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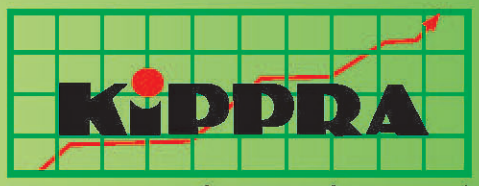

The KENYA INSTITUTE for PUBLIC POLICY RESEARCH and ANALYSIS

Road to Nuclear Power in Kenya

Brian Nyaware

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THE KENYA INSTITUTE FOR PUBLIC POLICY RESEARCH AND ANALYSIS (KIPPRA)

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Kenya Institute for Public Policy
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KIPPRA in Brief

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Abstract

Kenya plans to adopt nuclear energy to meet its growing energy demand, improve energy access and fast-track the energy transition through the nuclear power programme. The country is already taking the initial steps in implementing the programme, and this study seeks to assess Kenya's readiness for the implementation. The study identifies 19 prerequisites for nuclear power programme and uses an exploratory and qualitative method to analyse the status, identify existing gaps and suggest potential solutions. The prerequisites are grouped into 7 pillars. The findings show that Kenya has made significant progress in meeting most of the prerequisites. Kenya has put in place a nuclear energy policy and strategy needed for a strong national position and is receiving support from the International Atomic Energy Agency (IAEA) and countries such as Russia and South Korea to improve management. That said, Kenya needs to implement the Integrated Nuclear Infrastructure Review (INIR) mission's recommendation of developing a nuclear leadership programme. Kenya has ratified various international treaties, undertaken evaluation of the national emergency and response capability and adopted the United Nation's (UN) security protocols. The country can further develop and adopt specific laws and regulations for control and prohibition of radioactive materials, and use of advance physical infrastructure to better meet the radiation protection prerequisite. Despite the efforts made, there is need to identify and implement specific funding mechanisms or models to cover the operational costs of running the nuclear applications. In addition, it is important to promote technology transfer and localization under the procurement prerequisite. With Kenya meeting these prerequisites adequately, the country can establish nuclear networks of different professionals, both locally and internationally based, to nurture and share nuclear power knowledge and build human capacity for nuclear energy. Also, the country can have more all-inclusive stakeholder and industrial involvements to increase public acceptance and improve perceptions. To acquire the necessary grid reliability, continued investments and upgrading of the grid is a priority. Further, better compensation methodologies to deal with land issues and having more inclusive stakeholder engagements are recommended to reduce the probability of public opposition. The country has developed a comprehensive framework to facilitate the implementation of the nuclear power programme, including the Kenya Nuclear Regulation Act of 2019 and establishment of the Kenya Nuclear Regulatory Authority (KNRA). However, it is necessary to cover all aspects of nuclear law and therefore further development of frameworks and implementation of international legal instruments are recommended. While most of the prerequisites have been met, Kenya can establish more specific and qualified bodies such as nuclear regulatory bodies to efficiently carry out the sole duty of nuclear environmental assessments to further enhance how Kenya meets the environmental protection prerequisite.

Abbreviations and Acronyms

EPRA	Energy and Petroleum Regulatory Authority
GDP	Gross Domestic Product
GHGs	Green-house Gases
GoK	Government of Kenya
GW	Gigawatts
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
INIR	Integrated Nuclear Infrastructure Review
IRENA	International Renewable Energy Agency
KenGen	Kenya Generation Company
Ketraco	Kenya Electricity Transmission Company
KNEB	Kenya Nuclear Electricity Board
KNRA	Kenya Nuclear Regulatory Authority
LCPDP	Least Cost Power Development Plan
MoEP	Ministry of Energy and Petroleum
MoU	Memorandum of Understanding
MTPs	Medium-Term Plans
MW	Megawatts
NDCs	Nationally Determined Contributions
NEPC	Nuclear Electricity Project Committee
NPP	Nuclear Power Plant
NRR	Nuclear Research Reactor
NuPEA	Nuclear Power and Energy Agency
PESTLE	Political, Economic, Social, Technological, Legal and Environment
PPAs	Power Purchasing Agreements
PPP	Public Private Partnership
PRC	People's Republic of China
R&D	Research and Development
RE	Renewable Energy
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
SWOT	Strengths, Weaknesses, Opportunities and Threats
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WNA	World Nuclear Association

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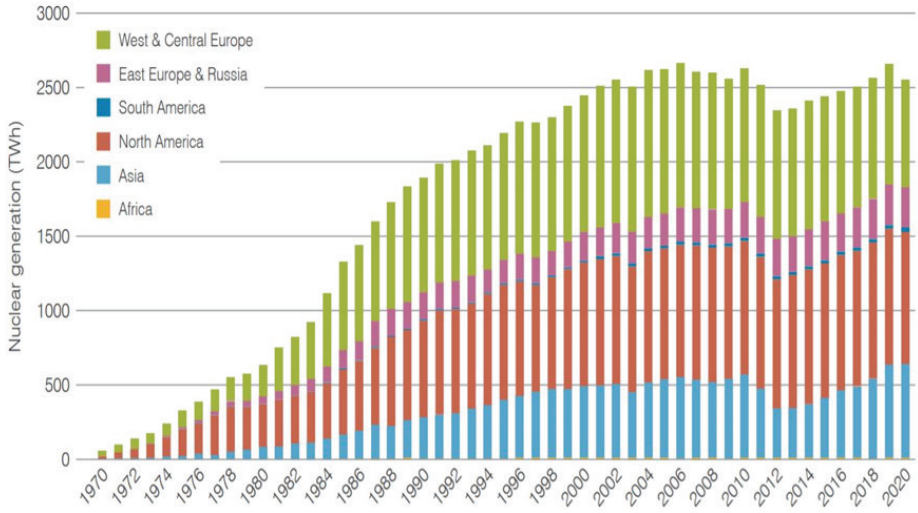
1. Introduction

Generation of nuclear energy has been on the rise globally. Since operations of the first commercial NPP in the 1950s, the number of countries in the world that generate nuclear energy has increased to 32 countries now (WNA, 2021). By 2020, nuclear energy accounted for about 10 per cent of the world total energy capacity (WNA, 2021). Increased nuclear adoption has been mainly because it is advantageous over other energy sources because of little land use, great capacity, stable supply, cheaper electricity costs and low carbon footprint. According to the United Nations Environment Programme Emissions Gap Report 2020, the energy sector is the greatest emitter of Green-House Gases (GHGs). Out of the total GHG emissions, 24 per cent, 10 per cent, 7 per cent and 11 per cent are from electricity and heat generation, energy transformation, energy use in buildings and other sectors, and industrial energy use, respectively (UNEP, 2020). Nuclear energy and renewable energy are among the clean energy sources with little to no emissions of GHGs. The United States of America (USA), Peoples Republic of China (PRC) and France are the leading countries in nuclear generation as at 2022 (WNA, 2023b). 63 per cent of France's energy mix is from nuclear energy, 18 per cent in the USA and 5 per cent in China. The North America region is leading in total nuclear energy generation, followed by West and Central Europe, Asia, East Europe and Russia, South America and lastly Africa, with the least nuclear energy generation capacity (Figure 1.1).

The nuclear energy sector in Africa is still at a nascent stage. South Africa is the leading country in Africa in implementing a nuclear power programme, as it is the only nation in the continent that has an operational Nuclear Power Plant (NPP). Its NPPs contribute about 6 per cent of the country's total energy mix. However, South Africa is still heavily reliant on fossil fuels, which make up over 80 per cent of the energy mix, making the nation's energy transition far from being 100 per cent achieved. Egypt began construction of its first NPP in 2022, with an expected completion date in 2028. The goal is for nuclear power to represent 9 per cent of the nation's electricity by 2030. Currently, renewable energy makes up 20 per cent of the country's energy mix and additional nuclear energy and renewables would further propel the energy transition in the region. Namibia, Nigeria, Senegal, Zambia, Uganda, and Ghana are other African countries that have expressed interest in NPP development (WNA, 2022). Kenya plans to join this list through its nuclear power programme. Over 80 per cent of Kenya's energy mix comes from renewable energy, and nuclear energy adoption may further improve the nation's energy transition. The International Renewable Energy Agency (IRENA) defines energy transition as the global energy sector transformation to zero-carbon by the year 2050, from the current fossil-fuel based. Currently, fossil fuels have an approximate share of 80 per cent of the world's total energy mix (IEA, 2022a).

Figure 1.1: Global nuclear electricity production



Source: World Nuclear Association Report 2021 (WNA, 2021)

The growth of the nuclear energy sector has been affected by various challenges. In the late 1970s to 2002, significant decline in growth and stagnation was witnessed, and this was linked to the sector's challenges such as its potential dangers (WNA, 2022). The Fukushima Daiichi Disaster (2011), the Chernobyl Disaster (1986) and the Three Mile Island Accident (1979) are three well-known accidents that have been at the centre of many nuclear debates to date (Ohba et al., 2021). Following these nuclear disasters and effects, several countries have plans to move from nuclear power or are against them to avert the associated potential dangers. Some of them include: Germany, Belgium, Italy, Austria, Australia, Malta, New Zealand, Norway, Portugal and Serbia (WNA, 2022). As a result, the International Atomic Energy Agency (IAEA) and other relevant energy stakeholders have revised safety standards and provided directions towards development of a better and safer nuclear sector. Comparisons with other energy sources such as renewable energy and negative perceptions that have led to public opposition are among other challenges. There is usually a general negative public attitude towards nuclear energy, and this varies depending on various factors such as educational levels, nuclear knowledge, age, political stance and gender (Chung, 2020). Renewable energy (RE) is also a preferred energy source for the energy transition over nuclear energy for some. However, its adoption has also been affected by various barriers. Siddharth (2018) listed low scalability, intermittency, dependence on weather patterns, large land use, ecological disruptions, technological incompatibility and technology barriers as challenges for RE adoption. Therefore, nuclear energy accompanied by effective public awareness and efficient safety precautions has been put forward as a viable clean energy option for the energy transition.

Countries intending to develop a NPP usually do so by implementing a nuclear power programme. A nuclear power programme refers to the programme that

establishes the necessary infrastructure to support a nuclear power plant project during its planning, licensing, construction, commissioning, operation, fuel and waste management, and decommissioning. Construction, commissioning and operations are the core elements of a nuclear power plant project (IAEA, 2007). Effective implementation of these programmes requires the necessary infrastructure, policies and regulations to be first developed and put in place. To assist in doing this, the IAEA has a framework whose main purpose is to assist emerging nuclear countries. The framework has three phases, each with its own milestone, and it is called the Milestone Approach (IAEA, 2012a). Phase one consists of the considerations to be made before the launch of a nuclear programme, the choice of whether to have a nuclear programme or not. Phase two is the preparatory work once the decision in phase one has been made and, lastly, phase 3 has the implementation activities (IAEA, 2007). Phases are usually summarized as consider, prepare and construct.

The implementation of a nuclear power programme may take at least 10 to 15 years or longer, depending on the programme's complexity, economic and technical constraints, and handling critical issues on health, environment and safety (Government of Kenya, 2004). The South Korean nuclear power programme began in 1958 and commercial operations of the first NPP began in 1978. The construction of the first localized nuclear power plant (the Korea Standard Nuclear Power Plant), based on accumulated experiences and technology, began later in 1989 and was commissioned in 1995 (Choi et al., 2009). Egypt had long considered establishing NPPs since the 1960s, with the country's Atomic Energy Commission being set up earlier in 1955. The El Dabaa site on the Mediterranean coast was selected site for the NPP in 1983 and construction began in 2022. The implementation of the nuclear power programme in Bangladesh has also taken a long time. The site selection at Rooppur occurred in 1961 and construction commenced in 2017. South Africa's nuclear industry started in the mid-1940s and the first NPPs (Koeberg plant) was commissioned in 1984. Nigeria's first NPP plans have also been lengthy, with the Nigerian Atomic Energy Commission (NEAC) being established in 1976. Construction of the NPP is yet to begin, though the country already has a nuclear research reactor (NRR). These examples demonstrate the variations of the programme's implementation periods across different countries, with some countries taking longer periods and others remaining stagnant at different stages before completion.

Some countries incorporate nuclear research reactors (NRR) as an essential step in their preparations towards their first NPP and nuclear power programme given their benefits. Technology development, education and training, isotope production and scientific research are among these benefits and applications of nuclear research reactors. Only a few nuclear research reactors are present in Africa, located in Morocco, Algeria, Egypt, South Africa, Libya, the Democratic Republic of Congo, South Africa, Nigeria and Ghana (WNA, 2022). The NRRs are mainly used to produce neutrons and are made of simpler designs, much smaller and use less nuclear fuel when compared to NPPs. Additionally, most of them are used for research and learning purposes and not for power generation. Therefore, the construction and operation of NRRs does not greatly contribute to the energy

transition, as most of them have a power output of under 1MW. However, they can be used to build the capacity of NPPs staff and NPP research, and thus indirectly contribute to the energy transition influenced by NPPs.

Kenya has adopted the Milestone Approach as it implements the nuclear programme. It is exploring the nuclear power option to further diversify its energy portfolio, boost stability and grow energy supply to meet the foreseen demand increase as highlighted in several policies such as the Least Cost Power Development Plan (2021-2030) and the Kenya Vision 2030 (Government of Kenya, 2007). The Least Cost Power Development Plan (LCPDP) is the government's energy sector roadmap that highlights the sector's status, gaps, expansion requirements and opportunities (Government of Kenya, 2018a). The planned development and connection of nuclear energy to the national grid from the year 2036 onwards are featured in the LCPDP 2021-2030 (Government of Kenya, 2021a). It also highlights the nuclear energy benefits to climate change mitigation and energy security. The plan further forecasts a rise in demand that is to be met by additional energy supply, including nuclear energy, with the peak demand projected to have an average growth of 4.9 per cent, 7.9 per cent and 4 per cent for the reference, vision and low scenarios, respectively. The country's main development agenda (Kenya Vision 2030) includes the nuclear energy generation being included in Kenya's energy mix. With the plans to adopt nuclear energy, this paper seeks to assess the ongoing implementation of the nuclear power programme in Kenya.

