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The Role of Research Reactors in Sustainable Development in Kenya

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ABSTRACT

Nuclear energy technologies have wide applications that have proved to enhance economic development and improve quality of life. To realize development goals stipulated in national development agenda, effective and sustainable application of nuclear and related technologies will be necessary. Additionally, by virtue of nuclear energy technology being knowledge intensive, there are myriad positive spin-off effects correlated with application of the technology. The Government of Kenya is aware of such benefits and is implementing a nuclear energy program for both electricity generation and other applications. Despite Kenya having no research reactor facility, products and services of research reactors are widely utilized locally in various fields. Local ownership and operation of a research reactor is envisaged to improve timely access and affordability of research reactor products and services. Preliminary studies have established the need for a research reactor in Kenya. From stakeholders need assessment, draft functional requirements for Kenya Nuclear Research Reactor (KNRR) concept design have been defined. Kenya is currently carrying out a feasibility study that seeks to identify obligations and commitments necessary for the safe and sustainable implementation of the KNRR Project. Successful implementation of KNRR project will foster sustainable development through economic growth and improved quality of life. Construction of KNRR is planned to commence in 2027 while commissioning is scheduled for 2030.

1- INTRODUCTION

Kenya Vision 2030 is the country's development blueprint with an aim of transforming Kenya into a newly industrializing, middle-income country providing a high-quality life to all its citizens by 2030. The Vision recognizes the critical role played by research and development (R&D) and innovation in accelerating economic development by raising productivity and efficiency. Further, the government has adopted regional and international development goals such as Africa Agenda 2063 and SDGs for global peace and prosperity. Towards realization of Kenya's development agenda, the Government has prioritized agriculture & food security; health care; infrastructure; and education that will lead to accelerated growth of the economy and improved quality of life [1].

Kenya is implementing a research reactor project guided by the IAEA's Milestone Approach [2]. The Milestone Approach represents a sequential three phased development of 19 infrastructure issues and the completion of work at each phase forms the basis of evaluation and decision making on whether to proceed to the next phase [3]. Currently, is in Phase I at which the country is making consideration before a decision to launch a research reactor project is taken. At the end of this Phase, the country will be ready to make a knowledgeable commitment to a research reactor project.

Research reactors offer a diverse range of utilizations, including education and training, neutron beam research, neutron activation analysis, radioisotope production, neutron irradiation for materials testing for fission and

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fusion reactors, and neutron transmutation doping [4]. Kenya Nuclear Research Reactor (KNRR) project seeks to accelerate economic development and improve quality of life through the application of nuclear energy technology in scientific research, healthcare and industry [5]. The implementation of the research reactor program will play a key role in the realization of the objectives of the development Agenda through its utilization in health, agriculture, industry and research sectors.

This paper discusses key findings of technical studies towards making a knowledgeable commitment to research reactor project. The studies include: stakeholder needs analysis, potential utilizations, analysis alternative technologies, functional requirements, Key commitments project progress and tentative timelines.

2. STAKEHOLDER NEEDS

Despite Kenya having no research reactor facility, research reactor products and services are widely utilized locally in various fields. Consumer of these products and services are the main stakeholders of the project [6]. The Figure 1 illustrates major stakeholders involved in the KNRR project.

Government
- Kenya Nuclear Regulatory Authority
- National Treasury
- National Council of Science and Technology Institute
- Ministry of Energy & Petroleum
- Ministry of Mining
- Ministry of Health
- Ministry of Water and Irrigation

Scientific Organization
- University of Nairobi
- Technical University of Kenya
- Kenyatta University
- Pwani University
- Karatina University

Energy
- Nuclear Power and Energy Agency

Industry
- Kenya Industrial Research Development Institute
- Kenya Bureau of Standards

Medicine
- Kenyatta National Hospital
- Moi Teaching & Referral Hospital
- Kenyatta University, Teaching, Referral & Research Hospital
- Aga Khan University Hospital
- Nairobi Hospital

