Evaluation of Utilization of Nuclear Technology Beyond Electricity Generation in Kenya

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Abstract

Nuclear technologies have wide applications that enhance economic development and improve quality of life. To realize development goals stipulated in the country's development blueprints (Vision 2030 and Big 4 Agenda), effective and sustainable application of nuclear and related technologies will be necessary. These technologies have the potential to open up opportunities in various sectors of the economy: education and training, health, industry, energy, agriculture and research. To effectively and sustainably implement a nuclear project for applications, other than electricity generation, the Nuclear Power and Energy Agency carried out stakeholder identification and sensitization followed by identification of stakeholder needs. Stakeholders' needs inform the type of nuclear technology to be adopted and functional requirements that in turn define functional and technical specifications of the adopted technology. A preliminary assessment of stakeholder needs identified six priority nuclear technology utilization in: education and training, radioisotope production, testing and calibration, neutron activation analysis, material structure studies, and transmutation effects. A detailed analysis of alternative nuclear technologies that can satisfactorily meet identified stakeholder needs was conducted. The technologies considered in the analysis were: research reactors, sub-critical assemblies, accelerators, spallation neutron sources and cyclotrons. A Research Reactor was identified as the optimum technology.

Keywords: Nuclear Technology, Stakeholder Needs, Utilization, Functional Requirements, Research Reactor.

1. Introduction

Nuclear technologies have wide applications that enhance economic development and improve quality of life for a country. These technologies have the potential to open up opportunities in various sectors of the economy: education and training, health, industry, energy, agriculture and research as shown in Fig 1. The non-power nuclear technologies offer a diverse range of applications, such as: neutron beam research for material studies and non-destructive examination; neutron activation analysis to measure minute quantities of an element; radioisotope production for medical and industrial use; neutron irradiation for materials testing for fission and fusion reactors; neutron transmutation doping of silicon; gemstone coloration; among others. Hence, the implementation of the non-power nuclear technology will play a key role in the realization of the objectives of the country's development blueprints (Vision 2030 and Big 4 Agenda).

For utilization of nuclear technology in non-power applications, it is of cardinal importance to thoroughly and accurately define the potential stakeholders' needs (current and future). Stakeholders' needs inform the type of nuclear technology to be adopted and functional requirements that in turn define functional and technical specifications of the adopted technology. A suitable technology should be selected to fully satisfy these needs.