The overall objective of this study is to explore Kenya's readiness in implementing the nuclear power programme. The specific objectives are: to assess the nuclear power programme's implementation prerequisites and their statuses in Kenya and; to identify the gaps and potential solutions in meeting the prerequisites to fast-tracking the implementation of the nuclear power programme.

The rest of the paper is structured as follows: section two provides the overview of the nuclear programme in Kenya; section three details the guiding literature review, including theoretical and empirical literature; section four provides the methodology including conceptual framework, the description of the pillars and their indicators. Section five presents the results and discussion of the study while the conclusion and recommendations are presented in section six.

2. Overview of the Nuclear Programme in Kenya

Kenya's association with nuclear power can be traced back to as early as 1965, when the country became a member of the IAEA. The IAEA is an intergovernmental agency that aims to promote peaceful use of nuclear technology and nuclear power worldwide. Later, the Sessional Paper No. 4 on Energy (Government of Kenya, 2004) highlighted Kenya's considerations of adopting nuclear power and its economic merit. The paper aimed to avail cost-effective, affordable and adequate quality energy services to Kenya's economy over the period 2004 to 2023 and mentioned the economic and technical constraints in having a nuclear power plant. It also showcased the emergence of cheaper nuclear technologies that could add merit for Kenya to consider the nuclear route in future. Addition of nuclear electricity into Kenya's grid was proposed by the National Economic and Social Council as a national priority in April 2010. Later that year, through the Kenya Gazette Notice No. 14188, the Nuclear Electricity Project Committee (NEPC) was gazetted under the then Ministry of Energy. The 13-member committee's key mandate was to spearhead Kenya's nuclear energy development, and prepare and implement the roadmap for Kenya's nuclear programme that is up to IAEA's standards and procedures. They were also to undertake civic education on nuclear power generation and lobby support from key stakeholders such as the Kenya Association of Manufacturers, Central Organization of Trade Unions and the civil society. The NEPC later transitioned to the Kenya Nuclear Electricity Board (KNEB) following its establishment in 2012. KNEB had the mandate of promoting and expediting the development of nuclear electricity and policies. In the same year, an Ad Hoc Inter Ministerial Committee on Nuclear Energy Policy and Law was formed to harmonize all nuclear energy initiatives, policies and bills. By 2015, Kenya had already developed a 15-year Strategic Plan for Kenya's Nuclear Power Programme, which recommended the development of an NRR.

Kenya has legislative, policy and institutional frameworks that support the implementation of the nuclear power programme. The enactment of the Energy Act on 2019 (Government of Kenya, 2019a) brought about the transition of the Kenya Nuclear Electricity Board (KNEB) to the Nuclear Power and Energy Agency (NuPEA). NuPEA continues KNEB's mandate and carries out research, development and dissemination activities in the energy and petroleum sectors in Kenya. The agency promotes and implements Kenya's nuclear power programme. The Nuclear Regulatory Act of 2019 (Government of Kenya, 2019b) establishes the Kenya Nuclear Regulatory Authority (KNRA), regulations and safety of nuclear material, emergency responses and nuclear waste management. KNRA's core mission is to provide effective regulatory control in the use of radiation and nuclear technology for social economic development, and has a mandate to oversee nuclear safety, nuclear safeguards, nuclear security and radiation protection. The Science, Technology and Innovation Act, 2013 (Revised 2014), Sessional Paper No. 1 of 2005, Sessional Paper No. 9 of 2012, and Sessional paper No. 1 of 2019 are examples of legislations and policies in the education sector that support the programme's implementation through research, education and capacity building. Furthermore, the Sector Plan for Science, Technology and Innovation 2017-2021 recommends the establishment of a Centre for Nuclear

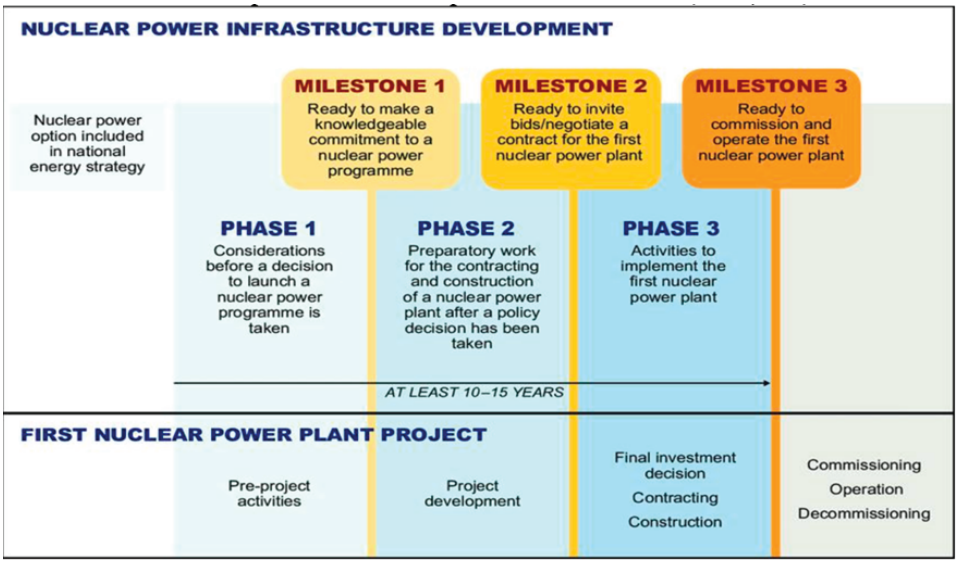
Research for Peaceful Applications (Government of Kenya, 2017). Land and environmental matters are also important in the programme's implementation and are governed by laws and policies such as the Land Act (Government of Kenya, 2012a), Environmental Management and Coordination Act 1999 (Revised 2012 and amended in 2015), Physical and Land Use Planning Act, (Government of Kenya, 2019c) and the National Environment Policy. Musyoka and Field (2018) did a review of the environmental oversight framework in Kenya, considering a nuclear power programme, and proposed a review of the national framework to ascertain its amendment and supplement the environmental law and supporting regulations and for there to be clear responsibilities of the environmental agency and nuclear regulatory body.

Additionally, some of Kenya's energy transition policies, strategies and programmes also support the nuclear power programme. During the 2023 Africa Climate Summit, Kenya committed to 100 GW clean grid and 100 per cent clean energy access by 2040 under a green industrialization agenda. This commitment demonstrates Kenya's great ambition to achieving the energy transition, which may include nuclear energy adoption. The proposed Kenya Energy Transition and Investment Plan (MoEP, 2023) further promotes nuclear energy adoption as it suggests replacing fossil fuels with nuclear power as a decarbonization technology to achieve energy transition in the country. The proposed plan will be the country's framework for the energy transition agenda, aimed at attracting investments, ensuring a just transition and supporting rapid economic growth. Deployment of nuclear power units is foreseen to begin in 2045 under this plan. However, consenting, planning and construction timelines can lead to significant delays in the commissioning of nuclear energy in the country and is a foreseen challenge, as accentuated in this plan. The Power Generation and Transmission Master Plan (MoEP, 2016) and the energy development plan, LCPDP (2021-2030) also feature NPPs in the nation's forecasted future energy sources - Nuclear Unit 1 (600MW) and Nuclear Unit 2 (1000MW). The development plan points out supply dependency and low amounts and costs for the needed fuels as advantages nuclear energy has compared to fossil fuels. The revised Feed-in-Tariffs (FiTs) policy assures market and returns for investors looking to venture into the identified energy sources, thus promoting the energy transition (Government of Kenya, 2012). However, it only focuses on renewable energy sources such as wind, solar, biomass, geothermal and hydro, and not nuclear energy.

Since the government's initial considerations of nuclear power programme and subsequent first steps in the early 2000s, the pre-project activities are still ongoing. Kenya has been implementing phase one of the adopted Milestone Approach for over 10 years and is almost concluding this phase (Figure 1.2). The programme's implementation and promotion is being spearheaded by the government agency - NuPEA. As part of implementing the programme, NuPEA has already signed a few Memoranda of Understanding (MoUs) to help with nuclear research, design and construction, capacity building and non-power nuclear applications. The MoUs signed are with Rosatom, Korea Electric Power Corporation (KEPCO) and China Generation Nuclear Power (CGN) (NuPEA, 2022). NuPEA has also embarked on other activities such as the process of NPP site identification and

increasing public awareness on nuclear energy. Other completed activities relevant to the programme's implementation include: preparation of the 15-year roadmap, completion of the pre-feasibility study to introduce the nuclear power programme, stakeholder engagements, enactment of the Energy Act and the Nuclear Regulatory Act in 2019, human resource development, establishment of nuclear bodies such as NuPEA and KNRA, cooperation and collaboration with other stakeholders and other countries, accession to international treaties and conventions and others (NuPEA, 2020).

Figure 1.2: Nuclear power programme implementation - Milestone Approach



Source: IAEA (2007)

Kenya's plans for the nuclear power programme have been majorly highlighted in the nation's main development plan, the Kenya Vision 2030. The Vision highlights energy as a key enabler and aims for Kenya to become a middle-income industrialized country by the year 2030. Its implementation is done through 5-year plans called Medium-Term Plans (MTPs). More energy generation at a lower cost is envisioned under this plan, with nuclear energy fitting well into this vision. The MTP 2 proposes the use of nuclear energy to meet growing energy needs, implementing the nuclear power programme in readiness to establish the NPPs, and the establishment of Nuclear Research Centre and Kenya Institute of Oil and Gas. It also targets for the development and implementation of the atomic energy policy that will address statutory and operational issues of nuclear electricity power generation, nuclear waste management and security, radiation protection and peaceful application of nuclear science in all sectors. The MTP 3 goes further to showcase the nuclear power development programme as a one of its flagship programmes for the period between 2018 and 2022. It entails site identification

of NPPs, establishment of the Research and Development Institute in the energy sector, public education, development of a legislative and regulatory framework, and capacity building. Among its proposed policy, legal and institutional reforms include: developing the national nuclear energy policy, and domestication and ratification of regional and international obligations such as the Convention on Nuclear Safety. Some of these plans have already been accomplished, such as the ratification of some regional and international conventions, enactment of nuclear legislation such as the Nuclear Regulation Act of 2019, establishment of institutions such as KNRA and activities on site identification.

Funding is a vital component in the implementation of the nuclear power programme. The Kenya Vision 2030 also contains the indicative budget estimates for implementing the nuclear programmes and projects. In the MTP 2, the nuclear power programme's implementation is estimated to cost about Ksh 300 million, while the implementation of the nuclear power development programme has an indicative budget of Ksh 19.6 billion in the MTP 3. The nuclear power programme's implementation has also been financially supported by the government through its budgetary allocations. A budget of Ksh 1.3 billion was set aside in the national budget statement for the financial year 2021-22 to cater for nuclear energy and coal mining. In the financial year 2022-23, the development of nuclear energy received Ksh 1.587 billion from the national budget. Prior financial years have also had significant budgetary allocations to the energy sectors. Kenya has already identified the initial source of funding for the construction of its first NPP (NuPEA, 2020).

3. Literature Review

3.1 Theoretical Review

The diffusion theory can be used to explain the spread of new technologies. Diffusion of technologies refers to the spread of technologies within populations over a given period. (Straub, 2009). Education levels, urbanization, and industrialization are among the factors that affect diffusion of technologies (Rogers, 1995). Growing urbanization and industrial growth, globally and in Kenya, have led to a rise in energy demand and need for additional supply. The nuclear power programme's implementation can help meet this demand with nuclear energy being introduced into the grid. Going by this theory, nuclear energy and associated technologies and infrastructure may be considered as new technologies as the nuclear power sector is in its early stages in Africa and Kenya.

The modern portfolio theory is also applicable in exploring diversification of portfolios. The theory considers the correlation between risks and returns when choosing assets for financial portfolios (Markowitz, 1952). Investors prefer less risk portfolios to more risky ones when both have equal returns. Spreading of risks and more returns may be positive outputs from the diversification of portfolios (Marrero et al., 2015). This theory has been used in the energy sector to explain the diversification of energy sources, policies and financing. Marrero et al. (2015) applied this theory as they analysed mean-variance portfolio methods for energy policy risk management. Ojiambo and Tsuyoshi (2020) also used the theory in their study of the Kenya's energy portfolio, which recommended further diversification of the energy mix. While exploring financing in Kenya's electricity sector, Nyaware (2022) used this theory and concluded that more diverse financing mechanisms in the sector can promote the sector's development further. Implementation of the nuclear power programme adds nuclear energy into the national grid, further diversifying Kenya's energy portfolio.