Agriculture
- Kenya Agriculture and Livestock Research Organization
- Kenya Marine and Fisheries Research Institute

Fig. (1): Stakeholders Involved in Kenya Nuclear Research Reactor project

Identification and quantification of the needs is fundamental for the justification of pursuing a research reactor project. Specific needs from stakeholders (potential KNRR users) are as follows:

2.1 Scientific Organizations (Education and Training)

a. Teaching and training facilities for science, medical and engineering students.

b. Supporting the nuclear power programme through training of future plant operators, inspectors and other relevant personnel.

c. Enhance the nuclear research and development capabilities

d. A platform for public information, creating awareness on peaceful, safe and secure nuclear application hence, gaining public acceptance for the nuclear programme.

2.2 Health and Industry (Radioisotopes)

a. Self-sufficiency in production of radioisotopes for medical, industrial and other applications both for the country and the region. Some of important radioisotope include: Mo-99/Tc-99m, I-131, I-125, Lu-177 and Ir-192

b. Availability of cost effective direct and indirect medical applications

2.3 Research and Industry (Irradiation Services)

a. Improve R&D programs and studies in nuclear science, technology and innovation

b. Enhance capacity and capability of the Nuclear Research Center

c. Enhance collaborative research and training within the region.

d. Improve calibration and testing services for industrial and medical instruments.

e. Explore and enhance industrial services (Non-Destructive Testing (NDT), neutron scattering, Neutron Transmutation Doping (NTD) to support industries.

f. Trace element determination

g. Manufacturing process development and process flow monitoring

3. ANALYSIS OF ALTERNATIVE TECHNOLOGIES

An analysis of potential alternative technologies that could satisfactorily meet the broad range of the identified stakeholder needs was conducted. These technologies have varied applications and capabilities. They include subcritical assemblies, spallation neutron source (SNS), research reactors and cyclotrons. In essence, these technologies complement each other rather than competing [6]. A suitable technology should have capabilities for:

- Education & Training (E&T)
- Radioisotope Production (RI)
- Instrument Testing and Calibration (IT&C)
- Neutron Activation Analysis (NAA)
- Material Structure Studies (MSS)
- Transmutation Effects (TE)
- Geochronology (G)

Table 1 captures a summary analysis of alternative technologies against required capabilities.

Table (1): Analysis of Alternative Technologies

Alternative Technologies	E&T	RI	IT&C	NAA	MSS	TE	G
Subcritical Assemblies	X	-	-	-	-	-	-
SNSs	X	-	-	X	X	-	-
RRs	X	X	X	X	X	X	X
Cyclotrons	X	X	-	-	-	-	-

From Table 1, it is evident that research reactor technology is suitable since it meets the identified stakeholder needs.

4. PRIORITY UTILIZATION AREAS

The relative importance of research reactor utilization areas was quantified across defined stakeholders to establish priority utilizations [5]. The utilization areas assessed include: Education & Training (E&T); Radioisotope Production (RI); Instrument Testing and Calibration (IT&C); Neutron Activation Analysis (NAA); Material Structure Studies (MSS); Transmutation Effects (TE); Geochronology (G); Prompt gamma neutron activation analysis (PGNAA); Positron Source (PS); Neutron capture therapy (NCT); and Fuel and materials testing (FMT) as illustrated in Table 2 below.

Table (2): Relative Importance of RR Utilizations

	Universities / colleges	Research Centres	Health	Agriculture	Industry	Culture & heritage	Mining	Total
E&T	5	4	4	4	5	4	4	30
RI	3	4	5	4	5	3	3	28
NAA	4	5	2	4	4	4	4	27
IT&C	4	4	4	3	4	3	3	25
MSS	4	5	1	3	5	3	3	24
TE	4	4	1	2	5	2	4	22
G	4	3	1	1	3	5	3	20
PGNAA	4	4	1	1	3	3	3	19
PS	2	4	4	1	3	1	1	16
NCT	2	3	5	1	1	1	1	14
FMT	1	3	1	1	4	1	1	12

Extremely Important-5;
Very Important-4;
Important-3;
Somewhat Important-2;
Not Important-1

From the analysis, the priority utilizations include: education and training; radioisotope production; instrument testing and calibration; neutron activation analysis; material structure studies; transmutation effects; and geochronology. These utilizations are described below.

