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Readiness of Nuclear Energy Development in Uganda

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

This study investigates readiness of nuclear energy development in Uganda. A developing nation like Uganda relies on about 87% renewable energy yet a lot of its power potential remains untapped. Uganda's energy potential of 41800MW exists abundantly of which 24000MW (57.4%) is nuclear energy potential, developing nuclear would be to explore its greatest potential. The growing global debate of the risks that accrue with the use of fossil fuels such as the existing state of climate change and the unprecedented global warming, many countries, Uganda inclusive, have realized the need to transition to de-carbonized economies.

This paper examines and discusses the potential of nuclear energy, considering it as a future energy from the perspective of sustainable development as it would emit less carbon dioxide compared to fossil fuels that also exist in plenty in the country. Comparative analysis with other countries are considered, Uganda's readiness for safe nuclear energy development is discussed.

The paper used a qualitative research methods where document, literature and archival information is analysed with complex data synthesised to give greater meaning.

The findings for Uganda's readiness are mainly embedded in the drivers as well as barriers to nuclear energy that not only affect Uganda but most sub Saharan Africa. Therefore Uganda needs to source for long term financing while assessing the geopolitical risk to develop nuclear power as a clean energy option.

Keywords: Nuclear energy; clean energy; drivers; barriers; Uganda.

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1. INTRODUCTION

Uganda has plenty of energy resources, with an energy potential of 41800MW, most of which is nuclear energy [1]. Uganda ought to focus on clean energy consumption to promote its sustainable development goals. There is a need for a smooth transition to clean, reliable and affordable energy sources for all as proposed in the sustainable development Goal (SDG 7). Electric utilities in Uganda, unlike those in, say, Kenya and Tanzania, have access to vast reserves of hydroelectric facilities as well as solar and bio-electric facilities. Uganda depends on 80% of its electricity is predominantly from hydro power and none from nuclear despite the fact that the rest of the world 8% of their electricity needs are from nuclear electricity [2]. Therefore, it is a wakeup call for Uganda to join the global community in devising clean energy solutions and that, nuclear energy development will promote its energy security goals over the long term [3].

The general objective of this paper is to assess the readiness of nuclear energy development in Uganda, but more specifically;

(i) To evaluate the nuclear energy potential for Uganda
(ii) To examine the drivers and barriers of nuclear energy development
(iii) To suggest strategies towards sustainable nuclear energy production

Global nuclear energy development has been adversely affected by COVID-19, with a decline of 4% while global energy demand grew by 4% in 2020. It is set to increase by 4.6% in 2021. Global electricity demand fell by 1% in 2020 and is set to grow by 100 TWh (4.5%) in 2021 [2]. By the end of 2020, nuclear energy generation was 441 reactors as shown in Fig. 1. The greatest global nuclear producers are USA, France, China and Russia. Nuclear energy generation capacity of 392GWe, this mitigated carbon dioxide (CO_2)emissions of about 2 billion tonnes, producing some 2553TWh of nuclear power with average capacity factor of 80.3% [4]. The period 2018-2020 had 26 nuclear reactors closed with a generation capacity of 20.8GWe while 20 others opened up with 21GWe.

Elsewhere in the world, U.S.A is leading with 96 nuclear reactors and contributing 20% to its energy mix, France with 58 nuclear reactors contributes 75% of its energy mix. China with 48 nuclear reactors, with most of the new reactors under construction. Japan has 37 while Russia has 36 reactors. Fig. 1 shows global nuclear reactors categorised according to regions.

Electricity supply capacity from nuclear reactors declining by 4% is unprecedented since the Fukushima accident of 2011 [5]. Major declines were in Japan 33%, European Union 11% and USA 2% while increases occurred in China 5%, Russia 3%.

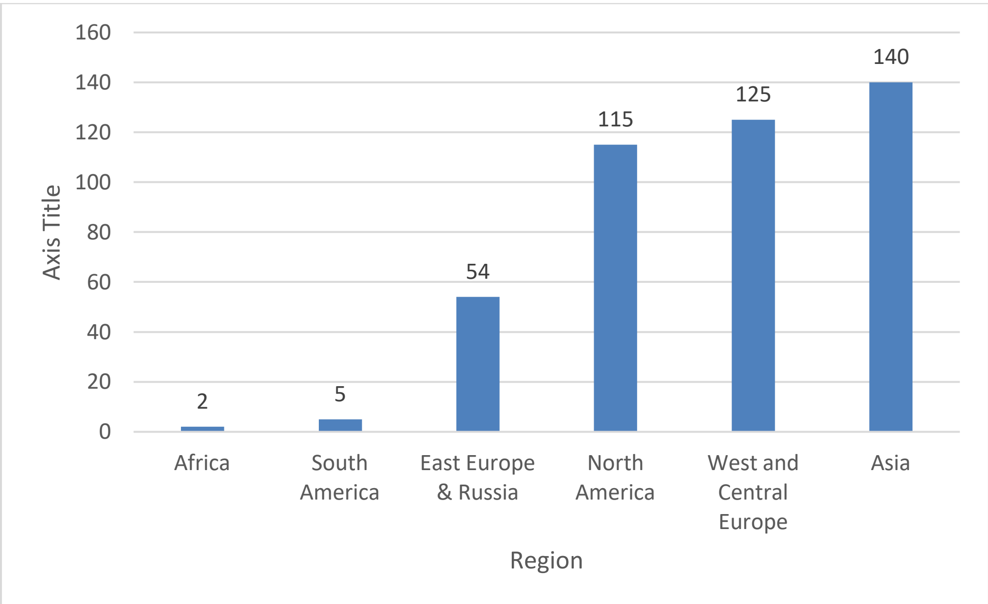

Fig. 1. Graph showing global nuclear reactors
Source: Adapted from [4]

Table 1. Present and future cumulative power generation in Uganda

Source of energy	Current installed capacity (MW)*	Percentage Current Vs overall generation (%)	Proposed potential capacity (MW), 2040**	(%)
Hydropower	1 010.8	79.7	4 500	10.8
Geothermal	0	0	1 500	3.6
Solar energy	60.8	4.7	5 000	12
Biomass energy	96.2	7.6	1 700	4.1
Peat energy	0	0	800	1.9
Nuclear	0	0	24 000	57.4
Thermal	101.1	8	4 300	10.3
Total	1 268.9	100	41 800	100