3.2 Empirical Review

Nuclear energy is considered as a potential pathway to the energy transition in many countries, including Kenya (Government of Kenya, 2023). The energy source has significant potential to contribute to the power sector's decarbonization and is historically one of the biggest contributors of carbon-free electricity in the world. About 70 Gt of CO2 emissions have been averted using nuclear energy globally over the last 50 years (IEA, 2022b). Multiple studies explore the interlinkage between nuclear energy and the energy transition. Wan et. al. (2023) used various tests such as the second-generation panel unit root test, panel cointegration test, panel fully modified ordinary least squares, and Heterogeneous Dumitrescu and Hurlin causality test, to explore the role of nuclear energy in the energy transition. They compared the effects of coal, oil, natural gas, renewable energy, and nuclear power on economic growth and carbon emissions using data from 24 countries. In their findings, they concluded that nuclear energy is a more powerful tool for energy transition, and that both nuclear and renewable energy can spur economic

growth without releasing GHGs. Fattahi et. al. (2022) also had similar findings in their analysis of the techno-economic role of nuclear power in the Dutch net-zero energy system transition. Their study illustrated the complementary role nuclear power can play, parallel to wind and solar power, in supporting the Dutch energy transition from the sole techno-economic point of view. An evaluation of the asymmetric effects of nuclear energy on carbon emissions in Pakistan also found that using nuclear technologies will lead to a decrease in fossil fuel use and dependence and elimination of GHGs emissions (Majeed et. al., 2022). Gralla et al. (2017) in their study showed that countries with nuclear energy have more carbon emissions compared to those without. This contradicts the idea that the adoption of nuclear energy translates to the reduction of emissions and fast-tracks the energy transition. Lerede et al (2023) forecasted that nuclear fusion may not be needed for the energy transition in the USA and Europe, leading upto the year 2100, but may play a major role in the transition of regions with high growing energy demand and industrial development, such as in Asia. They also suggested that the use of nuclear energy for energy transition in regions with low energy demand levels, such as in Africa, would not be justified due to the large investments needed.

The need for nuclear energy has been justified by multiple factors, key among them being its advantages and increasing energy demand. Rapid urbanization, economic development and industrialization have led to increased energy demand, causing an energy crisis in some countries (Agyekum et al., 2020). Globally, about 774 million people still lack access to electricity (IEA, 2022). It is estimated that by the year 2030, 620 million will still lack access if the current and planned policies remain constant (IEA et al., 2020). Given the direct correlation between poverty alleviation and access to cheap energy, it is essential to avail clean and affordable energy to assist in decreasing poverty, especially in Sub-Saharan Africa - SSA) (Reddy et al., 2000). Nuclear energy is deemed to be cleaner, more stable and cheaper compared to other energy sources. Studies done by Elliott (2007) and Ferguson (2007) supported this notion, with both highlighting that nuclear energy can be used to mitigate the global warming challenge and is a stable and nearly carbon-free source of energy. A study on mitigating CO_2 emissions in BRICS countries by Hassan et al. (2020) also found that nuclear energy sources greatly reduce carbon pollution in that region. Brook et al. (2014) sought to determine why nuclear energy is sustainable and must be part of the energy mix. Their findings illustrated that only NPPs can supply the large quantities of clean and economical energy to industrial societies in a reliable and sustainable way, with little GHGs emissions. Also, all the criteria of sustainability as defined by the UN Brundtland Commission are met by nuclear energy. Other sources such as renewable energy may not be as economically viable when it comes to supply of large energy quantities. South Korea's options for sustainable energy mixes were evaluated using scenario analysis by Hong et al. (2013). The study looked at seven model scenarios that include the present condition, renewable energy, maximum nuclear power, among others. It concluded that the maximum nuclear power scenario had the least overall negative impacts for both economic and environmental factors and, therefore, a more sustainable energy model for energy transition.

Due to its advantages, over 50 countries have expressed interest in wanting to start nuclear power programmes, including African countries (IAEA, 2008). Namibia, Tanzania, Zambia, Uganda, Ghana, Nigeria, South Africa and Kenya are the African countries that have shown significant progress in preliminary processes for the adoption of nuclear programmes. Africa possesses numerous resources, with the region producing 18 per cent of the total global uranium, a key resource for nuclear power generation. Out of the world's uranium production, 8.2 per cent is from Namibia, 7.7 per cent is from Niger, 1.2 per cent from Malawi, and 1.1 percent from Niger (UNEP, 2017). To boost security of nuclear facilities and prevent weapons proliferation, many African counties have also signed and ratified the Non-Proliferation Treaty and African Nuclear Weapon Free Zone Treaty (Pelindaba Treaty). The Pelindaba Treaty prohibits all activities related to transport of nuclear weapons, use and development (Sah et al., 2018), see Figure 2.1. These amplify the region's readiness to implement nuclear power programmes. Energy demand and security, financial, technical and institutional capacity and political stability are other examples of key indicators for nuclear readiness (Jewell, 2011).

Figure 2.1: International nuclear safety and security treaties

Source: Sah et al. (2018)

The assessment of the nuclear energy sector and wider energy sector has been done using various methodologies throughout literature. Agyekum et. al. (2021) and Zalengera et al. (2014) used PESTLE analysis to assess the renewable energy sector in Ghana and Malawi. This approach provides a wider scope for analysis from different angles and is fit for analysis of broad sectors but also fails to provide deeper analysis given the bulky information captured in the outcomes. The strengths, weaknesses, opportunities and threats (SWOT) analysis has been used by Ansah et al. (2021), Agyekum et al. (2020) and Ishola et al. (2019) to assess the

nuclear energy sector in Africa, Ghana and Nigeria. The renewable energy sectors in Pakistan (Kamran et al., 2020) and Jordan (Jaber et al., 2015) have also been examined by using the same method. Among the advantages of SWOT analysis is that it is cheap to conduct and highlights the main issues that positively and negatively affect sectors. Its limitations include lack of detailed analysis, and the bulk of information that makes it difficult to provide concrete solutions (Agyekum et al., 2020). Sah et al. (2018) used qualitative analysis and a comparative approach to explore the feasibility of commercial nuclear power in Sub-Saharan Africa. This approach gives a broad view of the nuclear technology's viability in the region but does not give a deeper analysis of key indicators that allows issue-specific solutions to challenges. Jewell (2011) developed a benchmarking framework with key indicators such as institutional capacity to evaluate the motivations and capacities of "Newcomer countries" to develop nuclear power programmes. This approach also overlooked some key indicators such as country specific characteristics, current technologies and data that are crucial in the analysis.

Multiple studies have analysed the nuclear energy sector by exploring nuclear power programmes, as they establish the needed infrastructure to support the new NPPs. Islam et al. (2021) reviewed Bangladesh's nuclear power programme and readiness by investigating the status 7 out of the 19 core nuclear infrastructure issues. They acknowledged the remarkable progress made in the implementation of the nuclear power programme, which was in phase 3. Radioactive waste management, comprehensive regulatory frameworks, emergency planning and human resource development are among the areas the study highlighted for improvement to ensure optimum safe nuclear infrastructure before commissioning and operating the country's first NPP. Hickey et al. (2021) looked into the financing and geopolitics of nuclear power programmes in 4 countries: Turkey, Jordan, the United Arab Emirates and Egypt. Their analysis used a qualitative approach and illustrated how exchange of sovereign assurances can be used to tackle NPPs' financing challenges, especially during construction. Political assurances, necessity of nuclear power and willingness to grant financial guarantees were the main policy areas highlighted by this study, with regard to implementing nuclear power programmes, geopolitics and financing. Choi et al. (2009) sought to draw lessons from the implementation of the nuclear power programmes in the Republic of South Korea. The study provided a timeline for the development of the nuclear power programme through 4 phases: preparation (phase 1), national plan (phase 2), contacting (phase 3) and operation and localization (phase 4). It also highlighted infrastructure issues and guidelines applied in the country. Strong national commitment that needs to be integrated with cooperation systems and diverse knowledge and planning processes that should incorporate feedback and plan assessments were among the key lessons in this study.

Similarly, other elements of the nuclear power programme have been further investigated by numerous authors. Sovacool and Valentine (2012) identified 6 drivers needed to sustain nuclear power programmes: social peripheralization; economic interventionism; technocratic ideology; centrally coordinated energy stakeholder network; national security and secrecy; and subordination of opposition to political authority. Ochuko et al. (2023) assessed various nuclear

power programmes in African countries: Egypt, Ghana, Kenya, Uganda, Morocco, Nigeria, South Africa, Niger and Sudan. Among the common implementation gaps and challenges pointed out included: inefficient human capacity, lack of financing, public opposition, and inadequate robust policy and regulatory frameworks. As a result, some of these countries have stalled in implementation of the nuclear programme and sought advice for the IAEA. Kim et al. (2023) also contributed to these discussions by showcasing that leadership changes, domestic politics (democracy), national energy security environments, low electricity demand, lack of military alliance with major nuclear suppliers and major nuclear accidents are factors that may lead to a country's nuclear programme being deferred, suspended or scrapped. Other than failures during programme implementation resulting in halting the process, both implementation and operational failures may lead to various outcomes such as accidents, power outages and environmental pollution. Csereklyei (2014) measured the impact of nuclear accidents and concluded that negative impacts are likely to happen to both the specific country and beyond. A dataset of 31 countries and three nuclear accidents (Three Mile, Chernobyle and Fukushima) are used in this study. Sich (2021) mentioned inadequate operator training, soviet societal and plant staff safety culture and reactor design deficiencies as some of the root causes of the Chernobyl Nuclear Power Plant Unit-4 accident in 1986. Public perception of nuclear energy is also negatively impacted from the occurrence of nuclear accidents (Huhtala and Remes, 2017).

Overall, the nuclear energy sector faces several challenges globally. Sah et al. (2018) and Jewell (2011) found that high construction costs, insecurity, corruption, political instability, lack of technical, financial and institutional capacity, poor institutional and regulatory frameworks and inadequate human capital and infrastructure are among the challenges hampering the implementation of nuclear programmes. Concerns over risk of accidents and spent fuel disposal have further negatively affected the adoption of nuclear energy. Anti-nuclear activism has also been on the rise, with increase in the number of groups that promote anti-nuclear ideologies. Hippel (2016) highlighted the potential dangers of production of nuclear weapons from radioactive material such as uranium. A study on public deliberation on the national nuclear energy policy in South Korea illustrated the hesitance people have towards nuclear energy and the importance of public deliberations to educate people and improve on inclusivity in energy policy making (Chung, 2020). Ansah et al. (2021) recommended cooperative government to government financing, international collaboration to boost knowledge sharing, building human capacity, strengthening national security, improving public awareness and providing stable political environment and strong legal frameworks as possible solutions to the challenges.

On the other hand, there are numerous benefits gained from the implementation of nuclear programmes by countries. The uses of research reactors are examples of these benefits. The uses can group into four categories (irradiations, human resource development, testing and extracted beam work) and include: education and training, neutron activation analysis, radioisotope production, geochronology, transmutation effects, neutron radiography, material structure studies, prompt gamma neutron activation analysis, positron sources and neutron capture

therapy (IAEA, 2014). Some other positive outcomes from these uses would be improved health, increased job opportunities and new innovations. Adoption of nuclear energy also increases clean energy capacity in the grid, improves access to cheap and reliable electricity, creates opportunities of potential collaborations and localization of technologies, provides green jobs and contributes to lowering green-house gases (GHGs). Muigua (2020), while exploring alternative sources of energy in Kenya, highlights improved energy efficiency and increased access and supply of sustainable energy and potential benefits to be gained from the adoption of nuclear power in Kenya. About 100,000 people are directly employed into long-term high-quality jobs and 375,000 people indirectly by the nuclear industry. At peak construction, a nuclear power plant employs 3,500 workers (Ansah et al., 2021). Kim and Yoo (2021) compared nuclear energy to renewable energy and concluded that nuclear energy is not intermittent in nature and takes up less space compared to renewable energy sources. Gralla et al. (2017) concluded that adoption of nuclear energy does not reduce the use of fossil fuels, and there is lack of substantial evidence illustrating that nuclear energy contributes to mitigating climate change.

4. Methodology

For successful implementation of a nuclear power programme, the IAEA's approach identifies 19 nuclear infrastructure issues that must be addressed. This study identifies these issues as the nuclear power programme prerequisites and investigates them in depth, cross checking to see the status in implementation of each using an exploratory and qualitative approach. The prerequisites are grouped into seven pillars, based on common areas covered in the issues. Pillar 1 looks at issues dealing with national nuclear management and planning, pillar 2 looks at issues related to nuclear security and safety, financial areas are covered in pillar 3, people related issues are in pillar four, pillar five explores issues linked to nuclear technical aspects, relevant frameworks are in pillar six and matters affecting nuclear fuel and the environment are in pillar seven. Figure 4.1 summarizes these issues in the seven pillars.

Figure 4.1: Conceptual framework

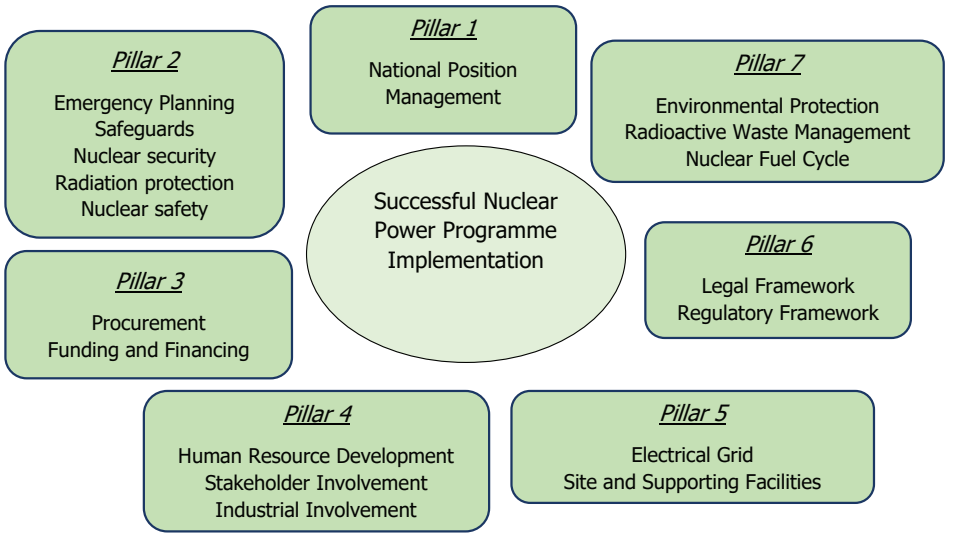


Table 4.1 identifies the key indicators for each prerequisite under each pillar to guide the analysis. Analysis is done to compare what Kenya has done so far to meet the prerequisites against their key indicators, and conclusions are drawn as to whether the specific prerequisites have been met. Comparisons are also done between Kenya and other countries and gaps identified through this process. Suggestions on how to better meet these gaps, potential challenges and the prerequisites are drawn from other countries such as Poland, USA, South Africa, South Korea, Japan, Russia and China that have advanced the implementation of their nuclear power programmes.