4.1 Education and Training

Education and Training is a top priority area of utilization of KNRR given the need for advancement of education and training in nuclear science and technology. Education and training programmes can encompass all aspects of civil society, from primary and high school students, the general public tours, university students, staff of scientific institutions, industries and the nuclear power programme. Specific areas to be covered include: public tour and visits; teaching nuclear engineering students; teaching students studying science; teaching radiation protection and radiological engineering students; training researcher of agriculture, livestock, fisheries and marine field; and training medical workers.

4.2 Radioisotope Production

Radioisotopes have been used extensively for research and technical development in industrial, scientific and medical sectors in Kenya. The prospective radioisotopes for both medical and industrial applications include: Molebdenum-99/Technecium-99m, Iodine-131, Iodine-125, Lutetium-177, and Iridium-192.

4.3 Instrument Testing and Calibration

The research reactor provides adequate capability for instrument testing and calibration. However, the use of research reactors for instrument testing and calibration may be limited to the calibration of neutron detectors. Testing and calibration of gamma-ray monitoring equipment and radiological protection instruments needs other radiation sources for their testing and calibration.

4.4 Neutron Activation Analysis

Neutron activation analysis (NAA) is useful as a sensitive analytical technique for performing both qualitative and quantitative multi-elemental analysis of major, minor and trace components in a variety of terrestrial samples and extra-terrestrial materials. NAA has been applied to trace minor and major components of nuclear, geological, biological and environmental samples, high purity materials, certified reference materials, forensic samples, archaeological materials, and various polymers. Areas to be covered by NAA include: education and training, applications in the R&D, applications in the industrial fields, analytical services and international activities and QA/QC and laboratory accreditation.

4.5 Material Structure Studies

The prospects of neutron beam utilization in Kenya are in the science and research fields, however there is little experience in the use of neutron beams. Potential neutron beam users including the academic community (Professors and Ph.D. students in Physics, Chemistry, Materials science, Life science, Engineering science, and Earth science) and industries (battery, fuel cell, rubber, steel, automobile).

4.6 Neutron Transmutation Doping

Neutron transmutation doping (NTD) involves the creation of impurities in an intrinsic or extrinsic semiconductor by neutron irradiation, thereby increasing its value for various applications. Potential application areas of neutron transmutation doping include: Production of high-quality silicon wafers and Research and development in scientific organizations, academic institutions and universities.

4.7 Geochronology

The use of research reactors for geochronology is a more specialized application. The user base is a relatively small but widespread group of geologists from many universities and research institutions.

5. FUNCTIONAL REQUIREMENTS

In order to meet the identified stakeholder needs, the proposed research reactor should have capability to carry out the priority utilization areas. The proposed research reactor should:

- Be a multipurpose reactor
- Provide both neutron irradiation spaces and neutron beams
- Be a thermal reactor with proper neutron moderation
- Perform fundamental safety functions [7] such as the capability to:
    - Safely shutdown the reactor
    - Remove residual heat after shutdown,
    - Reduce the potential for the release of radioactive material

6. KEY COMMITMENTS

The success of the research reactor project is dependent upon government and stakeholder commitment as well as alignment to internal policies, strategies, capacities, environmental conditions and needs of the country. Due to the fact that research reactors are long-term, complex, non-profit making ventures, the KNRR project will require commitments from the national government and potential stakeholders. These commitments include establishing robust legal, regulatory and institutional frameworks and funding arrangements for the project.