** [7] **[8]*

Overview of Nuclear energy development in Uganda

Following the international energy crisis of 1973, energy markets were plunged into a crisis, after 1974, energy demand doubled in most parts of the world. Countries started a search for newer energy sources. This was the motive that led to the first summit meeting of G7 (then G6) in 1975 [6]. The subsequent energy crises of 1978/79, Gulf crisis I (1990), Gulf crisis II (2000), 2009, and 2020 have threatened the Global economy in similar ways. To date, the leading nuclear consumers have diversified energy consumption for energy security and strategic reasons. Uganda's energy scenario is different, nuclear power potential is 24000MW, but preliminary findings indicate 50000 square kilometers of estimated uranium prospects around Buyende, Nakasongola, Mubende, Kiruhura, Buhweju plateau and Lamwo. The unit cost of developing 1 MW of Nuclear energy is U.S $6 Million. Government efforts are to build a 1000MW power plant in the medium term and 2000MW in the long run. Government of Uganda (GoU) plans to invest in energy infrastructure and raise generation capacity to 3500MW, it also seeks to increase per capita consumption from current 215 kWh to 674kWh over the medium term. It intends to construct large hydro power of 1800MW, mini-hydro of 150MW, thermal plants of 700MW, solar thermal of 150MW, geothermal of 150MW and 1000MW of nuclear energy. Uganda's nuclear potential is a reality that the political economy of the day must answer, however, Uganda has not made significant capital investment into the nuclear power sector and neither does it have a nuclear electrification master plan [3].

As shown in Table 1 nuclear energy dominates with 57.4%, there is a growing interest in developing nuclear energy not only in Uganda but also on the African continent as a whole.

Nuclear energy is a clean energy option that helps to mitigate carbon dioxide emissions as in line with Sustainable Development Goal (SDG) 7 which advocates for access to affordable clean energy for all. Nuclear electricity has avoided 72billion tonnes of CO2 since 1970 globally. This can salvage Uganda's energy situation where consumption is dominated by traditional biomass which brings both health and environmental hazards [1]. Most notable concerns include indoor air pollution (IAP) and deforestation that directly affect livelihood educational and health outcomes of household [9]. The development of nuclear electricity, there would be dividends of electrification that communities would forge a sustainable livelihood framework an overall aim of attaining sustainable growth and development.

The rest of the paper is made of section two empirical framework, section three is methods while section four is results and discussion while section five makes a comparison with other countries, section six interrogates whether Uganda is ready for safe nuclear energy development and final section makes conclusions and policy recommendations.

2. EMPIRICAL FRAMEWORK

[10] analysed drivers as security of energy supply, diminishing energy supply capacity, energy prices and climate change, while barriers included economics, public perception and policy changes, waste management policy and changes to the planning system as shown in Table 2. [11] made a comparison of other renewable like biomass CHP, wind and solar, which they later contrasted with nuclear energy technology. [12], Interrogated drivers including environmentally friendly, energy prices, shortage of Electric power and efficient energy producer, while barriers include the complex nature of

Table 2. Relevant empirical studies

Author (year)	Title	Approach and key findings
[10] Greenhalgh and Azapagic	Drivers and barriers for nuclear power in the UK.	It analyses drivers are security of energy supply, diminishing energy supply capacity, energy prices and climate change, while barriers included economics, public perception and policy changes, waste management policy and changes to the planning system
[11] Karakosta et al.	Renewable energy and nuclear power towards sustainable development: Characteristics and prospects	Drivers include increasing electricity demand, high prices of fossil fuels, low electricity generation costs, low sensitivity to fuel costs, reliable energy source while barriers include safety issues, waste disposal, proliferation, financial risks and social acceptance and adoption barriers
[12] Karim et al.,	Nuclear Energy Development in Bangladesh: A Study of Opportunities and Challenges	Examine drivers including environmental friendly, energy prices, shortage of Electric power and efficient energy producer, while barriers include the complex nature of nuclear technology, Health and safety issues, Lack of efficient human resource, management issues, nuclear waste treatment challenges, security and non-existent legal instruments
[13] Agyekum et al.,	Nuclear energy for sustainable development: SWOT analysis on Ghana's nuclear agenda.	Drivers included presence of uranium deposits, good legal and regulatory framework, skilled human resource, climate change while barriers include poor grid, poor culture of maintenance, dominance of fossil fuels, inadequate financing, porous security system, lack of investment will and corruption.

Source: Adapted from [1] Mutumba et al., (2021). Prospects and Challenges of Geothermal Energy in Uganda P.6

nuclear technology, health and safety issues, lack of efficient human resource, management issues, nuclear waste treatment challenges, security and non-existent legal instruments. Among the strategies recommended to overcome the bottlenecks included creating a robust legal and regulatory framework, improving home based nuclear technology, fast track efficient development of nuclear energy, cost minimisation of nuclear energy generation, switch to more efficient reactors and nuclear fuel cycle and conducting profile raising activities. [13] analysed sustainable use of nuclear power in Ghana by considering the SWOT analysis.

3. METHODS

Qualitative research methods were used [14]. It mainly involved looking at documents and empirical literature, Empirical literature was treated case by case in which meaning was made from data source [15]. Data from varying sourcesi was compared with different sources [16] Information from documents were observed from a number of sources to establish their validity and attain a higher level of truths.

3.1 Data Description, Literature searching, Compilation and Coding

The literature as shown in Table 2, has been obtained mainly through searching a number of sites mainly Google scholar, Scopus and some archival information from working papers in different research institutions and Universities. Data description on Google search was all content on 'Nuclear energy development: drivers and barriers', Mendeley general search made on 21st October, 2021 on Nuclear energy Barriers and drivers gave results of 125,000 of which 602 were from journals, 488 from conference proceedings, 500 from book section, 204 from generic and 48 from thesis, while Scopus search done in November 2021 brought 302 results for which 14 have been used for this study.