The study acknowledges that Kenya's implementation process is still ongoing, with phase 1 almost complete, and therefore not all the prerequisites will be completely met.

Table 4.1: Nuclear power programme prerequisites - Description and conditions

Pillar	Nuclear Infrastructure Issues (prerequisites)	Description	Indicators	NPP	NRR
1	National Position	This refers to the government's intent to develop a nuclear power programme (based on national energy policies that support economic development), long term commitment and importance of safety, security and non-proliferation recognized	Bold national position	+	+
			Strong national support	+	+
	Management	This is described by the roles and responsibilities of management and management systems along the process of nuclear power programme implementation, from planning to operation	Competent management: good leadership, transparency and openness	+	+
			External support	+	+
2	Emergency Planning	This touches on planning done to ensure the capability to actions taken to effectively mitigate the consequences of an emergency, minimizing the probability of a large release of radioactive material from the plant	Arrangements for preparedness and response to radiation or nuclear incidences made by government	+	+
	Safeguards	This refers to the measures taken to prevent the diversion of nuclear material from peaceful uses	Government to have supporting infrastructure in place	+	+
			A clear understanding and commitment to its safeguards by government	+	+
	Nuclear Security	This describes the prevention of, detection of, and response to, intentional unauthorized acts related to nuclear material, other radioactive material, and associated facilities and activities	Government to have infrastructure in place	+	+
			Security culture and technical competence	+	+
			Contingency planning	+	+
			Compliance with international standards	+	+

	Radiation Protection	This covers the protection of the public and workers from radioactive releases, on-site and off-site	Relevant and supporting laws, regulations and programmes	+	+
			Government to have infrastructure and programmes in place	+	+
	Nuclear safety	This refers to all aspects of a nuclear power programme ensuring safety and requiring commitment to the same from all relevant stakeholders such as government, regulatory body and nuclear technology suppliers	Presence reliant engineering safety systems	+	+
			Nuclear technology with specific requirements	+	+
			Legal and regulatory frameworks that enhance safety	+	+
			Compliance to safety principles and standards such as the IAEA safety standards	+	+
			A good safety culture	+	+
3	Funding and Financing	This alludes to the funding and financing requirements for a nuclear power programme, with funding being the government's responsibility and financing being the NPP owner's/operator's responsibility	Cost considerations on infrastructure and other related facilities, capital commitment depending on size of facilities, and lifecycle cost	+	+
			Strong funding mechanisms and strategies	+	+
	Procurement	This addresses the procurement of specific equipment that has requirements beyond those of standard procurement and the procurement of services for a nuclear facility	Special technical competencies	+	+
			Rigorous oversight	+	+
4	Human Resource Development	This is the development of the necessary knowledge and skills needed to introduce nuclear power in a country and may vary from administrative and management, to technical skills	Relevant expertise, experience and skills considering international best practises	+	+
			Specialized trainings and a good safety and nuclear security culture	+	+

	Stakeholder Involvement	This describes the involvement of stakeholders through the programme to facilitate government support	Involvement of both internal and external stakeholders	+	+
			Public participation through open and honest dialogue	+	+
	Industrial Involvement	This covers the involvement of industry that support and supply equipment and services during the programme's implementation	Industrial organizations involved should comply with the relevant codes and standards	+	+
5	Electric Grid	This is the grid on to which nuclear energy will be added into and it ought to be stable and large enough to take in the base load of the NPP	Adequate grid size and reliability	+	+
	Site and Supporting Facilities	This refers to the siting of the NPPs and their supporting facilities and involves several stages, including selection and licensing	Site surveys	+	+
			National and cultural considerations and nuclear safety and security considerations	+	+
6	Legal Framework	This touches on the framework that establishes the responsibilities of all necessary organizations, comprehensively cover all aspects of nuclear law (i.e. nuclear safety, nuclear security, safeguards and civil liability for nuclear damage)	Establishes all necessary responsibilities of relevant organizations	+	+
			Extensively covers all aspects of nuclear law and implementation of international legal instruments	+	+
			Have separate bodies for regulating and enabling the nuclear power programme	+	+
			Adherence to all relevant international legal instruments planned	+	+

	Regulatory Framework	This is the framework that covers regulatory compliance and evaluation of the programme's nuclear and radiation safety, security and safeguards	Existence of an independent and competent regulatory body or bodies, with adequate independence, authority, independence, finances and competent staff	+	+
			Ability to accommodate various sizes of aspects of the nuclear power programme	+	+
			Consistent and compatible with existing laws, policies and regulations	+	+
7	Environmental Protection	This addresses the impacts on the environment and people from liquid and gaseous radioactive releases during normal operations of NPPs and NRRs	Considerations on land use, water use and quality, release of gaseous and liquid radioactive effluents and other environmental impacts	+	+
	Radioactive Waste Management	This refers to the management and disposal of all the NPP's and NRR's radioactive waste	Application of safe, practicable and environmental acceptable solutions for waste management	+	+
	Nuclear Fuel Cycle	This refers to the process of the used fuel: before being used in a NPP and after use	Efficient fuel management strategy	+	+
			Commitment to use of low enriched uranium	+	+
Note: + means that the prerequisites stated are needed for its (NPP or NRR) implementation					

Source: IAEA (2012b) and IAEA (2021)

5. Results and Discussions

5.1 Analysis of Nuclear Power Programme Prerequisites

5.1.1 National position and management

Bold national position and strong national support are the indicators for the national position issue that needs to be addressed as a prerequisite (IAEA, 2012b). Bold national position refers to the presence of national policy and strategy for the nuclear power programme. Kenya has fulfilled this requirement, with the Government already having developed a national nuclear policy and 15-year nuclear strategic plan. The nuclear power programme is also incorporated in the country's main policies such as the development agenda (Kenya Vision 2030) and the energy sector plans (LCPDP). Strong national support is evident from the significant actions and pronounced stance on the nuclear power programme by the Government. Additionally, the Government, Ministry of Energy and Petroleum and other key nuclear government agencies such as NuPEA and KNRA have greatly contributed to the nuclear sector's growth and programme implementation, with phase one of implementation almost complete. Additionally, the country's consideration to the programme's implementation is apparent from its continued membership to IAEA since 1965. Appendix 1 highlights the Energy Act of 2019 and the Nuclear Regulatory Act of 2019 as national legislative examples that showcase Kenya's bold national position and strong national support, making fulfil Kenya this prerequisite. These and other government policy documents cement the government's strong stance as they provide guidance and regulation on the implementation of the nuclear power programme. In Poland, the Polish Nuclear Power Programme is a strategic government document that defines the activities needed for the construction of the first NPP and their implementation schedule over the period 2020 to 2043.

In the NuPEA Strategic Plan 2020-2025 (NuPEA, 2020), changes in government policy have been identified as potential barriers affecting the national position and the overall implementation of the nuclear programme. Examples may include postponement of the NPP commissioning and recommendations suggested by the presidential taskforce on the review of Power Purchasing Agreements (PPAs) in 2021 to vest the nuclear agency into a department within the Ministry of Energy and Petroleum (Government of Kenya, 2021b). These could have an impact on support for the programme's implementation in terms of resource allocation and prioritization. Kim et al. (2023) also highlighted that political leadership can stall nuclear power programmes, giving an example of temporary suspension of two NPPs under construction in South Korea by the former President Moon Jae-In after his election. Taiwan also switched to abandoning nuclear energy by 2025 following the 2016 presidential and parliament elections that saw the anti-nuclear party come into power (Gao et al., 2022). A possible solution to this would be establishing clearer pathways and detailed strategies for NPP development to build stronger justification and national consensus. Poland, also in the process of implementing its nuclear power programme, has detailed and clear pathways to achieving its objective of implementing nuclear power under the Energy Policy of Poland until 2040 and the Nuclear Power Programme strategic government

document. They highlight specific details and timelines of the planned NPPs steps and plans, strengthening the national position. South Korea's nuclear power plans and programme were integrated into the national development plans and the implementation of these plans were closely coordinated (Choi et al., 2009). This built strong nation position and support for the programme.

Under management, the IAEA (2012b) highlights a highly competent management as being key in the nuclear programme implementation. This type of management incorporates leadership and management of safety, transparency and openness and external support organizations. Part of this requirement is already being fulfilled, given the existing support the Kenyan government is receiving from external organizations such as the IAEA and nations such as Russia, South Korea and China with regard to the nuclear programme. Kenya also aims to ensure there is competent management in the country's nuclear sector. The NuPEA Strategic Plan showcases regular competencies for leadership and management being conducted in the Nuclear Power Programme and an implemented Quality Management System (QMS) among its achievements. There are also other government policies and legislation that promote competence, such as the Public Service Act (Government of Kenya, 2015a) and the Leadership and Integrity Act (Government of Kenya, 2012b), which contribute to meeting this prerequisite. Planning, resources management and process implementation are elements of the management system for nuclear facilities and activities as envisaged by the IAEA (2006c). These elements have been applied by the government through nuclear strategic plans, budget allocations and support, among other activities.

However, the status of this prerequisite remains incomplete, with the latest Integrated Nuclear Infrastructure Review (INIR) mission in Kenya recommending the development of a nuclear leadership programme (IAEA, 2023). These missions are knowledge sharing sessions, involving IAEA Member State representatives and experts, that help in the development of nuclear infrastructure. In South Africa, this prerequisite is met through the Nuclear Energy Policy for the Republic on South Africa of 2008 that incorporates nuclear governance framework and cooperation, providing clear guidelines on the management of NPPs and boosting cooperation that strengthens management. The management's inability to adopt to circumstances within the nuclear sector is a major challenge during the programme's implementation. Underfunding, under-utilization and lack of efficient stakeholder engagement are among the other bottlenecks to nuclear programme implementation under management (IAEA, 2012b). These can be addressed by efficient planning and rigorous management trainings. Cost forecasting and planning, incorporated in the Polish Nuclear Power Programme strategic government document, is a solution to these challenges.

Table 5.1: Analysis summary of pillar 1 - National position and management

Nuclear infrastructure issues (prerequisites)	Indicators	Status: How Kenya has met the prerequisites	How other countries have met the prerequisites
National Position	• Presence of national policy and strategy • Strong national support	• Establishment of nuclear bodies like NuPEA and KNRA • Presence of a national nuclear programme roadmap and nuclear strategy • Financial support through budgetary allocations	Poland: Polish Nuclear Power Programme (2020)- strategy defines the needed actions for the construction of the first NPP, for the period 2020-2043
Management	• Competent management: good leadership, transparency and openness • External support	• Existing support from external organizations (e.g. IAEA) and nations such as Russia and South Korea • Carrying out regular competences for leadership and management • Implementing the Quality Management System (QMS) at NuPEA • Presence of policy on management of the Kenya Nuclear Power Programme	South Africa: Nuclear Energy Policy (2008)-nuclear governance framework providing clear guidelines on the management of NPPs

Source: Author's compilation

5.1.2 Emergency planning, safeguards, radiation protection, nuclear security and nuclear safety

Potential occurrence of failure and accidents is a salient factor to consider in all the programme's implementation phases. Because of these and related risks, emergency planning and response actions must be in place to mitigate or avert the negative outcomes such as release of radioactive materials or fatalities in extreme scenarios. Therefore, it is necessary for the government and the regulatory body to establish arrangements for preparedness and response to radiation or nuclear incidences. The probability and possible consequences of such events affect nature and locations of nuclear programme implementation. Closeness to populations and radiation risk features are among the factors to consider when making these arrangements. Emergency planning also helps boost personal, emergency workers, public and infrastructure safety. Safeguards and nuclear security actions are also among the measures taken to avert risks related to the nuclear programme. The government of a country implementing a nuclear

programme ought to have infrastructure in place and have a clear understanding and commitment to its safeguards, nuclear security and radiation protection (IAEA, 2012b). The Government of Kenya has already evaluated the national emergency and response capability and done a comparative review of safeguards in other countries and made recommendations. Also, Kenya has ratified the Non-Proliferation Treaty and African Nuclear Weapon Free Zone Treaty that contain safeguards and an IAEA Site and External Events Design (EPREV) Mission Action Plan is being implemented that incorporates emergency planning. Kenya also has the National Disaster Risk Management Policy of 2017 (Government of Kenya, 2017) that aims at strengthening disaster management through relevant institutions and partnerships and mainstream disaster risk reduction. The duty of ensuring safe, secure and peaceful use of nuclear science and technology fall under KNRA, as described in the Nuclear Regulation Act of 2019 (Government of Kenya, 2019).