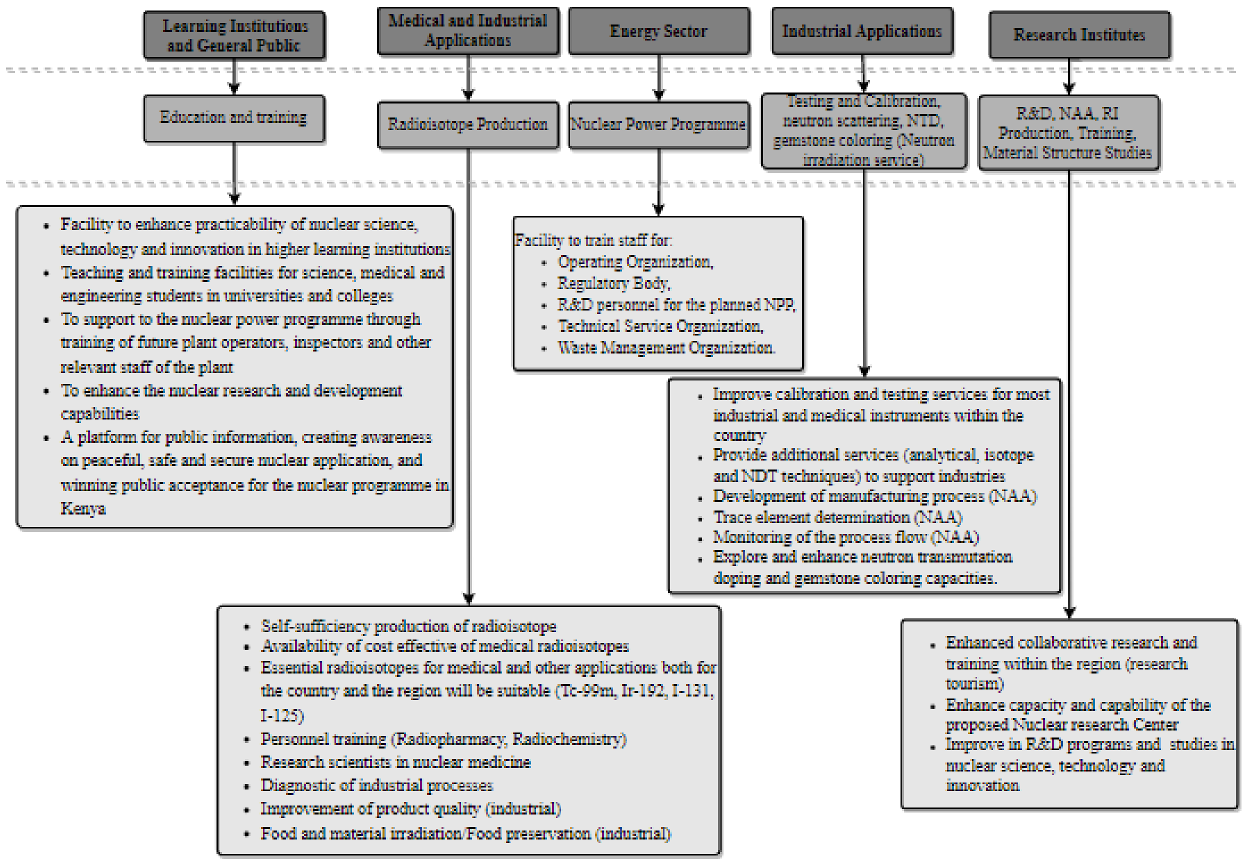

Fig 1:Non-power Nuclear Technology Utilization Areas

2. Methodology

Potential stakeholders both nationally and regionally were identified and their profiles developed based on their objectives and interest/needs. The stakeholders' needs were consolidated and assessed to ensure sustained, high, facility utilization throughout its operating life. The assessment informed the translation of the stakeholders' needs into specific utilization areas/categories. Subsequently the capabilities of the potential technologies to meet the identified stakeholders' needs was assessed. Fig 2 shows the flow chart representing the process.

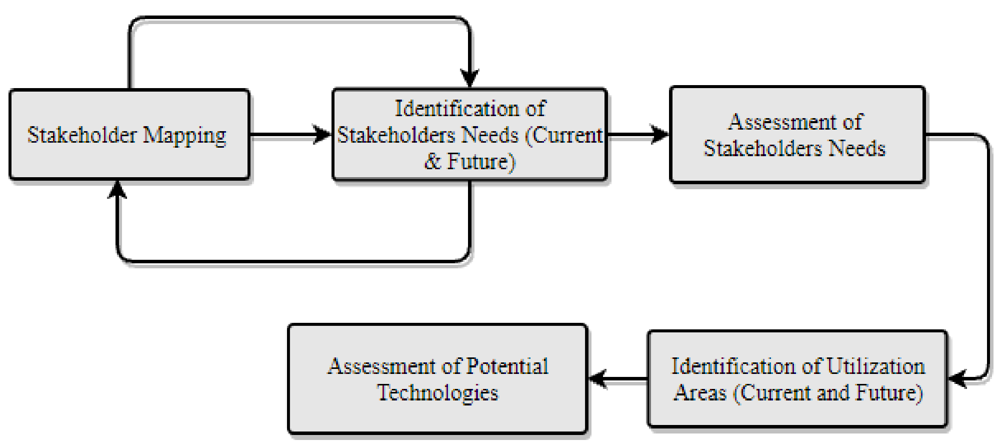

Fig 2: Methodology

Additionally, a V-model shown in Fig 3 was adopted to perform reviews on multiple levels tracing all requirements through the entire project life cycle so as to ensure clear and unambiguous requirements.

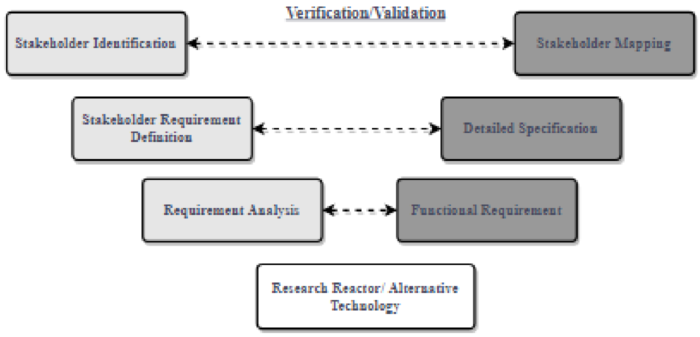

Fig 3:Validation and Verification Mode

3. Results

The potential stakeholders of the non-power nuclear technology in Kenya were categorized into five major groups: education and training, health, industry, energy, and research applications as shown in Table 1.