6.1 Legal and Regulatory Commitment

The Government, through its various agencies, has developed requisite legislations and policy frameworks to support the implementation of both nuclear power and research reactor programmes. These legislations and policy frameworks include:

- Energy Act, 2019 establishes Nuclear Power and Energy Agency (N*u*PEA) as the lead agency for implementing Kenya's Nuclear Power Programme. The Act further mandates N*u*PEA to coordinate nuclear and energy research and development [8].
- Nuclear Regulatory Act, 2019 provides a framework for the regulation of safe, secure and peaceful utilization of atomic energy and nuclear technology. The Act establishes the Kenya Nuclear Regulatory Authority (KNRA) as the national nuclear regulatory body [9]
- Science, Technology and Innovation Act, 2013 (Revised 2014) regulates and assures quality of the science, technology and innovation in Kenya [10]
- Environmental Management and Coordination (Amendment) Act (2015) has enlisted nuclear reactors as projects that need environmental assessment [11].

6.2 Financing and Management

- Government of Kenya, through the Ministry of Energy, funds all the activities related to the feasibility study of Kenya Nuclear Research Reactor (KNRR) project
- Preliminary economic cost benefit analysis for the research reactor project has been conducted which aims at assessing the viability of the project and developing a utilization plan.
- Government of Kenya has commenced discussions with potential partners on viable financing options for the KNRR project.
- Budget for the KNRR project is captured in the N*u*PEA's Strategic Plan 2020-2025

6.3 International Cooperation

To enhance capacity development in nuclear R&D in the country, N*u*PEA has entered into collaborations with international institutions including:

- Partnered with the Korea Atomic Energy Research Institute (KAERI) in conducting the feasibility study through a Memorandum of Understanding (MoU) on technical cooperation in Research and Development in Nuclear Energy.
- Participating in the Regional IAEA Technical Cooperation Project (RAF1009) aimed at supporting the development of infrastructure for establishing nuclear research reactors that enable education and training, industrial, medical, and research applications.
- Pursuing a cooperation agreement with Belgian Nuclear Research Centre (SCK•CEN). This will allow N*u*PEA to receive support from SCK•CEN on nuclear R&D and capacity building objectives relevant to identified national priorities/needs.

7. PROJECT PROGRESS AND TIMELINES

7.1 Project Progress

N*u*PEA is carrying out a feasibility study for the KNRR project. Activities undertaken include:

- Self-assessment for national nuclear infrastructure
- Stakeholder needs assessment
- Alternative technology assessment
- Preliminary Design concept
- Economic cost benefit analysis
- Human resource requirements
- Project management options
- Proposed project schedule
- Utilization plan and user groups development
- Risk management framework for the project
- Preliminary Site investigation

7.2 Proposed Timelines

Major milestones of KNRR project and tentative timelines are captured in Table 3 below.

Table (3): KNRR Project Timelines

Activity Milestone	Timeline
Completion of FSR preparation for KNRR	2022
Acquisition of national approval and budget plan	2023
Start of construction of KNRR	2027
KNRR commissioning	2030

8. CONCLUSION

Research reactor project is a major undertaking especially for an embarking country. For a successful RR project there is need of support and commitment from the Government. Towards realization of Kenya's development agenda, the Government has prioritized agriculture & food security; health care; infrastructure; and education that will lead to accelerated growth of the economy and improved quality of life. The Government of Kenya has developed requisite legislations and policy frameworks to support the implementation of a research reactor project. Preliminary studies have established the need for a research reactor in Kenya which will support education and training, industrial, medical, and research applications. From stakeholders need assessment, draft functional requirements for Kenya Nuclear Research Reactor (KNRR) concept design have been defined. Kenya is currently carrying out a feasibility study that seeks to identify obligations and commitments necessary for the safe and sustainable implementation of the KNRR Project. Construction of KNRR is planned to commence in 2027 while commissioning is scheduled for 2030. For sustainability of KNRR project, Kenya seeks to leverage on local, regional and international collaborative platforms and programs. Successful implementation of KNRR project will foster sustainable development through economic growth and improved quality of life.

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