The People's Republic of China (PRC) has specific legislations that cater for emergency planning and safeguards, such as the Regulations on Emergency Measures for Nuclear Accidents at Nuclear Power Plants (PRC, 1993). The Regulations on Emergency Measures for Nuclear Accidents at Nuclear Power Plants expound on emergency management for nuclear accidents, responsible departments, function on emergency organizations, onsite and off-site nuclear emergency plans, emergency categories, national nuclear emergency plans and other factors. The Nuclear Safety Law (PRC, 2018) and Regulation on the Safety Supervision and Administration of Civil Nuclear Facilities (PRC, 2005) are other examples of legislation that reinforce nuclear emergency planning and safeguards. The Nuclear Safety Law provides for mechanisms on nuclear emergency response planning and coordination and the licensing system for nuclear materials and facilities. South Korea has an annual national radiological preparedness plan and prepares national radiological emergency plans every five years to boost its safeguards and emergency planning. The country also has operational offsite emergency management centres. Bangladesh also has emergency preparedness, planning, and preventive and remedial measures that cater for off-site and on-site emergencies, under its Section 40 of BAER Act-2012. South Korea has a long safeguard history, beginning with its safeguard agreement with the USA and IAEA in 1968. The country has also signed other agreements such as the Comprehensive Safeguards Agreement in 1975, the Non-Proliferation Treaty on nuclear weapons ratified in 1975, and the Safeguards Transfer Agreement relating to the bilateral agreement between Republic of Korea, IAEA, and France also signed in 1975. As Kenya continues to implement the nuclear programme, specific legislation and regulations on nuclear emergency planning and protocols and safeguards can be considered as a gap in both the prerequisites and areas of further development.

Supporting laws, regulations and monitoring programmes are indicators of nuclear security and radiation protection prerequisites that need to be fulfilled. Implementing countries ought to have infrastructure that is compliant with international standards, with special considerations dependant on nuclear energy applications. More specifically, security culture, contingency planning, technical competence and financial stability are among the necessities for nuclear

security. Kenya has the Nuclear Regulatory Act of 2019 that has provisions for radiation protection and nuclear security and has acceded to several international instruments. Also, a preliminary national threat assessment has been initiated, the status of nuclear security infrastructure evaluated and the United Nations security resolutions adopted (NuPEA, 2020). Shocks such as earthquakes and weather catastrophes pose a threat to nuclear programme implementation. The Fukushima Daiichi accident in Japan occurred after a major tsunami caused an interruption in the cooling system of the nuclear facility. Political instability and security risks such as terrorism are other potential challenges. China's National Security Law of 2015 acknowledges nuclear threats and attacks and includes response to them and protection of nuclear infrastructure. Similarly, South Africa's Hazardous Substances Act of 1973 features radiation protection and provides for control and prohibition of radioactive materials. In Bangladesh, the Bangladesh Atomic Energy Regulatory Authority handles radiation protection arrangements and jurisdictions. The UAE and Belarus both have a dosimetry laboratory and equipment, respectively, that can be used to investigate and assess the occupational exposures and help advance protection and security. More specific laws and regulations, as is the case in China and South Africa, could boost Kenya's nuclear security and radiation protection and are gaps in these prerequisites.

Presence of reliant engineering safety systems, nuclear technology with specific requirements, legal and regulatory frameworks that enhance safety, compliance to safety principles and standards such as the IAEA safety standards and a good safety culture are among the indicators of nuclear safety (IAEA, 2012b). To address this issue, the Government of Kenya has undertaken a risk assessment of the nuclear power programme and identified mitigation measures. Also, the Government has signed various bilateral agreements and is in the process of acceding to the key nuclear safety conventions (NuPEA, 2020). Under the legal and regulatory frameworks, the Nuclear Regulations Act of 2019 states one of KNRA's functions as coordinating the fulfilment of national obligations in respect of nuclear safety, security and safeguards, which is relevant in addressing the nuclear safety issue. The National Construction Authority Act of 2011 establishes the National Construction Authority that promotes and ensures quality assurance in the construction industry, a function that may be applicable in the implementation of the nuclear programme, especially during construction. As per the Standards Act of 2012 (Government of Kenya, 2012d), the Kenya Bureau of Standards has a mandate of promoting standardization in industries, which may include technology being used in the implementation of the nuclear programme. The MoEP strategic plan 2018-2022 also highlights the development of the nuclear safety and security policy. The Integrated Nuclear Infrastructure Review (INIR) also pointed out the ratification of international conventions in nuclear safety by Kenya as an area of further improvement, thus showcasing potential gaps in this prerequisite. Nuclear safety surveillance, inspection and information disclosure are provided for in China's Nuclear Safety Law.

Table 5.2: Analysis summary of pillar 2- Emergency planning, safeguards, radiation protection, nuclear security and nuclear safety

Nuclear infrastructure issues (prerequisites)	Indicators	Status: How Kenya has met the prerequisites	How other countries have met the prerequisites
Emergency Planning	• Arrangements for preparedness and response to radiation or nuclear incidences made by government	• National emergency and response capability evaluated by Government of Kenya • Supporting polices in place: Nuclear Regulation Act of 2019 and National Disaster Risk Management Policy of 2017	• China: Regulations on Emergency Measures for Nuclear Accidents at Nuclear Power Plants (1993) - expound on the emergency management for nuclear accidents, responsible departments and function on emergency organizations. Bangladesh: Section 40 of BAER Act 2012 - emergency preparedness, planning, and preventive and remedial measures
Safeguards	• Government to have supporting infrastructure in place • A clear understanding and commitment to its safeguards by government	• Government of Kenya has already done a comparative review of safeguards • Government of Kenya has signed and ratified treaties that have safeguards such as the Non-Proliferation Treaty • KNRA ensuring safe, secure and peaceful use of nuclear science and technology	• China: Nuclear Safety Law (2018) provides for the licensing system for nuclear materials and facilities

Nuclear Security	• Government to have infrastructure in place • Security culture and technical competence • Contingency planning • Compliance with international standards	• Supporting polices in place: Nuclear Regulatory Act of 2019 has provisions for nuclear security, nuclear safety and security policy • Government of Kenya acceded to several international instruments • Preliminary national threat assessment has been initiated, the status of nuclear security infrastructure evaluated and United Nations security resolutions adopted	• China: National Security Law (2015) acknowledges nuclear threats and attacks and includes response to them and protection of nuclear infrastructure
Radiation Protection	• Relevant and supporting laws, regulations and programmes • Government to have infrastructure and programmes in place	• Supporting polices in place: Nuclear Regulation Act of 2019 that has enhanced measures for radiation protection	• South Africa: Hazardous Substances Act (1973) - control and prohibition of radioactive material

Nuclear safety	• Presence reliant engineering safety systems • Nuclear technology with specific requirements • Legal and regulatory frameworks that enhance safety • Compliance to safety principles and standards such as the IAEA safety standards • A good safety culture	• Risk assessment done and mitigation measures identified by Government of Kenya • Government of Kenya has signed various bilateral agreements and potentially acceding to key nuclear safety conventions • Government of Kenya has various laws, regulations and bodies supporting compliance of standards, such as KNRA • Presence of nuclear safety and security policy	• China: Nuclear Safety law (2018) - nuclear safety surveillance and inspection provided for

Source: Author's compilation

5.1.3 Funding and financing and procurement

Considerations regarding financing infrastructure and other related facilities, capital commitment depending on size of facilities, and lifecycle costs are essential when looking at funding and financing. Auxiliary facilities, such as staff quarters and education and training facilities, are examples of other nuclear-related facilities that need funding and financing. The size of facilities may vary from a large nuclear power plant to a small training room, costing far much less. Other major costs may include components of lifecycle costs such as: operations and maintenance costs, legal issues, physical security, provisions for decommissioning and waste management and insurance. It is also important to identify strong funding mechanisms for non-commercial elements of a nuclear programme, such as a nuclear research reactor, as they are unlikely to become financial self-supporting and are costly (IAEA, 2012b). Du and Parsons (2009) estimated that a 1 GWe NPP would require US$ 4 billion to construct. The agency tasked with carrying out the implementation of Kenya's nuclear programme has already determined the needed costs, identified the initial source of funding and established a technical working group to analyse funding and financing infrastructure issues (NuPEA, 2020). The government has also been supporting the nuclear programme financially over the years, allocating Ksh 1.3 billion and Ksh 2 billion to nuclear energy in its annual budget during the financial year 2021-2022 and 2022-2023, respectively (Government of Kenya, 2021c; 2022). Kenya

also uses incentives such as tax deductions and various financing models to attract additional investments for projects and programmes, including those in the energy sector. A model example is the Public Private Partnerships (PPPs), enabled through the enactment of the Public Private Partnerships Act of 2013 (Government of Kenya, 2013b), that has helped finance various projects in different sectors such as energy and transport.

Changes in government policies may translate to shifts in its financial priorities and may pose a challenge in funding and financing. Another challenge would be inefficient funding mechanisms being used, especially for non-commercial elements such as research and educational applications. The findings from the Presidential Taskforce on PPAs highlighted that nuclear energy may not be implemented soon and therefore a need to re-evaluate the associated costs of implementing the programme currently. (Government of Kenya, 2021b). The Electricity Sector Investment Prospectus 2018-2022 (Ministry of Energy-Kenya, 2018) also reiterates insufficient funding in the electricity sector as a challenge, with an investments gap of US$ 14.8 billion. With the country only having identified the initial source of funds, incentives and funding mechanisms to cover operational and other costs for the rest of the programme's implementation period, this can be a gap under this prerequisite. The United States of America (USA) has legislation and incentives that support the nuclear power sector's funding and financing, such as the Energy Act of 2005 and Inflation Reduction Act of 2022. The Energy Act has incentives such as the production tax credit for new NPPs, federal rick insurance to cover delays in operation for new plants, loan guarantees, support for advanced nuclear technology and others. It is also important for countries have strong commitment and prioritization to the nuclear programmes to reduce uncertainty and financial risk and attract additional private investments (Choi et al., 2009). Financial support in form of loan guarantees, subsidies and tax credits are in the Inflation Reduction Act. Governments can also explore alternative models of financing their NPP agenda. For its first NPP, Turkey is using the Build-Own-Operate model with Russia, while joint-ownership models are to be used by Jordan and the United Arab Emirates (Hickey et al., 2012).

Due to the unique nature and security and safety concerns of a nuclear programme, the need for special technical competencies is fundamental in its procurement processes. Consumables, equipment and services are among items that can be procured during the implementation of the nuclear programme (IAEA, 2012b). Rigorous oversight is also essential to uphold high quality and performance and avoid issues that may jeopardize successful implementation, such as corruption and bribery. Kenya has already identified the requirements of nuclear items such as nuclear power equipment, research reactor equipment and services. Policies, laws and regulations are also already in place to ensure quality procurement processes occur within government. The Public Procurement and Asset Disposal Act of 2015 (Government of Kenya, 2015b) and Public Procurement and Asset Disposal Regulations of 2020 (Government of Kenya, 2020) are examples of policies and regulations that offer guidance and oversight guidelines with procurement. Under this Act, there are also classified procurement methods and procedures and allowance for specially permitted procurement procedures in specific cases.

The Public Finance Management Act of 2012 (Government of Kenya, 2012c) also aims to ensure proper use and management of public finances in accordance with the Constitution's principles. Procurement of nuclear energy infrastructure is not extensively covered in Kenya's energy policies. One identified gap under this prerequisite is that specific nuclear procurement standards and steps are yet to be developed, and there is lack of localization strategies. The Nuclear Energy Policy for the Republic of South Africa emphasizes on implementation of a fleet approach in the procurement of power reactors and optimization of technology transfer in any procurement of nuclear and related equipment. South Korea has also adopted localization strategies that were implemented with foreign vendors during the development of its NPP. The localization policy helps to build capacity and save on foreign currency as there is more engagement with local suppliers (Choi et al., 2009). The IAEA also has procurement guidelines on engineering and supply chain for nuclear facilities (IAEA, 2016). In China, the China Nuclear and Radiation Safety Management System (2018) provides general principles on nuclear procurement control and activities. Appendix 3 showcases examples of relevant policies in Kenya and other countries that guide procurement and funding and financing.