TITLE-ABS-KEY (Nuclear energy development: drivers and barriers'nexus) AN
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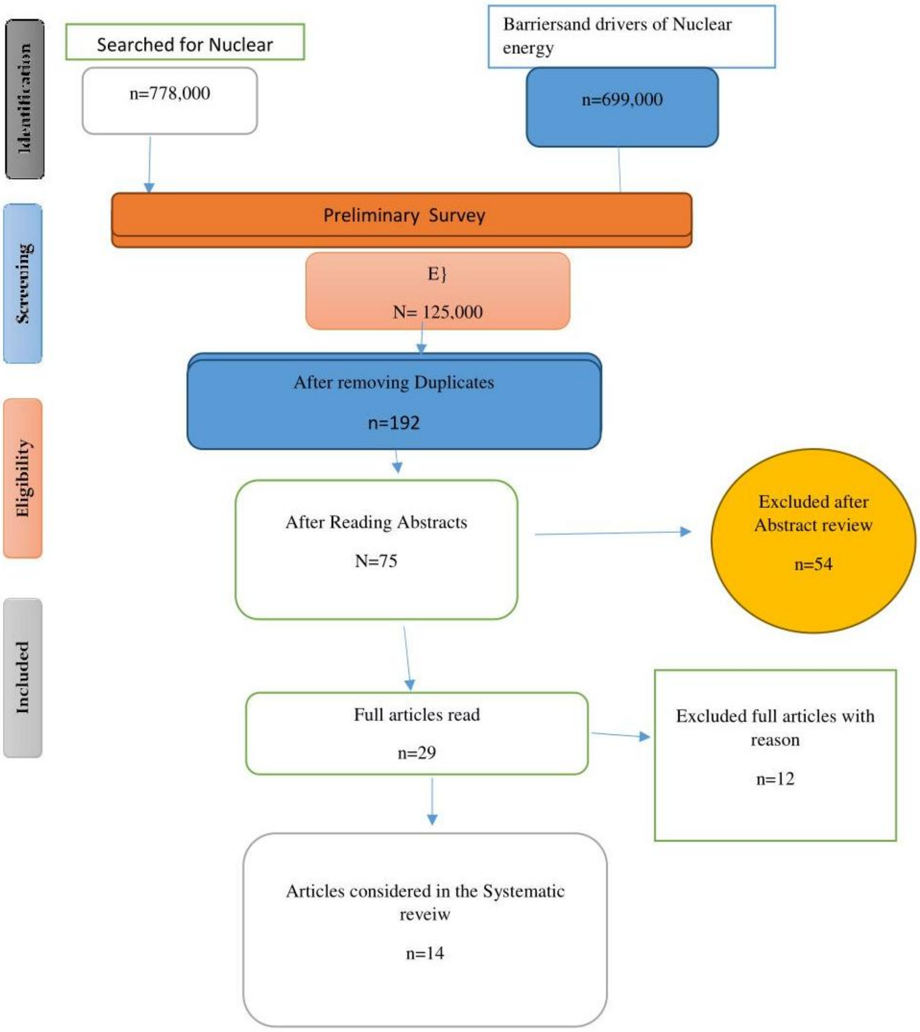

Fig. 2. A flow chart for the search and selection of observations

(causality OR cointegration) AND
(LIMIT-TO (SUBJAREA , "ECONOMICS")) AND
(LIMIT-TO (LANGUAGE , "English")) AND
(LIMIT-TO (SRCTYPE , "j"))

3.2 Inclusion Criteria

(i) This study has taken into consideration peer reviewed journal articles mainly available on open access due to the ease of access by the academic web based search engines.

4. RESULTS AND DISCUSSION

This paper addresses drivers and barriers of nuclear energy development as a way of advancing readiness to embrace this clean energy option. The drivers include the following:

4.1 Drivers of Nuclear Energy

In the face of growing energy needs arising from the rapidly growing population, there is need to find alternative clean, efficient, reliable and affordable sources of energy in Uganda which can meet this need. As such, nuclear energy has been considered a good fit that could cover this unprecedented energy demand as well as soothing socio-economic activities in the country. Consequently, the following sub-section presents the main drivers for development of this energy resource for various applications in Uganda.

4.1.1 Energy security and access

Security of fuel supply is an important issue and a forceful driver of nuclear energy development. With Uganda's energy per capita consumption being one of the lowest in the world, it must increase the supply of all its energy potential. Due to increasing population and economic activities, there has been a surge in electricity demand over time in Uganda in recent years. According to Ministry of energy and mineral development strategic development plan 2014/15 – 2018/2019, electricity demand has been growing at an average of 10% per year. This growth in demand has led to occasional load shedding arising from unmatched supply which did not increase proportionately with the increase in demand. Furthermore, about 79.6% of the population is still left out in terms of access to electricity, and it was noted that, the household sector has the lowest levels of electricity access in Uganda [17]. As such, with this enormous increase in demand for electricity and supply-side opportunity, the development of nuclear energy in Uganda could serve supplementary role as source of energy for premises with access to grid electricity and major source of electricity for premises without electricity access. Otherwise, households and businesses with unreliable supply and lack of electricity may tend to meet their growth in demand with the use of firewood and charcoal, which are unsustainable sources of energy as they pose a serious detriment to the environment. Therefore developing nuclear power would increase energy security and access.

4.1.2 Policy reforms, regulatory and institutional drivers

Uganda undertook a number of reforms to promote growth in the energy sector, including Electricity Act of 1999 which resulted into the formation of Uganda Electricity Generation Company Limited (UEGCL), Uganda Electricity Transmission Company Limited (UETCL) and Uganda Electricity Distribution Company Limited (UEDCL) replacing Uganda Electricity Board (UEB) which was a vertically integrated state owned enterprise. Uganda Electricity Generation Company Ltd (UEGCL) and Uganda Electricity Distribution Company Ltd (UEDCL) later leased their assets to Eskom (U) Ltd and UMEME Ltd respectively. In addition, in April 2001, the Electricity Regulatory Authority was also formed and given the responsibility of overseeing and regulating all the players in Uganda's electricity sector [18]. The electricity grid mostly covers the urban parts of the country, yet about 80% of the population lives in the rural areas. The rural electrification agency was thus formed in 2001 to ensure that rural electrification is improved from 1% in 2001 to 10% by 2012. In the meantime, The period between 2005 and 2019 were epitomised by greater challenges of electricity like continuous load shedding, high fuel costs, despite the completion of two major dams that is Bujagali hydro power (completed in June 2012) and Isimba (completed in March 2019). In 2002, the Government of Uganda approved the National Energy Policy (Power sub-sector reform). This reform was aimed at stimulating provision of sufficient, consistent, and cost-effective power supply in Uganda to meet the increasing energy demand, as well as promote efficient operations of the power sector with the aim of driving energy access. Additionally, the reform provided opportunities for private organizations, businesses and individuals to invest and contribute electrical power generation in the country. The reform paved way for the initiation of the Renewable Energy Policy of 2007, which drive the application and development renewable energy resources (such as nuclear, solar energy, geothermal and clean biomass energy products biodiesel, biogas and cogeneration power plant). Therefore, as a result of the energy reform and favourable other related regulations, there are now more opportunities for different players (from individual, small-scale to large-scale enterprise in both private and public) to invest in nuclear energy development in this country. The Atomic energy Act of 2008 was crafted for Uganda, with limited tangible results up to date. Draft energy bill (2019) is also being crafted, it is not clear whether this regulatory and institutional set up, the complex energy system in Uganda would foster sustainable livelihoods and sustainable development. With increasing liberalisation of the economy more private investors were now allowed to participate in supply of electricity at a small scale, this can drive nuclear power development.

