana's Nuclear Power Programme is progressing steadily. The GNPPO will continue to involve the Ghanaian Society Vendor, Countries, and International Partners so as to deliver its mandate base on best pracitces in the field and also ensure that, the success of the programme brings reliability of the Ghana electricity mix.