Table 5.3: Analysis summary of pillar 3 - Funding and financing and procurement

Nuclear infrastructure issues (prerequisites)	Indicators	Status: How Kenya has met the prerequisites	How other countries have met the prerequisites
Funding and Financing	• Cost considerations on infrastructure and other related facilities, capital commitment depending on size of facilities, and lifecycle cost • Strong funding mechanisms	• Government of Kenya carried out a study to determine the needed costs • Government of Kenya financial support, e.g. budget allocations • Initial source of funding identified • Established working group looking into financing • Government incentives and provisions to execute various finance models • Supporting polices in place: Nuclear Regulation Act of 2019 and Energy Act that has provisions of funds, such as the decommission funds	• USA: Energy Act of 2005 offers incentives such as the production tax credit for new NPPs, federal rick insurance, and loan guarantees that promote financing

Procurement	• Special technical competencies • Rigorous oversight	• Government of Kenya has already identified nuclear requirements • Policies, laws and regulations in place that guide oversight and regulation within public procurement, e.g. Public Procurement and Asset Disposal Act of 2015 • Policy on Institutional Infrastructure for Nuclear Procurement	• China: China Nuclear and Radiation Safety Management System (2018) provides general principles on nuclear procurement control and activities. • South Korea: Localization policy increases capacity and engagement with local suppliers

Source: Author's compilation

5.1.4 Human resource development, stakeholder involvement and industrial involvement

Relevant expertise, experience and skills lie at the core of human resource development for nuclear programme implementation, while considering the international best practices. These particularly relate to the various aspects in all the phases of implementation, such as planning, procurement, purchasing, construction, licensing, legal, operation and maintenance, decommissioning, safety, security and radiation protection. They may span across multiple disciplines, including but not limited to engineering, scientific and administration. Specialized trainings and a good safety and nuclear security culture are also essential for human resource development. Both assist in instilling personal responsibility for safety and security for all involved in the programme (IAEA, 2012b). The necessary skills and knowledge needed have already been identified by a Nuclear Power Human Resource Development Concept Model developed by the Government of Kenya. Trainings are also being offered on nuclear power plant technology and a Human Resource Development Strategy has been developed. Those being trained are to be added to the country's human resource database consisting of those that have completed trainings in various nuclear-related areas (NuPEA, 2020). There are also numerous professional bodies that promote professionalism in different sectors relevant to the nuclear programme. Examples include the Engineers Registration Board established by the Engineers Act (Government of Kenya, 2011) and the Law Society of Kenya enacted by the Law Society of Kenya Act (Government of Kenya, 1992). Since the nuclear sector is fairly new to Kenya and SSA, the number of nuclear-trained personnel is low in the region compared to other regions. Inadequate competence and human resources have also been identified as a weakness in the NuPEA strategic plan. Absence of the necessary human resources may slow the programme's implementation. Government support, collaborations and partnerships can be used to build capacity and expand personnel. The Nuclear Energy Policy for the Republic of South Africa has the development and maintenance of human capital as a core

element. In Japan, Nuclear Human Resource Development Strategy Planning Council Report of 2010 led to the establishment of the Nuclear Energy Human Resource Development Network. The network is a system comprising of nuclear organizations from government, academia and industry working together to build human capacity for nuclear energy in the country. South Korea has also taken this integrated approach of using a vast range of professionals to implement its nuclear programme, with the Nuclear Energy Programme Implementing Organization (NEPIO) having extensive human resources from different fields and human resources development programmes. This collaborative approach can help Kenya further develop and maintain its human resources.

Stakeholder involvement ought to engage those with specific interest in the programme (internal) and or those who may be affected by its implementation (external). Stakeholder comments and insights play a major part in shaping specifications, implementation and utilization of the programme and its elements. The public are part of the stakeholders and engagement with them is best done through public participation and open and honest dialogue. Given the various elements and services needed in the programme, such as supply of nuclear and non-nuclear equipment and trainings, different industries may all be involved in the programme's phases. Their involvement may be in form of insights or materials and services required to construct or support implementation. To uphold good quality of the programmes, industrial organizations involved in supplying equipment and services should comply with the relevant codes and standards (IAEA, 2012b). To meet these requirements, the Government of Kenya has already developed a comprehensive communication strategy and is implementing a broad public education programme with informational, educational and communication materials having been developed and distributed to the public. A database assessing the capabilities of local industries to participate in the nuclear power programme has been developed (NuPEA, 2020). Public participation is a fundamental constitutional principle supported by the provisions of Articles 1,10, 35, 118, 119, 124, 201, 221 and 232 of the Constitution of Kenya (Government of Kenya, 2010). Inefficient stakeholder support and engagement has also been identified as a weakness under the Strengths, Weakness, Opportunities and Threats (SWOT) analysis in NuPEA's strategic plan, highlighting gaps in meeting the prerequisite. Poland's energy policy recognizes the vital and active role stakeholders play in its implementation, more importantly, enterprises and households as they are the main stakeholders. Additionally, the Polish Nuclear Power Programme strategic government document incorporates stakeholder and industrial involvement among its planned activities. Rao's (2011) study explored the development of nuclear materials for the Indian nuclear power programme and supported the narrative of stakeholder involvement by advocating for more collaboration among and with the different groups of stakeholders to improve the programme's implementation.

Table 5.4: Analysis summary of pillar 4 - Human resource development, stakeholder involvement and industrial involvement

Nuclear infrastructure issues (prerequisites)	Indicators	Status: How Kenya has met the prerequisites	How other countries have met the prerequisites
Human Resource Development	Relevant expertise, experience and skills considering international best practises Specialized trainings and a good safety and nuclear security culture	Human Resource Development Strategy already developed by Government of Kenya Training on nuclear power plant technology being offered Needed knowledge and skills have already been identified Human resource database has been developed Professional bodies ensure professionalism is upheld; such as the Engineers Board of Kenya	Japan: Nuclear Human Resource Development Strategy Planning Council Report (2010) establishes a network of nuclear organizations from government, academia and industry working together to build human capacity for nuclear energy
Stakeholder Involvement	Involvement of both internal and external stakeholders Public participation through open and honest dialogue	A comprehensive Communication Strategy developed by Government of Kenya Broad public education programme being implemented Public participation being a constitutional principle	Poland: Polish Nuclear Power Programme strategic government document incorporates stakeholder involvement among its planned activities
Industrial Involvement	Industrial organizations involved should comply with the relevant codes and standards	Government of Kenya has developed a database to assess the capabilities of local industries to participate in the programme	Poland: Polish Nuclear Power Programme strategic government document incorporates stakeholder and industrial involvement among its planned activities

Source: Author's compilation

5.1.5 Electrical grid and site and supporting facilities

Electric grid issues are mostly prominent under nuclear power applications. Adequate grid size and reliability are obligatory for the connection of nuclear power to an electrical grid. Therefore, assessment of these two qualities is required before implementation of a nuclear power programme (IAEA, 2007). The agency further

recommends that a single NPP should not constitute more that 5 to 10 per cent of the electric grid, and that the grid be bigger than 10GWe or have international grid connections. To this regard, an electric grid study has been conducted to identify the grid's ability to support NPPs (NuPEA, 2020). Also, the country's electric grid already has connections with neighbouring countries and is part of regional energy pools such as the Easter Africa Energy Pool. However, Kenya's power supply system, which includes the electric grid, still needs advancement as shown by indicators in the Energy and Petroleum Regulatory Authority's (EPRA) Statistics Report 2022 (EPRA, 2023). The reliability indicators are the System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI). CAIDI is the ratio of sum of interruption durations and total customers, and SAIFI is the ratio between the number of customer interruptions and total customers. During the period between June 2021 and July 2022, the average SAIFI and CAIDI were 3.1 and 2.76, respectively. These numbers are higher when compared to the international best practices of 1.0 for SAIFI and 2.5 for CAIDI. These indicators show that the grid's reliability is yet to reach an optimal level, and there is need for improvement. Therefore, poor quality and inadequate size and reliability are among potential gaps for electric grid issue. Jewell (2011) categorizes the Kenya's electric grid size as low and unlikely suitable for NPPs. The Energy Act of 2019 empowers various organizations with functions connected to the nation's grid, such as the Kenya Power and Lighting Company, Kenya Electricity Transmission Company (Ketraco) and EPRA. Continued investments, upgrades and developments can enhance Kenya electric grid to be more optimal. The fast-tracking of key projects, such as further adoption of e-mobility and the Konza Technopolis, can also upscale electricity demand to be met by the additional nuclear power. Russia's Energy Strategy on Russia for the period up to 2030 (Russia, 2010) also recognizes grid challenges, such as grid absence and inefficiencies and aims to develop, expand and modernize the country's grid network to make it more efficient to relay electricity from sources such as nuclear energy.

Site surveys to determine site suitability and availability should be carried out when identifying potential sites for implementation of the nuclear programme. Public acceptance and costs are some indicators that are affected by site selection. National and cultural considerations, and nuclear safety and security considerations and supporting facilities also take precedence during site selection and evaluations. Support and security zones, post-irradiation analysis, interim spent fuel storage and waste management facilities are examples of facilities required for different nuclear programme applications (IAEA, 2012b). The criteria for siting nuclear installations has already been developed and the national Site Selection Team (SST) for nuclear installations established in Kenya. Also, feasibility studies, general survey, screening and ranking of potential nuclear plant sites have been completed (NuPEA, 2020). Public opposition, hiked costs and wayleave acquisition are the challenges in the development of energy infrastructure in Kenya and may complicate meeting this prerequisite. The stalling of the Kinangop wind project and Lamu coal were due to unresolved land issues and public opposition respectively, serving as examples (Eberhard et al., 2016). Considerations on the same ought to be done during the site identification

and selection processes. South Korea engaged in multiple feedback and review processes, with both domestic and international experts and stakeholders, in the site selection process of its NPP (Choi et al., 2009). This simplified the process of addressing the site and support facilities prerequisite. The IAEA has also standards on site surveys and site selection for nuclear installations used in countries such as Egypt (IAEA, 2015).

Table 5.5: Analysis summary of pillar 5 - Electrical grid and site and supporting facilities

Nuclear infrastructure issues (prerequisites)	Indicators	Status: How Kenya has met the prerequisites	How other countries have met the prerequisites
Electric Grid	• Adequate grid size and reliability	• Electric grid study has been undertaken	• Russia: Energy Strategy on Russia for the period up to 2030 (Russia, 2010) aims to develop, expand and modernize the country's grid network
Site and Supporting Facilities	• Site surveys • National and cultural considerations and nuclear safety and security considerations	• Siting nuclear installations criteria developed • National Site Selection Team (SST) for nuclear installations established • Surveys, screening and ranking of potential nuclear plant sites completed	• The IAEA standards on site surveys used by IAEA member countries

Source: Author's compilation

5.1.6 Legal and regulatory frameworks

All organizations necessary for successful implementation of the nuclear power programme and their responsibilities should be established under the nation's legal framework. Extensive cover of all nuclear law aspects (i.e nuclear security, safeguards, safety and civil liability for nuclear damage) and implementation of international legal instruments also ought to be covered by the framework. Based on experience, it is recommended that the regulatory and enabling bodies and functions be separate and this is enacted through legislation (IAEA, 2007). Kenya has met this prerequisite by having various bodies for separately enabling and regulating aspects of the nuclear programme: NuPEA and KNRA. The Energy

Act of 2019 (Government of Kenya, 2019) supports the nuclear programme as it establishes NuPEA as the nuclear energy programme implementing organization, mandated to carry out research, development and activities in the energy and nuclear power sector. On the other hand, the Kenya Nuclear Regulation Act of 2019 (Government of Kenya, 2019b) provides a comprehensive regulatory coverage on nuclear aspects: safety, security and peaceful utilization of nuclear technology and energy. Among the key government achievements under legal framework has been accession to inherent conventions nuclear non-proliferation and security that affect the framework (NuPEA, 2020). Gaps still exist under this prerequisite, with NuPEA's plan highlighting inadequate legal and regulatory frameworks for nuclear energy and change in legislations as challenges in its analysis. Kenya is yet to have agreements with its neighbouring countries on trans-bounder effects of nuclear disasters and is not yet a member of various conventions such as the Vienna Convention on Civil Liability for Nuclear Damage. South Africa has an extensive legal framework that has multiple laws covering all the nuclear aspects. The National Nuclear Regulator (NNR) Act 1of 1999, the Nuclear Energy Act 1999, and the National Radioactive Waste Disposal Institute Act of 2008 are examples of these laws.

Existence of an independent and competent regulatory body or bodies, with adequate independence, authority, independence and resources such as finances and competent staff, is essential for long term success for nuclear programme implementation. The regulatory framework should efficiently accommodate various sizes of aspects of the nuclear power programme, such as nuclear power plants and research reactors of different capacities or sizes and be consistent and compatible with existing laws and regulations (IAEA, 2012b). The KNRA is Kenya's nuclear regulatory body, established by the Nuclear Regulatory Act of 2019. Identification of imperative resource requirements and competences for nuclear regulation have already begun, with an Integrated Regulatory Review Service (IRRS) being conducted (NuPEA, 2020). With the nuclear sector being young in Kenya and the region, lack of relevant experience and expertise is a barrier in the development and implementation of legal and regulatory frameworks. Capacity building on new legislations and collaborations with institutions and countries for enactment of laws and regulations and trainings can strengthen the legal and regulatory frameworks. The country may also be having gaps in regulatory guides, codes and standards as is the case in Bangladesh (Islam et al., 2021). China has various regulations in its nuclear industry, such as the Regulation on the Management of Nuclear Material (1987) and Regulation on the Control of Nuclear Material (1990). It also has the National Nuclear Safety Administration (NNSA) that is the regulatory body under the China Atomic Energy Authority (CAEA). India also has a detailed regulatory framework whose implementation is spearheaded by the Atomic Energy Regulatory Board (AERB). AERB prescribes and enforces rules, regulations and requirements dealing with the safety of nuclear and radiation facilities and radiological safety (Kumar et al., 2017).