4.1.3 Job creation

Promotion of nuclear energy technology across the country will contribute poverty reduction through natives benefiting from employment opportunities, skills acquisition and development, investment opportunities and technology transfer. Many clean energy pilot projects in developing countries give evidence of the role that clean energy sources can play in energy-poor communities. Therefore, increased investment in nuclear energy applications will lead to the development of indigenous expertise in repairs, installations and manufacture of the various devices and in particular the rural, where RESP project was particularly unsuccessful, off-grid communities thus leading to job generation [19]. The analysis shows that installing the entire 24000 MW capacity of would led lead to a creation of 10 jobs/MW for a nuclear cogeneration plant would create 240,000 jobs [20], in addition every nuclear reactor employs a total of 138 workers; where 24, 1GW plants are built would employ an additional 3312 [21]. This in total brings the total number of jobs to 243312 jobs, which is the greatest number of jobs that can be created in the energy sector by a single power source.

4.1.4 The desire to meet Uganda vision 2040

The planned Uganda Vision 2040 is an ambitious plan anticipated to increase in the country's electricity production from the 1268.9 MW (in 2021) to 41 800 MW (by 2040) and electricity consumption per capita to 3668 kWh/year [8]. The proposed distribution of installed capacity of power generation in Uganda in 2040 is shown in Table 1. As shown in this table, overall, renewable energy resources (hydropower, geothermal, solar, biomass and peat) are expected to contribute 13 500 MW to national grid in 2040. Furthermore, in can be deduced from the same table that, nuclear energy resource is expected to provide about 57% of the Uganda's installed power capacity by 2040 and 39.4% of renewable-based power capacity. To meet the government's target, therefore, there is great opportunity to investment and development nuclear energy resource.

4.1.5 Need for an efficient energy source

Uganda's power system has had an issue of quality its unreliable for both lighting as well as heating, nuclear would be a timely solution due to its high calorific value as shown in Table 3.

This would make nuclear a desirable high quality source of power to run industrial and commercial enterprises.

4.2 Barriers of Nuclear Energy

Government of Uganda (GOU) is passionately dedicated to offering a clean energy menu to all its citizens in efforts to improve their livelihoods and forge a sustainable livelihood framework (SLF). The leadership challenge is that they know just as much, about nuclear energy as its people. There are couple of issues that are limiting nuclear energy development. Some of these issues or barriers are carefully presented in the following sub-section.

4.2.1 Economic and financial barriers

The High initial capital costs of building a 1000MW nuclear power station in Uganda averaged almost U.S $6 billion (in 2020 dollars). Years of technological refinements and potential cost-saving measures being undertaken may succeed in significantly lowering that price tag in years to come. This makes nuclear power the single most expensive technology in Uganda. As if this is not bad enough, there is a shortage of long term financing and equity for Uganda's nuclear energy program. This is a critical barrier in developing Uganda's nuclear industry.

4.2.2 Socio cultural barriers

There is insufficient public awareness of nuclear power development. Worse still technical information is inadequate, data is insufficient to accurately assess the availability and true potential of nuclear energy (Massachusetts Institute of Technology, 2011). Public awareness of cost of provision of electricity and loss in productivity due to power outage or unavailability of power remains unknown. Uganda still faces some load shedding due to system failure and vandalism but on the whole load shedding has greatly reduced [21]. Therefore there is urgent need to make information more readily available through high quality research in nuclear power development.

4.2.3 Competition with other energy sources

When measured on a present-value basis, the capital-intensity of a nuclear plant means that two-thirds or more of its costs may be incurred up front, before it opens for business—and that is without factoring in interest payments accrued during the long construction ordeal. In most of the country base loads are handled predominantly by hydro-electricity, which is cheap and relatively more abundant. The persistence of this enormous overhead, averaging to U.S $6 000 per KWh, compared to hydro which is U.S $2600 per KWh and solar which is U.S $1100 per KWh makes it less attractive for new investments. For the most part, the edge over nuclear energy simply reflects market forces: a nation so richly endowed with this particular energy naturally would put it to extensive use.

Table 3. Different sources of power and their heat value

Type of Fuel Heat	Value (MJ/kg)	GHG g/CO2 emission/KWe
Firewood (CHP)	16	150-260
Fuel (MCFC) wood gas	0.25	50
Solar PV	46.63	18-34
Solar thermal	400	16
Offshore winds	24	8
Brown Coal	9	8887
Black Coal (low quality)	13-20	8960
Black Coal	24-30	8916
Natural Gas	39	
Crude Oil	18,845–4638	10180
Natural Uranium (in light water reactor)	500,000	5

Source: Adapted from [12] P. 5.

4.2.4 Nuclear and waste management Policy

Uganda that has no policy on nuclear energy is not expected to have a waste management policy on nuclear wastes. There is a danger of occurrence of nuclear accidents and the risks of proliferation [22]. Nuclear technology is very complex and demanding that requires specialized knowledge and excellence in human performance- a rare quality in the country. Superior safety need to be established and satisfied with sophisticated systems that are designed, constructed, maintained, operated in tandem with rigid and precise technical procedures. This remains a barrier to nuclear energy development. The existing energy policy frameworks are weak at implementation, therefore there is need to quickly and carefully draft a meaningful nuclear energy policy informed by evidence based policy making and research.

4.2.5 Technological and technical barriers

Another critical barrier to the development of nuclear energy development in Uganda is the absence of the enabling infrastructure (Grid unreliability) in form of transmission and distribution lines that can transmit Electricity to the remote places and because of this limitation, they resort to rudimentary technologies used in most of the rural places in Uganda are essentially small and very inefficient [23]. It has been argued that, building extension high-voltage transmission lines to these remote areas is inefficient and not cost effective [23]. Grid unreliability prevails as a limiting factor especially for large transmissions and this leaves most remote areas in Uganda without access to electricity. It is noted that some areas in Uganda are not yet connected to the national grid, where there is grid connectivity. It is fairly an old and out of date central grid makes nuclear energy suitable for rural communities. Government can also promote access for rural electrification through provision of nuclear energy will prove very successful in providing energy services to the remote and inaccessible areas of Uganda, such as on islands and mountainous areas, For instance, Kalangala District (Ssese Island) and the hills of Kigezi in Kabale, Kisoro, Bwera and other remote places where the national grid is likely not going to extend its services in the near future because of the associated costs of grid extension.