Table 1:Potential Stakeholders and Utilization areas of the non-power nuclear technology

Area/Sector	Application
Education and Training	• Teaching and training for science, medical and engineering students. • Enhance the nuclear research and development capabilities.
Medical and Industrial Applications	• Self-sufficiency in production of radioisotopes for medical and other applications both for the country and the region, such as (Tc-99m, Ir-192, I-131, I-125). • Availability of cost-effective medical radioisotopes. • Diagnostic of industrial processes - Tracers (pipeline leaks, malfunctions, wear and corrosion).
Energy Sector for Nuclear Power Programme	• Carry-out nuclear research, • Training staff for operating organization, regulatory body; R&D personnel for the planned NPP, technical service organization, waste management organization.
Research	• Improve R&D programs and studies in nuclear science, technology and innovation. • Enhance capability of the Nuclear Research Center. • Enhance collaborative research and training within the region (research tourism). • Improve calibration and testing services for industrial and medical instruments. • Explore and enhance industrial services (Non-Destructive Testing (NDT). neutron scattering, Neutron Transmutation Doping (NTD), gemstone coloring) to support industries. • Manufacturing process development and process flow monitoring by NAA • Trace element determination by NAA and tracer technique

3.1. Potential technologies

An analysis of potential technologies that could satisfactorily meet the broad range of the identified stakeholder needs was conducted. These technologies have varied applications and capabilities. They include sub-critical assemblies, accelerators, spallation neutron sources, research reactor and cyclotrons as shown in Table 2.

Table 2: Potential Technologies

Technology	Description
Subcritical Assemblies	Subcritical assemblies are a system consisting of fuel and a moderator, which is gradually built up until it approaches the critical dimensions, but not until it becomes actually critical. At the center of the assembly, a neutron source could be placed. The source neutrons are multiplied by the fissile material, and detectors are used to count them. A steady state neutron flux is attained as long as the source is present.
Cyclotrons	A cyclotron is a type of particle accelerator that makes use of the effect of magnetic force on a moving charge. The magnetic force bends the moving charges into a semi-circular path. Then it is accelerated by a rapidly varying electric field i.e. an alternating voltage of several thousand volts. The charged particles are accelerated outwards from the center along a spiral path.
Research Reactors	Research reactors are nuclear reactors that serve primarily as a neutron source for research and various applications, including education and training. They are also called non-power reactors, in contrast to power reactors that are used for electricity production, heat generation, or maritime propulsion.
Spallation Neutron Sources	A Spallation Neutron Source (SNS) is an accelerator-based facility that produces pulsed neutron beams by bombarding a target with intense proton beams. The neutron pulses produced are highly intense and are used in scientific research and industrial development.

Analysis was done to compare the capabilities of these technologies to meet the identified stakeholder needs as summarized in Table 3.

Table 3:Capabilities of Potential Technologies

Potential Technologies	Education & Training	Radioisotope Production	Instrument Testing and Calibration	NAA	Material Structure Studies	Transmutation Effects
Sub-critical Assemblies	X	-	-	-	-	-
SNSs	X	-	-	X	X	-
Research Reactors	X	X	X	X	X	X
Cyclotrons	X	X	-	-	-	-

4. Discussion

Non-power nuclear technologies have the potential to open up opportunities in various sectors of the economy: education and training, health, industry, energy, agriculture and research. The main utilization/applications envisaged from these sectors include: enhancing national research and development capabilities and intergovernmental collaborations; improving and encouraging industrial competitiveness; enhancing material structure study for various applications; quality in material design and manufacturing; production of radioisotopes for medical and industrial applications; improving calibration and testing services for industrial and medical instruments, education and training of students and staff of various institutions; among other applications. Hence non-power nuclear technology will play a critical role in the realization of the development goals stipulated in local development blueprints Kenya Vision 2030 and Big 4 Agenda in education and training, health, industry, energy, and research.

Various technologies are available that can address the identified stakeholders needs, however most of these technologies are complementary. For sustainability of the project it is necessary to select the optimal technology that adequately addresses identified stakeholder needs. Research reactors cover a diverse range of applications and meet all the identified stakeholder needs. Based on the evaluation of identified current and future stakeholders needs, a multipurpose research reactor was proposed. Table 4 show the relative importance of the utilization of the research reactor in the above-mentioned sectors.

Table 4: Relative importance of Research Reactor Utilization

	Education & training	**Radioisotope Production**	**Instrument Testing and Calibration**	**NAA**	**Material Structure Studies**	**Transmutation Effects**
Academia	5	2	2	4	4	2
Research Centers	4	4	3	5	3	4
Health Sector	4	5	4	1	1	1
Agriculture	3	4	2	2	1	2
Industry	5	5	4	2	4	5

5. Conclusion

Various non-power nuclear technologies exist that can address some of the identified stakeholder needs, research reactors cover a diverse range of applications and meet all these stakeholder needs. Hence, they are more suitable and sustainable for the country towards enabling achievement of the development goals set out in the vision 2030 and Big 4 Agenda. Based on this assessment a research reactor project has been proposed for implementation.

To ensure a viable and sustainable implementation of the research reactor project, there is a need for a comprehensive feasibility study. The feasibility study should identify obligations and commitments necessary for the safe and sustainable implementation of the research reactor project. Further the feasibility study should quantify stakeholder needs and identify project costs and benefits that will inform project financing. This will ensure effective application of the research reactor which will in turn enhance sustainable development through economic growth and improved quality of life.

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