Table 5.6: Analysis summary of pillar 6 - Legal and regulatory frameworks

Nuclear infrastructure issues (prerequisites)	Indicators	Status: How Kenya has met the prerequisites	How other countries have met the prerequisites
Legal Framework	• Establishes all necessary organizations and their responsibilities • Extensively covers all aspects of nuclear law and implementation of international legal instruments • Have separate bodies for regulating and enabling the nuclear power programme • Adherence to all relevant international legal instruments planned	• Existence of separate bodies regulating and enabling the nuclear power programme: NuPEA and KNRA • Presence of comprehensive framework: Kenya Nuclear Regulation Act of 2019 • Government accession to inherent conventions nuclear non-proliferation and security	• South Africa: has an extensive legal framework covering all aspects of nuclear law. Examples include Nuclear Energy Act 1999, and the National Radioactive Waste Disposal Institute Act of 2008
Regulatory Framework	• Existence of an independent and competent regulatory body or bodies, with adequate independence, authority, independence, finances and competent staff • Ability to accommodate various sizes of aspects of the nuclear power programme • Consistent and compatible with existing laws	• Existence of regulatory body: KNRA • Resource requirements and competencies identified • An Integrated Regulatory Review Service (IRRS) being conducted	• China: extensive regulatory framework. Examples include Management of Nuclear Material (1987) and Regulation on the Control of Nuclear Material (1990). National Nuclear Safety Administration (NNSA) - regulatory body • India: Atomic Energy Regulatory Board (AERB)- regulatory body

Source: Author's compilation

5.1.7 Environmental protection, radioactive waste management and nuclear fuel cycle

Under environmental protection, the indicators include land use, water use and quality, release of gaseous and liquid radioactive effluents and other environmental impact considerations. Environmental protection can also be part of radioactive waste management that seeks to find and apply safe, practicable and environmental acceptable solutions for handing and disposing radioactive waste (IAEA, 2012b). In Kenya, the initial baseline environmental information has been collected and analyzed. Additionally, capacity building on Environmental Impact Assessment and Strategic Environmental Assessment (SEA) have been conducted. As for radioactive waste management, a national policy and strategy on radioactive waste management has been developed and suitable waste management options evaluated (NuPEA, 2020). There are also other existing polices, laws and regulations that promote environmental protection (Appendix 7). The Sessional Paper No. 6 of 1999 on Environment and Development emphasizes on sustainability and integrates environmental aspects in the national development planning (Government of Kenya, 1999a), that includes developing NPPs. Environmental management and conservation is also supported by the Environmental Management and Coordination Act of 1999 (Government of Kenya, 1999b) that establishes various principles, administrative bodies such as the National Environmental Management Authority (NEMA) and caters for environmental audits, monitoring and impact assessments. The completion of phase I of the Central Radioactive Waste Processing Facility (CRWPF) in Oloolua Forest, Ngong has been motioned in the MoEP strategic plan. Kenya's Constitution (Government of Kenya, 2010) also caters for environmental protection, with Article 42 and Article 70 offering guarantee to every Kenyan the right to a clean and healthy environment. Musyoka and Field (2018) note that environmental impact assessment for NPPs is done by the nuclear regulatory body in the USA and Canada, whereas in Sweden, authorization is gotten from the Radiation Safety Authority and an environmental court. Accidental release of radioactive effluents and mismanagement of radioactive waste are potential challenges for environmental protection and waste management. Other countries such as Belarus and the UAE have environmental monitoring laboratories that help with radiation monitoring, sampling and testing. Studies show that about 5,000 thyroid cancer cases may have been caused by the radioactive material released from the Chernobyl accident (WNA, 2023). Therefore, Kenya can further improve on how it meets the environmental protection prerequisite to protect the environment and its people. South Africa has the Radioactive Waste Management Policy and Strategy (2005) that provides guidelines and principles relating to radioactive waste management for purposes of ensuring safety. Environmental protection is also covered in its Nuclear Energy Policy (2008).

Nuclear fuel is a key resource for nuclear implementation and applications. Fuel management strategy and commitment to use low enriched uranium are among the indicators for the nuclear fuel cycle issue (IAEA, 2012b). So far, the Nuclear Fuel Cycle Policy and Strategy have been developed, and an evaluation of Nuclear Energy System Options conducted by the Government of Kenya. The government

has also undertaken the assessment of user requirements and reactor technology and the suitable fuel cycle options for Kenya's Nuclear Power Programme (NuPEA, 2020). The country is yet to start using nuclear fuel and has not settled on the nuclear fuel cycle to be used. South Africa's nuclear energy policy of 2008 looks into the different aspects in the nuclear fuel cycle, including but not limited to: uranium (mining, milling, conversion and enrichment), fuel fabrication, used fuel management and reprocessing. Bangladesh has a state-owned waste management company that handles radioactive waste and nuclear fuel. South Korea also has a radioactive waste management agency established by the Radioactive Waste Management Act. Japan has a closed nuclear fuel cycle policy that prioritizes the recycling of spent nuclear fuel to reduce the dependence on imported fuel and radioactive waste that needs to be disposed of. This entails the reprocessing and partial reuse of spent nuclear fuel. More specifically, the county has been recycling plutonium since the nuclear programme's commencement in 1956. Among the lessons learnt from the implementation of South Korea's nuclear power programme, Choi et al. (2009) recommended countries to factor in considerations of the long institutional control period required for spent nuclear fuels, the process of public discussions and legislative framework and start their implementation during phase 1. Appendix 8 further showcases how the USA and South Africa have met the prerequisites when implementing their nuclear power programmes, and the relevant policies and benefits gained from the programmes' implementation. Job creation, economic growth and additional supply of cheaper electricity are among the benefits.

Table 5.7: Analysis summary of pillar 7- Environmental protection, radioactive waste management and nuclear fuel cycle

Nuclear infrastructure issues (prerequisites)	Indicators	Status: How Kenya has met the prerequisites	How other countries have met the prerequisites
Environmental Protection	Considerations on land use, water use and quality, release of gaseous and liquid radioactive effluents and other environmental impacts	The initial baseline environmental information has been collected and analyzed Capacity building on Environmental Impact Assessment and Strategic Environmental Assessment (SEA) conducted Existence of supportive laws, regulations and policies and bodies	South Africa: Nuclear Energy Policy (2008) covers environmental protection

Radioactive Waste Management	Application of safe, practicable and environmental acceptable solutions for waste management	A national policy and strategy on radioactive waste management developed Suitable radioactive waste management options evaluated Phase I of the Central Radioactive Waste Processing Facility (CRWPF) in Oloolua Forest, Ngong was completed	South Africa: Radioactive Waste Management Policy and Strategy (2005) has guidelines and principles on radioactive waste management
Nuclear Fuel Cycle	Efficient fuel management strategy Commitment to use of low enriched uranium	Assessments of User Requirements and Reactor Technology and the suitable fuel cycle options for Kenya's Nuclear Power Programme undertaken Nuclear Fuel Cycle Policy and Strategy developed Evaluation of Nuclear Energy System Options conducted	South Africa: Nuclear Energy Policy (2008) covers the nuclear fuel cycle South Korea: Radioactive Waste Management Act established the body that deals with nuclear fuel management

Source: Author's compilation

6. Conclusions and Policy Recommendations

6.1 Conclusions

There are multiple benefits to be gained from implementation of the nuclear power programme, including: cheaper and stable electricity, boosted energy security, increased sustainable energy supply, more employment opportunities, economic development and the associated application benefits in cases where research reactors are part of the programme. Findings from this study show that Kenya is well on track in implementing the nuclear power programme, having significantly progressed in meeting all the prerequisites (19 infrastructure issues) in the IAEA Milestone approach adopted.

6.1.1 National position and management

The national position prerequisite is vital in implementing the nuclear power programme and has been adequately met by Kenya as its indicators - a nuclear energy policy and strategy - already exist in the country. Additionally, the nuclear power programme is incorporated in the Kenya Vision 2030 and its implementation is financially supported through government budgetary allocations.

To build solid management capability, Kenya is receiving external support from organizations such as the IAEA and countries such as Russia and South Korea and has a policy on management of the nuclear programme. Also, the lead implementing agency (NuPEA) carries out regular competencies for leadership and management. These initiatives help Kenya meet the prerequisite's main indicators - external support and competent leadership. However, the INIR mission further recommended the development of a nuclear leadership programme in Kenya.

6.1.2 Emergency planning, safeguards, radiation protection, nuclear security and nuclear safety

The country has already evaluated the national emergency and response capability and has supporting policies in place, such as the National Disaster Risk Management Policy of 2017, to meet the emergency planning prerequisite. However, lessons from other countries show that the country can further develop specific legislation, regulations and procedures on emergency management for nuclear accidents to promote its emergency planning.

Much progress has been made to meet the safeguards prerequisite, with the government already undertaking a comparative review of safeguards, signing and ratifying treaties that promote safeguards. Similarly, lessons from other countries show that more can be done to better meet this prerequisite. More particularly is to have more specific laws and regulations aimed at improving safeguards.

Supporting laws, regulations, monitoring programmes and supporting infrastructure are indicators for both nuclear security and radiation protection prerequisites that need to be fulfilled for a country to successfully implement

a nuclear power programme. Kenya sufficiently meets these prerequisites. For nuclear security, the Nuclear Regulatory Act of 2019 has provisions for nuclear security, nuclear safety and security policy. The Government of Kenya has also acceded to several international instruments, adopted the UN security resolutions, and evaluated the status of nuclear security infrastructure. The Act also supports the efforts to achieve the radiation protection prerequisite as it enhances measures for radiation protection. Further development and adoption of specific laws and regulations, covering areas such as control and prohibition of radioactive materials, and use of advance physical infrastructure can help Kenya better meet the radiation protection prerequisite.

To strengthen nuclear safety, Kenya has taken multiple steps such as conducting a risk assessment, identifying mitigation measures, signing various bilateral agreements, acceding to key nuclear safety conventions and having various laws, regulations and bodies supporting compliance of standards. The INIR mission also recommended for Kenya to ratify more international conventions in nuclear safety.

6.1.3 Funding and financing and procurement

The Government of Kenya has taken many actions to meet the funding and financing prerequisites. Under the funding and financing prerequisite, one gap found is that specific funding mechanisms or models to cover the operational costs of running the nuclear applications, such as NPPs or NRRs, are yet to be identified. Lack of efficient funding mechanisms may lead to early decommission of nuclear applications, especially for non-commercial nuclear applications such as NRRs that have a higher probability as they are not profit making. The findings also show that more can be done to promote technology transfer and localization under the procurement prerequisite.

6.1.4 Human resource development, stakeholder involvement and industrial involvement

To develop and have relevant expertise, experience and skills considering international best practises, the Government of Kenya has developed a human resource development strategy, human resource database, and offers training on nuclear power plant technology and has identified the needed knowledge and skills. These and more actions assist in the development of human resources in the country. Other countries such as Japan and South Korea have established networks that work together to build human capacity for nuclear energy in the specific country. This can also be adopted in Kenya.

The involvement of stakeholders and industrial players in implementing the nuclear programme is critical to its success. To this end, Kenya has made remarkable progress to involve stakeholders and industrial players in the nuclear programme's implementation process. Public education campaigns, development of a database assessing the capabilities of local industries to participate in the

programme and a comprehensive communication strategy are among the actions taken by the Government to meet the stakeholders and industrial involvement prerequisites. Public opposition to nuclear programmes remains a challenge in the implementation of nuclear programmes and therefore Kenya should continue to have more all-inclusive stakeholder and industrial involvements.

6.1.5 Electrical grid and site and supporting facilities

A reliable electric grid with an adequate grid size is needed for efficient uptake of the nuclear power generated. The Government of Kenya has undertaken an electric grid study as one of its initial steps in meeting this prerequisite. However, grid reliability indicators from the EPRA reports show the need for improvement on the grid.

Site surveys ought to be done and national, nuclear safety and security considerations should be considered while selecting the site for the NPP and its supporting facilities. To meet the site and supporting facilities prerequisite, Kenya has already completed surveys, screening and ranking of potential nuclear plant sites, developed siting nuclear installations criteria and established a national Site Selection Team (SST) for nuclear installations. Some potential challenges are opposition from locals and wayleave acquisition, which have led to the stalling of some key energy infrastructural projects such as the Lamu coal plant.

6.1.6 Legal and regulatory frameworks

Kenya has majorly progressed in meeting the legal and regulatory frameworks prerequisites. Several policies, laws and regulations have been developed to facilitate the implementation of the nuclear power programme. They have led to the establishment of separate bodies to regulate and enable the nuclear power programme. The country has also identified resource requirements and competencies and acceded to inherent conventions nuclear non-proliferation and security. However, further development of these framework is needed for them to cover all aspects of nuclear law and implementation of international legal instruments and accommodate various sizes of aspects of the nuclear power programme.

6.1.7 Environmental protection, radioactive waste management and nuclear fuel cycle

These prerequisites have been adequately met by Kenya. Lessons from other countries show that Kenya can establish more specific and qualified bodies, such as nuclear regulatory bodies, and nuclear fuel and radioactive waste agencies, to further enhance how Kenya meets these prerequisites.

6.2 Recommendations

As Kenya continues to implement the nuclear power programme, the following recommendations can help the country to better meet the prerequisites and reap the programme's benefits:

- For the management prerequisite, the government could fast-track the implementation of the Integrated Nuclear Infrastructure Review (INIR) mission's recommendation to develop a nuclear leadership programme that will promote competent management through good leadership, transparency and openness.
- For the emergency planning prerequisite to be adequately addressed, the government and other stakeholders could further develop policies, legislation and regulations that expound on emergency management for nuclear accidents, responsible departments, functions of emergency organizations, onsite and off-site nuclear emergency plans, emergency categories and national nuclear emergency plans and provide mechanisms for nuclear emergency response planning and coordination, emergency preparedness and preventive and remedial measures.
- Further development of more specific laws and regulations, covering areas such as control and prohibition of radioactive materials and radiation protection arrangements and jurisdictions, and advancement of physical infrastructure, such as laboratories and equipment to assess radiation exposures, by the government and other relevant stakeholders, can improve the county's status in addressing the radiation protection prerequisite.
- Kenya could ratify more international conventions in nuclear safety as suggested by the INIR. This will boost safety in all aspects of a nuclear power programme and strengthen the commitment to safety from all relevant stakeholders such as government, regulatory bodies and nuclear technology suppliers. In the long run, this will improve the nation's approach in meeting the nuclear safety prerequisite.
- There is need for the government to identify effective funding and financing mechanisms, especially for non-commercial aspects of the nuclear power programme such as research reactors to enable long-term continued operations of the programme's aspects and better meet the funding and financing prerequisite. This can be done through strengthening of interlinkages and partnerships with other countries, organizations, institutions and sectors such as education, agriculture and health, that could mutually benefit from implementation of these aspects, innovative models such as joint ownership and financial incentives that may boost funding and financing.
- To further advance meeting of the procurement prerequisite, more specific nuclear procurement standards and steps should be developed and adopted by the government to guarantee quality, value for money spent, nuclear safety and security, while focusing on technology transfer and promoting localization.