4.2.6 Inadequate attention to research and development

Presently, there is limited research effort by the government of Uganda in nuclear energy. The government has done little in encouraging innovations in the area of developing nuclear energy technologies, and to be precise there is no visible effort by the government to fund universities and other institutions of higher learning to conduct research on how to develop nuclear energy technologies [24]. Notably, there is no nuclear energy research and development program that is reinforced with government funding. There are clear working systems that could foster quality international research and some collaborations that can speed up skills and technological transfer. More so, the development of nuclear energy technologies has been limited by the laxity on the government of Uganda to provide an enabling supportive environment. As a consequence, the local technical knowledge regarding these products is insufficient and, hence, associated technologies are imported expensively. Nonetheless, with a local skilled and semi- skilled workforce, this suggests that scholars from multidisciplinary backgrounds and research institutions are needed to champion the research and development activities in the country in the area of nuclear energy technologies.

4.2.7 Inadequate capacity and training

Availability of trained professionals to work and maintain nuclear energy installation and equipment is crucial for a successful disposition and development of nuclear energy projects in Uganda. Furthermore, the development of nuclear energy technologies calls for special skills in the areas engineering, physics and energy economics and governance, as well as business management and project planning and development [25]. Nevertheless, capacity building in form of training on the use and development of various nuclear technologies is crucial for the enhancement of the varied skills of the different groups of people. As such, both users and non-users of nuclear energy technologies should be trained on how this resource could be tapped into and used. There is a lot of ignorance by the populace about the various uses of nuclear energy. Notably, simple nuclear energy technologies could be used for cooking food, warming water for bathing and so on. This knowledge seems basic but it is lacking in the majority of the citizens. Ugandans require a platform where they can get technical and engineering training especially the artisans but also create an avenue for them to access spare parts which can be used in their training.

4.2.8 Environmental barrier

The threat of climate change is another forceful driver Nuclear energy development. The need to move away from the traditional fire wood (78%) and charcoal (5%) of the energy mix to cleaner and modern energy sources. Dependence on traditional biomass leads to deforestation and increased emissions of greenhouse gases (GHGs), this has also triggered off undesirable climatic change [1]. A plausible way to slow emissions of carbon dioxide into the atmosphere is to generate a larger share of electricity through nuclear power stations. This could lower emissions by about one-third lower than they otherwise would be. Given that straightforward proposition, however, one might suppose that by now the climate-change issue would have boosted nuclear projects more than it has. It would seem logical, in other words, that nations formally committed to cutting emissions of heat-trapping gases would be the most pro-nuclear.

4.2.9 Political and commercial risks

Politics and geopolitical risks are embedded in nuclear energy development. An energy source that is politically sensitive is nuclear energy. Developing nuclear energy in Uganda would enrich Uganda’s energy sector that would strategically improve not only its economic but also political domain this would consequently affect geopolitical stability. However, a nuclear agency or authority to manage these operations has not yet been set up though a unit in the ministry of energy and mineral development was set up, this is not sufficient for full scale nuclear power operations. There is need for an independent body to oversee the development of nuclear power industry

4.3 Steps and Policies to Overcome Barriers of Nuclear Energy Development

4.3.1 Energy subsidy reform Program

The government of Uganda may undertake an energy subsidy reform by transferring subsidies from fossil fuels to nuclear energy technologies. More so undertaking this measure will go a long way in bridging the competitive gap that exists between nuclear energy technologies and fossil fuels (COMSATS; 2005). An energy subsidy reform program will shift consumption from both fossil fuels and traditional biomass to clean energy- Nuclear in particular which will drive sustainable growth and development.

4.3.2 Favourable feed-in-tariffs policies (FiTs)

This withstanding to overcome economic and financial barriers, there is a need for this policy to be appropriately crafted with the intent of inviting potential investors, at the same time their activities should be closely examined. Nonetheless, the government should appoint skilled personnel charged with the responsibility of managing the process of energy feed-in-tariffs. Notably, satisfactory policies are prime requirements for the lasting sustainable nuclear energy development. Consequently, ensuring that regulations are put in place and enforced is critical in building assurance to the prospective investors in nuclear energy that the set regulations will remain stable, unambiguous and enforceable, thus stimulating future stability of the investments. As such, the would-be investors may be induced to inject money into nuclear energy businesses.

4.3.3 Stimulation of ICT awareness

Information and communication technology (ICT) plays a fundamental role in rapid economic growth, productive capacity improvements, education, governance and many others. Previously, we noted that a need to create awareness and as well as capacity building. Capacity building can be achieved through the use of ICT. There is a need for the creation of online trainings on the use of nuclear energy systems. This will go a stride in promoting numerous experiences in the areas of installation, operation and repairs of nuclear energy technology schemes and avail the information connected to nuclear energy incentives, nuclear energy technologies, the collection of such information from Google, Google scholar, Elsevier, Emerald insight and other sources could create an important window for learning more about the different nuclear technologies thereby permitting nuclear energy workers to develop and become accustomed to nuclear energy technologies for specific environmental settings.

4.3.4 Establishment of strong quality standards for nuclear energy components

There is a need for regularizing manufacturing processes in order to promote nuclear energy technology in Uganda. Relatedly, there is urgency for the regulators such as Uganda National Bureau of Standards (UNBS) and other agencies of the government to come up with strict guidelines regarding the standard of nuclear energy equipment that are imported and sold to citizens. UNBS should strictly administer suitable manufacturing standards and equipment specifications. The government of Uganda in the bid to strengthen enforcement of quality standards for energy technologies developed for nuclear, what remains unclear is how to create incentives that will induce local companies to assemble nuclear energy devices. Equally, to ensure sustainability of supply of these nuclear energy equipment, the government should encourage domestic manufacturers to be more innovative and start designing and producing these nuclear energy technologies in the country rather than continuing to import them. Additionally, the outbreak of Covid-19 pandemic should also act as stimulus to create more awareness for the government to begin encouraging local producers to become more innovative than relying on imports all the time.

4.3.5 Capacity building

The knowledge offered by the academic institutions is considered to be a catalyst in capacity building for any country. These institutions occupy an important and envisaged central role, in contributing to capacity building for sustainable energy development. It is anticipated that capacity building can easily be achieved through education and research. It is argued that, the development and success of sustainable energy systems depends on enhancing capacities of the local population through education and as such, in Uganda, Makerere University introduced Ph.D. and Master of energy economics and governance, M.Sc. renewable energy with the aim of building capacity in the area of energy systems and resources. It is envisaged that when the students on these programmes, will be having adequate knowledge that could be utilized to promote the utilization of nuclear energy and its development in Uganda. No course specifically addresses nuclear energy studies, and world over the training of nuclear scientists remains a myth. By investing in education and training to ensure the availability of skilled employment in the sector, Uganda will be able to accelerate market growth, scale up the number of jobs created- especially in the rural areas and expand energy access. As market grows, nuclear energy will create 243312 more jobs, and helping Uganda achieve universal energy access targets [20].

5. COMPARISON WITH OTHER COUNTRIES

Uganda's readiness can be compared to other African nations with similar aspirations and level of development. Africa's nuclear energy scenario is as amazing as it is controversial, with over 441i nuclear power plants (NPPs) operating around the globe, only two are located in the Africa (0.4%); these are Koebergi-1 and Koebergi-2 in South Africa. Africa's potential is shown in Fig. 3 by its leading uranium producers. However, in recent years, African governments have fired up their ambition in adopting nuclear energy. Issues arising about price and security of fossil fuel supplies, as well as the continent's perpetual power crises, electricity outages and overall energy poverty, have created a renewed interest in nuclear power. Africa is battling an unprecedented power crisis in most parts due to insufficient generating capacity as well as ageing grid infrastructure. As much as one-quarter of the installed capacity is unavailable because of aging and grossly under-maintained infrastructure and plants. Of the 48 Sub Saharan African (SSA) countries, over 30 African countries are currently experiencing power shortages and interruptions. Firms and enterprises experience unreliable power supply with an average of 56 days of power outages in a year. Many are forced to resort to leased diesel generating plants as a crisis stopgap [3].

Therefore, energy security of the continent is in great peril. For the average citizens, extensive load-shedding is adversely affect social and economic life, this in turn affects the standard of living. For the industrial and commercial customers, the costs of electricity shortages can be huge. Frequent power outages cause substantial losses in forgone sales and damaged equipment—on average, 6 % of sales turnover for formal businesses, and as much as 16% of sales turnover for informal businesses that are unable to provide their own back-up generating capacity. The estimated economic costs of power shortages are more than 2 % of GDP. In some countries, these shortages have reduced the annual per capita GDP growth rate by as much as one-quarter of a percentage point [26].

1. Kenya. Its overwhelming desire to introduce nuclear power into its energy mix began in 2008, in an energy conference to enable local scientists to meet international experts with experience in establishing and managing NPPs. During the same year, the government unveiled a nuclear power generation program with the creation of the Nuclear Electricity Program Committee. It also announced its intention to build a 1 GW nuclear power plant by 2017 as a lower-cost alternative to the country's thermal power stations. Kenya has a total installed capacity of 2670MW and electricity consumption of 8635GWh [27].
2. Tanzania. Epitomising a typical energy crisis is Tanzania, most of the load is located in industrialized northern Tanzania, while most generation is unequally distributed and is mostly in southern Tanzania. Prolonged periods of drought have exposed huge risks of reliance on hydropower. The Tanzanian power sector is plunged into this energy crisis, and the government has to forge a strategy to place energy sector on a more sustainable growth path. It has taken bold steps in efficient generation using natural gas. Moreover, the strategy is more on fossil fuels rather than nuclear power development. It is in the face of the looming energy crisis rather than good planning that is shaping Tanzania's energy landscape. Tanzania overall installed capacity is about 2250 MW and electricity consumption of 2026 GWh [27].
3. South Africa's electricity system had an electricity surplus over 30 years yet now this reserve capacity is declining. There has been a declining reserve margin estimated at 3.3%, compared with the system's target of 15%. A strategy of replacing South Africa's coal with nuclear power is critical for ensuring the country's energy security and sustainable development. Nuclear power is the best replacement option for South Africa. Indeed, government relies on nuclear power as a key component of the country's energy matrix. Its new nuclear build program, will add 9.6 GW of generating capacity to the grid by 2030. South Africa's overall installed capacity is about 44,500i MW [28].
4. Nigeria. But if there is a country in Africa whose overriding ambition to produce nuclear power exceeds its ability, then it is Nigeria. From 1976i, when the Nigerian Atomic Energy Commission (NAEC) was formed with a clear mandate to develop nuclear power for the socioeconomic development of Nigeria, results are yet to emerge. The country has stepped up its efforts towards building a pioneer nuclear power plant. The rationale for developing nuclear power for Nigeria's insufficient generating capacity and the need for energy security, autonomy and diversity. The dependence on hydroelectric dams on rivers originating in neighbouring states renders the underlying generating capacity vulnerable and raises significant issues about energy security [29]. In 2006, the Nigerian government unleashed a roadmap developed by the NAEC that called for at least 1 GW of nuclear generating capacity by 2017 and up to 4 GW by 2027 [30]. Nigeria is facing an energy crisis with shortfalls in the power

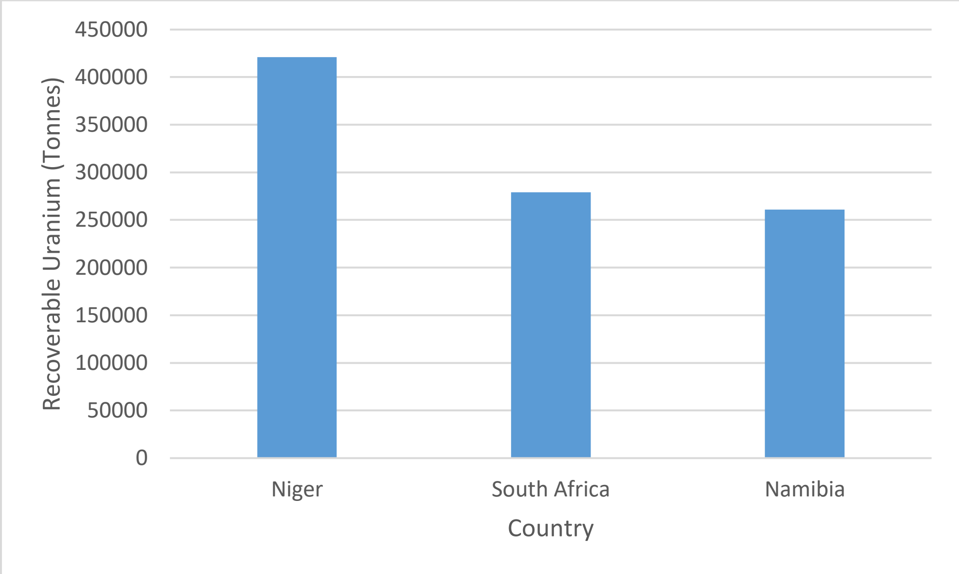

Fig. 3. Showing Africa's leading uranium producing countries

generation from the country's hydroelectric system due to drought, the high costs of thermal plants (generating and operating these plants together with natural gas and light crude oil) worsened by fluctuations in the price of crude oil, and delays in the delivery of natural gas from Nigeria have been the main causes of this crisis [31]. Nigeria's installed capacity is about 7500MW.