- To better meet the electric grid prerequisite, continued efforts by the government to invest, upgrade and expand the electricity grid are encouraged to improve the electric grid's performance to optimal levels needed for feeding nuclear power into the national grid.
- The legal framework prerequisite can be better addressed by the government fast-tracking the development of extensive nuclear legal and regulatory frameworks needed to sufficiently cover and address all aspects and issues of a nuclear power plant and nuclear infrastructure issues such as radiation protection, radioactive waste management, emergency planning, nuclear security and safety, and strengthening implementing institutions such as NuPEA. This can be done through learning from aspirator countries, using guidelines from established nuclear energy bodies such as the IAEA and building local human, technical and financial capacity to support the programmes.
- To sufficiently tackle the sites and supporting facilities prerequisite, the government could put in place better compensation methodologies to deal with land issues and have more inclusive stakeholder engagements with the public to take in public views and reduce the likelihood of public opposition and stalling of the programme's implementation.
- To enhance the way Kenya meets the human resource development prerequisite, more capacity building, collaborations and partnerships can be utilized by the government to further develop and retain human resources. Nuclear networks comprising of different experienced professionals, both locally and internationally based, can also be established to nurture and share nuclear power knowledge, as is the case in Japan and South Korea.
- Addressing the environmental protection prerequisite can be further enhanced by the government assigning specific qualified bodies, such as the nuclear regulatory bodies, with the responsibility of carrying out the environmental impact assessment for NPPs, and development of additional nuclear infrastructure, such as environmental monitoring laboratories, to help with radiation monitoring, sampling, testing and environmental protection.

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Appendix

Appendix 1: National position and management- Policy review

Nuclear infrastructure issues (prerequisites)	Indicators	Relevant policies- Kenya	Examples of relevant policies - Other countries
National Position	Bold nation position Strong national support	Energy Act of 2019 that established NuPEA Nuclear Regulatory Act of 2019 that established KNRA Kenya's Vision 2030, LCPDP and the 15-year nuclear strategic plan	Polish Nuclear Power Programme (Poland, 2020) Energy Policy on Poland until 2040 (Poland, 2021)
Management	Competent management: good leadership, transparency and openness External support	Public Service Act of 2015 Leadership and Integrity Act of 2012	Nuclear Energy Policy for the Republic on South Africa (South Africa, 2008)

Appendix 2: Emergency planning, safeguards, radiation protection, nuclear security and nuclear safety - Policy review

Nuclear infrastructure issues (prerequisites)	Indicators	Relevant policies- Kenya	Examples of relevant policies - Other countries
Emergency Planning	Arrangements for preparedness and response to radiation or nuclear incidences made by government	Nuclear Regulation Act of 2019 National Disaster Risk Management Policy of 2017	Regulation on Emergency Measures for Nuclear Accidents at Nuclear Power Plants (PRC, 1993)
Safeguards	Government to have supporting infrastructure in place A clear understanding and commitment to its safeguards by government	Non-Proliferation Treaty and African Nuclear Weapon Free Zone Treaty that have safeguards	Nuclear Safety Law (PRC, 2018) Regulation on the Safety Supervision and Administration of Civil Nuclear Facilities (PRC, 2005) Safeguards Agreement of 1991 (South Africa)

Nuclear Security	Government to have infrastructure in place Security culture and technical competence Contingency planning Compliance with international standards	Nuclear Regulatory Act of 2019 has provisions for nuclear security Government of Kenya acceded to several international instruments	National Security Law of the People's Republic of China (PRC, 2015) Non-Proliferation of Weapons of Mass Destruction (WMD) Act 87 (South Africa,1993)
Radiation Protection	Relevant and supporting laws, regulations and programmes Government to have infrastructure and programmes in place	Nuclear Regulation Act of 2019 enhances measures for radiation protection	Hazardous Substances Act (South Africa, 1973)
Nuclear Safety	Presence reliant engineering safety systems Nuclear technology with specific requirements Legal and regulatory frameworks that enhance safety Compliance to safety principles and standards, such as the IAEA safety standards A good safety culture	Government of Kenya has signed various bilateral agreements and potentially acceding to key nuclear safety conventions Government of Kenya has various laws, regulations and bodies such as the Nuclear Regulatory Act of 2019 that established KNRA that supports nuclear safety Standards Act of 2012	National Construction Authority Act of 2011 Nuclear Safety Law (PRC, 2018) IAEA safety standards

Appendix 3: Funding and financing and procurement - Policy review

Nuclear infrastructure issues (prerequisites)	**Indicators**	**Kenya's related policies**	**Examples of relevant policies- Other countries**
Funding and Financing	Cost considerations on infrastructure and other related facilities, capital commitment depending on size of facilities, and lifecycle cost Strong funding mechanisms	Government of Kenya Budget statements Private Partnerships Act of 2013 Government incentives like tax reductions on certain products	Energy Act of 2005 (USA) Inflation Reduction Act of 2022 (USA)

Procurement	Special technical competencies Rigorous oversight	Public Procurement and Asset Disposal Act of 2015 Public Finance Management Act of 2012 Anti-Corruption and Economic Crimes Act No. 3 of 2003	Nuclear Energy Policy for the Republic on South Africa (South Africa, 2008) Procurement Engineering and Supply Chain Guidelines in Support of Operation and Maintenance of Nuclear Facilities (IAEA, 2016)

Appendix 4: Human resource development, stakeholder involvement and industrial involvement- Policy review

Nuclear Infrastructure Issues (prerequisites)	**Indicators**	**Kenya's related policies**	**Examples of relevant policies- Other countries**
Human Resource Development	Relevant expertise, experience and skills considering international best practises Specialized trainings and a good safety and nuclear security culture	Human Resource Development Strategy already developed by Government of Kenya Legislation establishing professional bodies such as the Engineers Act of 2011 and the Law Society of Kenya Act of 1992	Nuclear Energy Policy for the Republic on South Africa (South Africa, 2008) Nuclear Human Resource Development Strategy Planning Council Report (Japan, 2010)
Stakeholder Involvement	Involvement of both internal and external stakeholders	Public participation through open and honest dialogue A comprehensive Communication Strategy developed by Government of Kenya Constitution of Kenya, 2010	Energy Policy on Poland until 2040 (Poland, 2021) Polish Nuclear Power Programme (Poland, 2020)
Industrial Involvement	Industrial organizations involved should comply with the relevant codes and standards	Constitution of Kenya, 2010	Energy Policy on Poland until 2040 (Poland, 2021) Polish Nuclear Power Programme (Poland, 2020)

Appendix 5: Electrical grid and site and supporting facilities - Policy review

Nuclear infrastructure issues (prerequisites)	Indicators	Kenya's related policies	Examples of relevant policies - Other countries
Electric Grid	Adequate grid size and reliability	Energy Act of 2019 LCPCP (2021-2030)	Energy Strategy on Russia for the period up to 2030 (Russia, 2010)
Site and Supporting Facilities	Site surveys	Constitution of Kenya, 2010 Land Act of 2012 Physical and Land Use Planning Act of 2019	Site Survey and Site Selection for Nuclear Installations, IAEA Safety Standards Series No. SSG-35, IAEA, Vienna (2015)

Appendix 6: Legal and regulatory frameworks - Policy review

Nuclear infrastructure issues (prerequisites)	Indicators	Kenya's related policies	Examples of relevant policies- Other countries
Legal Framework	Establishes all necessary organisations and their responsibilities Extensively covers all aspects of nuclear law and implementation of international legal instruments Have separate bodies for regulating and enabling the nuclear power programme Adherence to all relevant international legal instruments planned	Nuclear Regulation Act of 2019 Energy Act of 2019 that establishes NuPEA Nuclear Energy Act (South Africa, 1999)	National Nuclear Regulatory Act (South Africa, 1999)

Regulatory Framework	Existence of an independent and competent regulatory body or bodies, with adequate independence, authority, independence, finances and competent staff Ability to accommodate various sizes of aspects of the nuclear power programme Consistent and compatible with existing laws and policies	Nuclear Regulation Act of 2019 that establishes KNRA	National Nuclear Regulatory Act (South Africa, 1999) Regulation on the Management of Nuclear Material (PRC, 1987) Regulation on the Control of Nuclear Material (PRC, 1990)

Appendix 7: Environmental protection, radioactive waste management and nuclear fuel cycle- Policy review

Nuclear infrastructure issues (prerequisites)	**Indicators**	**Kenya's related policies**	**Examples of relevant policies- Other countries**
Environmental Protection	Considerations on land use, water use and quality, release of gaseous and liquid radioactive effluents and other environmental impacts	Sessional paper No. 6 of 1999 Environmental Management and Coordination Act of 1999 Climate Change Act of 2016	Nuclear Energy Policy for the Republic on South Africa (South Africa, 2008)
Radioactive Waste Management	Application of safe, practicable and environmental acceptable solutions for waste management A national policy and strategy on radioactive waste management developed	Nuclear Regulation Act of 2019	Radioactive Waste Management Policy and Strategy (South Africa, 2005) National Radio -Active Waste Act 53 (South Africa, 2008)
Nuclear Fuel Cycle	Efficient fuel management strategy Commitment to use of low enriched uranium	Nuclear Fuel Cycle Policy and Strategy developed	Nuclear Energy Policy for the Republic on South Africa (South Africa, 2008) Radioactive waste management Act (South Korea)

Appendix 8: Case studies

USA (aspirator country)

The USA produces the most nuclear power in the world with a capacity of 98GW, accounting for about 18 per cent of the country's energy mix and 30 per cent of the global nuclear electricity generated. Since its inception in the 1960s, the country's nuclear sector has grown enormously. The country's nuclear regulatory body - Nuclear Regulatory Commission (NRC)- was established in 1974 is responsible for the nuclear industry's regulation, that includes NRRs, NPPs, nuclear waste and other materials. Following the Three Mile Island accident, the Institute of Nuclear Power Operations (INPO) was formed to establish performance standards and carry out plant inspections. The USA Energy Policy Act of 1992 allowed for the sectors deregulation, giving way to changes in plant ownership and better management. The Energy Policy Act of 2005 and the Inflation Reduction Act of 2022 were a boost to funding and financing, and they support existing and new nuclear development through investment and tax incentives. The country also has the Nuclear Power 2010 programme whose objectives include: to encourage utilities to take the initiative in licence application; and to encourage reactor vendors to undertake detailed engineering and arrive at reliable cost estimates (WNA, 2023c). These factors touch on nuclear safety, procurement, legal framework, national position and stakeholder engagement.

The USA has also faced growth challenges at different periods, including the period after the Three Mile Island incident. Studies have shown that 55 per cent of the country's carbon free electricity comes from nuclear power, equating to over 750 million tonnes of CO_2 emissions averted every year (WNA, 2023b). NPPs and other nuclear infrastructure also provide boost economies of communities and states within the US. The Nuclear Energy Institute estimates that over US$ 12 billion worth of Federal and State tax revenues is produced by the nuclear energy sector annually. The sector also directly employs approximately 100,000 people in high quality jobs and supports 475,000 secondary jobs (NIE, 2023).

South Africa (comparator country)

South Africa is among the few African countries that have implemented a nuclear power programme, and the only country in the region operating a NPP- the Koeberg Nuclear Power Plant. The 1800MW NPP was connected to the national grid in 1984 and produces the country's cheapest electricity, costing 44 cents per unit. Under the nuclear programme. The South African Nuclear Energy Corporation (NECSA), formed in 1999, oversees the nuclear programme. It was formally the Atomic Energy Corporation of South Africa. The National Nuclear Energy Executive Coordination Committee (NNEECC), established in 2011, is in-charge of nuclear energy expansion programme- decision-

making, monitoring, and general oversight. National position is also met by both the Integrated Resources Plan (IRP) of 2010 and 2018, that incorporate NPPs, showing that the expected to operate until 2045-2047 and growth in nuclear power to supply 23 per cent of the country's electricity. Russia has also offered financial assistance under an agreement signed in 2014 in increase nuclear capacity to 9.6GWe by 2030. Human Resource Development perquisite has met with the country's NRR and the 2014 agreement with China providing trainings to nuclear staff. For the sites and supporting facilities and environmental protection prerequisites, site identification and initial environmental impact assessments (EIA) were done in 2006 of three possible sites for the next nuclear power units (WNA, 2023d). The National Radioactive Waste Disposal Institute (NRWDI), established by the National Radioactive Waste Disposal Institute Act of 2008, is responsible for radioactive waste disposal in South Africa. Nuclear regulation is done by the National Nuclear Regulator (NNR) – previously the Council for Nuclear Safety and established by the National Nuclear Regulator Act of 1999.

South Africa also has a 20MW nuclear research reactor- the South African Fundamental Atomic Reactor Installation (SAFARI-1) - built in 1962. The reactor has many applications including research and development, education and training and irradiation and analytical services. Production of radioisotopes, like the Iodine-131 (I131) and molybdenum-99 (Mo99), used for medical applications (used with the country and exported), digital neutron radiography and neutron transmutation doping for silicon ingots are among the services offered at the reactor. The SAFARI-1 is considered as the African continent's main supplier of medical radioisotopes, having a potential of meeting up to 25 per cent of the world's Mo99 needs. NESCA, the group that oversees the running of SAFARI-1, achieved a 20 per cent market share expansion in the financial year 2020-21 and had a net profit of 32.39 million rand from the sale of nuclear medicine and industrial isotopes in the same year.

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