5. Ghana. Ghana's overwhelming ambition for nuclear dates back in1961, with a view of the increasing demand for electricity and the unreliability of existing supply capacity. Ghana made its intention explicit to explore nuclear power to stabilise electricity supply capacity and facilitate smooth industrialization and urbanisation. Ghana's installed capacity is about 4310MW and electricity consumption of 10,129GWh [13]. Electricity access in Ghana is 83.24% with a residential demand profile of 39%, while industrial demand is 45%, commercial and transport energy demand is 16%.
6. Namibia has power generation options fairly limited compared to its other African counterparts. It does not have any economically exploitable coal reserves and its hydro options are limited because it is an arid country. Resultantly, it imports about half of its electricity, mainly from Eskom in South Africa and the balance from ZESCO in Zambia. However, Namibia has two significant uranium mines capable of providing 10 percent of global mining output. There is strong government support for expanding uranium mining and a growing interest in using nuclear power [28].

6. IS UGANDA READY FOR SAFE NUCLEAR ENERGY DEVELOPMENT?

Sustainable economic growth and development requires diverse energy production. The energy sources must cater for safety, thus, for nuclear power to make a significant contribution, Uganda's nuclear programs themselves must be sustainable and address the following four issues:

(i) Techno safety issues, a well-established technology exists for producing nuclear power. Nuclear reactor technology has greatly been enhanced to cater for safety
(ii) Ease of connectivity to main grid, Electrification in Uganda offers main grid solutions therefore a power source to dominate must connect to the main grid. Nuclear technology is amenable to grid interface.
(iii) Legal, institutional and regulatory framework. It is got from a natural resource- Uranium that is abundant in Uganda. But a strong regulatory regime is key to the success of this program.
(iv) Environmental viability. Nuclear power is a clean energy source with a small carbon footprint.

One of the key concerns regarding nuclear development in Uganda is whether it has the required technical capability, availability of trained personnel, and safety culture for nuclear operations. In Uganda, a culture of maintenance is grossly missing and there is a severe shortage of engineers to maintain the existing infrastructure of traditional hydro and thermal power plants. For example the Nalubaale dam formerly Owen falls dam built in 1954 with a life span of 60 years was reassessed in 2010 and assumed to have another 20 years up to now it is still poorly maintained in spite of its old age and zero salvage value. This raises key concerns whether at all, nuclear power maintenance will be handled prudently.

6.1 Technical Capacity Limitations and Safety Concerns

Nuclear plant is the most complex energy systems that humanity has developed. The risk of failure is a remarkable feature of phenomenal complexity. In the case of nuclear power, the consequences of failure could be on a large spectacular scale which no other energy technology has presented. Nuclear technology is to be perfected hitherto any human errors may bring ecological, socio environmental and economic impact that are catastrophic and irreversible. Any build-up of nuclear plants in Uganda would lead to operation and maintenance of a large number of fuel cycle facilities. It would involve more trade and transfer of nuclear technologies and movement of fissile materials from traditional nuclear power states around the globe to new nuclear reactors in the country. The grand question is whether such an expansion can be carried out with minimal occurrence of nuclear accidents and risks of proliferation [22]. Nuclear technology is not only complex, but also a demanding technology that requires advanced scientific knowledge and perfection in performance standards- a quality that is short supply in the country. Superior safety needs to be established and met; NPPs must be worked and maintained in line with strict set technical procedures. Nuclear plant engineers frequently have to work with extremely restrictive specifications and standards that increase the level of technical skill requirements for effective operation. Moreover, the entire workforce of nuclear plants must demonstrate a great dedication to a culture of safety. Such staff should be drilled in rigorous training that covers a variety of themes to include material science, radioactivity, radiation and measurement; radiation health effects; radiation protection methods and regulations; neutronics exposure and contamination control; fuel fabrication, radioactive wastes; radiation protection; releases and emergency response; procedural and regulatory compliance; thermal hydraulic safety, workers' health and safety; configuration management; and a questioning attitude. There is a lack of detailed data on the educational backgrounds of workers in the nuclear industry around the world. In the United States, it has been estimated that approximately 65 nuclear engineers, 42 nuclear operators, and 31 nuclear technicians are needed for the operation of a single nuclear reactor [32]. While these estimates are for a giant developed nuclear power and may be exaggerated of the actual manpower needs, they do point to fundamental technical workforce requirements. With 138 technical workers or nuclear scientists on a single nuclear plant. Uganda needs to set up and develop nuclear engineering programs to produce a sufficient number of graduates to meet the workforce requirement to expand nuclear power development. This requires a robust education system well-funded, well equipped with competent staff of nuclear engineering programs in the major universities of Uganda. Shortage of skilled workforce is an even more limiting factor in the transfer and deployment of nuclear technology. In Uganda, meeting the skilled manpower requirements of nuclear facilities will be an enormous challenge. The workforce will have to be outsourced or receive training from alternative universities outside Uganda this does not ascribe to sustainable nuclear energy development.

6.2 Integrating Nuclear Power Plants with National Electric Grid

The deployment of Nuclear power plants (NPPs) to supply a portion of a country's electricity imposes a number of important preconditions of electric system development, reliability and stability of the grid that are unique to nuclear power. NPPs to function, in a relatively safe, secure, technically sound mode certain requirement need be carefully taken care of by grid planners and system operators, as the characteristics of the grid will impact the size and types of reactors that can be deployed in the country. The national grid requires significant changes, from an obsolete, old grid to a modern high performance grid that is compatible with NPPs. Otherwise, the introduction of NPP into weak grids can lead to severe problems— it may adversely affect safety and operation of the NPPs and power systems. High performance grids compatible with NPPs have been integrated [33]. With salient features like a large total installed capacity of the power system, often more than ten times the size of the largest generating unit; a large degree of network interconnection; a sufficient amount of spinning reserve and total operating reserve; automatic control of generation to obtain a fine regulation of frequency; sufficient capacity of reactive compensators and automatic controls for maintaining satisfactory voltages at all nodes of the network; reliable high speed protective systems, with system-wide co-ordination of relaying schemes; high stiffness of the grid—that is, the drop in frequency following forced outage of a generating unit is low (in most cases a drop of less than 1 Hz following loss of the largest unit without the action of system emergency controls); a low rate of drop of frequency for loss of generation, making the duties of control easier; the existence of well-planned emergency control measures, like load shedding and restoration during occurrences of serious generation—load imbalances, though these are rare; an efficient means for communication and co-ordination between generating stations and load dispatch centres; improved system controls and operating methods obtaining a high degree of system security; as a result of the foregoing, high reliability and quality of power supply at major parts of the power system.

Another salient feature of NPPs is after a reactor has been shut down (with the last the chain reaction having ceased), it continues to emit large amounts of heat for a period of time due to the long-term decay of highly radioactive fission products. This residual heat must be discarded from the reactor core to avert overheating of the reactor fuel and damage to its core. Hence, the NPP's cooling systems needs to be supplied with power for months by a reliable and stable source of electricity—either from the grid (off-site power) or from on-site back-up power systems (batteries, diesel generators or gas turbines). The safety systems and various auxiliaries of a reactor (reactivity control, heat transport from the core, confinement of radioactive materials, control of operating discharges, and limits on accidental releases) require highly reliable and uninterruptible electric power [34]. A diverse and multiple set of generators connected to the transmission system, as well as two or more independent transmission circuits connected to the NPP, ensures the stability and reliability of off-site power. Off-site power is typically thought to be more reliable and available than on-site emergency systems, and as a result, it is the preferred electric power supply for cooling the reactor during normal and emergency shutdowns. The extent to which the grid is capable of providing an uninterruptable power supply to the NPP with sufficient capacity and adequate voltage and frequency is a key dimension of grid reliability. This is so for several reasons:

(i) there must be enough reserve generating capacity to ensure that the NPP can be taken offline for refueling or maintenance (or due to unforeseen events) without compromising grid stability; Uganda currently has a reserve capacity of about 500MW (40%), whether this will remain in the medium term remains to be seen.
(ii) off-peak demand might be too low for the NPP to be operated in base load mode;
(iii) an unforeseen sudden disconnect of the NPP could trigger a sever imbalance between generation and consumption that could lead to sudden reduction in grid voltage and frequency, potentially cascading into widespread grid collapse if additional generating units are not immediately brought on-line [35].

6.3 Legal and Regulatory Infrastructure

In light of the importance of safety, nuclear regulatory agencies have developed detailed policies for monitoring and quality control. Thus, operation of nuclear reactor is a subject of stringent regulations, checks and audits. This in turn promotes the technical capability requirements for nuclear regulatory agencies. But Uganda is far from a sound nuclear energy policy which would embrace these functions:

(i) Instituting controls and guidelines for NPP applicants and licensees;
(ii) Licensing and accreditation of suitable applicants to develop nuclear plants and operate nuclear facilities,
(iii) Put in place clear decommissioning programs at the terminal point when nuclear power development ceases;
(iv) Guiding licensee operations and facilities ensure compliance with safety requirements
(v) Evaluating operational reports at licensed facilities or involving licensed activities;
(vi) Conducting research and development to disseminate information that addresses challenges of parties affected various decisions, and drafting programs to support decisions by regulatory regimes.

The basic human resources of a nuclear regulatory agency may include experts in: energy policy, management and governance, legal and legislative matters; nuclear regulatory review, licensing and enforcement process; radiation protection, economists and other social scientists transport and physical protection; legislative process for the establishment of nuclear industry; nuclear safety and probabilistic safety evaluation; power plant technologies; waste disposal; process and mechanical systems and equipment; electrical, control and instrumentation technologies; software development and qualification; layout and design of buildings and structures; seismic hazard assessment for the site, and seismic analysis and qualification for structures and components; surveillance, audits and inspections; nuclear law and international conventions and treaties. Uganda may struggle to provide sufficient scientific, engineering, legal, governance and economic expertise to adequately staff their national nuclear regulatory agencies. A quick response to the lack of a well-coordinated nuclear regulatory capacity increase policy guidelines and implementation cooperation—and finally to create regional nuclear regulatory regimes by an established authority.

R&D for disseminating information and expertise from benchmarking success stories with those that have long experience in robust nuclear regulatory regimes. The Forum of Nuclear Regulatory Bodies in Africa (FNRBA) was founded in 2009 to improve, reinforce, and harmonise radiation protection, regulatory infrastructure for nuclear safety and security, and the exchange of regulatory experiences and practises among African nuclear regulatory bodies. FNRBA's specific goals include fostering regional collaboration, providing opportunities for mutual support and coordination of regional efforts, and leveraging resource development and optimization.

7. CONCLUSIONS

Uganda faces a huge potential of nuclear energy yet providing sufficient energy to meet it requirements for a rapidly urbanising, industrialising and growing population remains a challenge. Developing her nuclear energy potential while mitigating the risks of climate change will be a daunting task [36]. It will require a significant shift in the historic pattern of biomass and dismal hydroelectricity, to use and transformation of the country's energy system. The choice of technology, policy, and economic levers that will be used to transform and expand Uganda's energy supply infrastructure will have profound implications for its growth, international competitiveness, and economic security and prosperity. Uganda is considering including nuclear power into its energy mix. The desire to provide sufficient capacity for their ambitious economic development programmes, improve the stability, efficiency, reliability, and security of their power supply, and provide adequate power that is environmentally friendly and clean with a low carbon footprint is driving this growing interest in nuclear power.
Many people are still sceptical of nuclear power, and this opposition has grown significantly in the aftermath of the Fukushima disaster. To play a significant part in Uganda's future energy mix, the risks of another Fukushima must be significantly lowered. Even if the increased safety worries subside, the massive construction delays and cost overruns that have plagued the nuclear industry's large-scale reactors would be a big stumbling block to their implementation in Uganda. Analytical help to Uganda's energy sector planning and policy creation is just as important as financial support for investment in order to ensure sustainable growth and poverty reduction. In turn, providing analytical advice to countries on nuclear concerns is vital for ensuring that any investment in nuclear energy is cost-effective and fulfils the highest safety, security, and non-proliferation criteria. Uganda may and should rely on multilateral institutions to help it make educated policy decisions about if, when, and how to pursue nuclear power, as well as to build the necessary institutional and physical infrastructure. Governments having to examine technical offers from vendors pursuing their own business interests can turn to multilateral institutions for advice and knowledge. Multilaterals might also help Uganda establish and develop nuclear training programmes by mobilising and funding support from experienced nuclear research and education institutions and regulatory authorities. Drivers for nuclear energy development will not be considered unique as the same drivers also influence renewable energy so have competing interests [10].

Areas for future research include making an assessment of geopolitical and technological risk in Uganda's context. Further research still needs to be done why these independent African states, Uganda, inclusive have still failed to generate sufficient power from nuclear despite huge reserves of Uranium.

DECLARATION

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Further I declare that no financial interests/personal relationships which may be considered as potential competing interests.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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