Importance of Law and Policy on Successful Utilization of Nuclear Technology for Electricity Generation

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Abstract**—** Law and policy is often said to have no correlation with scientific research and application, yet law is frequently utilized to resolve not only complex social conflicts towards sustainable economic growth, but also complex scientific disputes as well. As Kenya considers the use of nuclear energy for peaceful purposes and especially the generation of electricity, the development of a comprehensive law and policy is indispensable. This paper discusses the role of law and policy in the use of nuclear energy and technology for electricity generation. It also discusses the role that law and policy plays in developing research and development (R&D) programmes in the area of nuclear technology. It makes recommendations on how nuclear energy technology use for electricity generation and research in Kenya ought to be regulated to stimulate sustainable development, and the role that engineers can play in this regard. The status of Kenya's law with respect to nuclear energy is also discussed.

Keywords**—**Law and policy, nuclear energy, sustainability

I. INTRODUCTION

Law and science has interacted in various ways throughout the development of mankind. This interaction has been catalyzed by the desire to exert some form of control over the risks posed by technological advancement. These risks include those to public health and the environment on individual and collective (community) levels [1]. The consensus on the use of nuclear technology for peaceful purposes only - 'atoms for peace' – and the related development in nuclear technology, has led to adoption of varied policies on nuclear technology use on a global scale, as well as the development of an extensive international nuclear legal regime covering the areas of nuclear safety, security, safeguards and liability for nuclear damage.

The paper attempts to expound on the role(s) that law and policy play first, in the utilization of nuclear technology generally and for the purposes of electricity generation in particular, and second, in research and development (R&D) activities in the area of nuclear technology. It underscores the importance of ensuring robust regulatory effectiveness in the use of nuclear technology and examines how this either strengthens sustainable development or detracts from it. Finally, the paper recognizes the salient role that engineers have to play in the development of safe and efficient use of nuclear technology.

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II. DEVELOPMENTS IN NUCLEAR TECHNOLOGY AND THE EVOLUTION OF NUCLEAR LAW AND POLICY

The exploration of nuclear energy for electricity generation originated from the discovery in Europe in 1938, that the process of uranium fission had the capacity to release vast amounts of energy [2]. Continuous research into nuclear fission eventually led to the development and testing of the world's first nuclear weapon (NW) on 16 July 1945 by the United States (U.S.) in New Mexico and its subsequent explosion on the Japanese civilian population in the cities of Hiroshima and Nagasaki on 6 and 9 August 1945 respectively, bringing the Second World War to an end. This act triggered legitimate fear that other nations, and indeed even terrorist groups, might acquire nuclear weapons capability. Spurred on by this concern, in November 1945, a joint declaration by the U.S., the United Kingdom (U.K.), and Canada resulted in the advancement of the concept of nuclear 'safeguards' for the first time. These three allied nations positively affirmed that they would be willing 'to proceed with the exchange of fundamental scientific literature about atomic energy', but only when 'it (was) possible to devise acceptable, reciprocal and enforceable safeguards acceptable to all nations' against its destructive use' [3].

In line with this affirmation, on 14 June 1946, less than a year after the twin nuclear bombings at Hiroshima and Nagasaki, the United States proposed a Plan - known as 'the Baruch Plan' – (named after the principal U.S. delegate at the time), to the United Nations for the International Control of Atomic Energy [4]. The Plan provided for the abolition of the Security Council veto and the creation of a strong atomic development authority. The atomic development authority was to receive from the U.S., through several stages, access to all its atomic technological information, raw materials, production plants, stockpiles of fissionable materials, and finally its remaining atomic bombs. It also advocated for the avoidance of a nuclear arms race and even the “elimination of war” [4]. However, the Baruch Plan failed and led to an ‘arms race’ which was characterized by a rapid increase in the quality of instruments of military or naval power by rival states [5]. The Soviet Union (USSR) tested its NW on 29 August 1949 on the Kazakhstan Steppe and by the 1970s, soviet arsenal had surpassed the U.S. stockpile. Despite the collapse of the Soviet Union, Russia in 2007 had the world’s largest nuclear arsenal. Later, on 3 October 1952, the U.K. tested its NW at the Montebello Islands in Western Australia. France followed closely with its own NW test in the Algerian Sahara Desert in 1960 while China tested its NW in 1964.

The second phase in the evolution of the nuclear safeguards system stemmed from calls for the use of nuclear technology for ‘peaceful’, non-military purposes, leading to policy shifts and initiatives by governments that permitted regulated development of nuclear technology for civilian uses referred to as ‘atoms for peace’[6]. Although electricity was generated by a nuclear reactor for the first time on December 20, 1951, at the Experimental Breeder Reactor No. 1 (EBR-I) experimental station near Arco, Idaho, U.S., nuclear reactor technology still remained a military secret and a government monopoly. It was the commissioning of the former USSR’s Obninsk Nuclear Power Plant in 1954, that marked the commencement of the development of nuclear power and the accessibility of the technology needed to produce nuclear reactors [6]. The need to regulate development of nuclear technology for civilian uses culminated in the establishment of the International Atomic Energy Agency (IAEA) in July 1957 as the worlds “Atoms for Peace” organization tasked with the core mandate of ensuring that nuclear technology was applied exclusively for peaceful purposes through the establishment and administration of safeguards either at the request of the party state to the Statute of the IAEA, or pursuant to bilateral and multilateral arrangements (Article II.A.5 of the IAEA Statute) [7].

The first IAEA Safeguard (SG) System was outlined in the document Information Circular (INFCIRC) no.26 (INFCIRC/26) [8]. The principles set forth in INFCIRC/26 served the dual purpose of allowing Member States (to the IAEA) to determine the circumstances in which the Agency would administer safeguards and provided guidance to the Agency itself so that it could determine which provisions ought to be included in safeguards agreements and how these provisions ought to be interpreted. This System was subsequently expanded between 1965 and 1968 to include further additional provisions for safeguarded nuclear material. These additional provisions were contained in the documents INFCIRC/66. Rev.1 and INFCIRC/66/Rev.2, respectively. In 1967, the Latin America Nuclear Weapon Free Zone Treaty (NWFZ) opened for signature while in 1968; the Nuclear Non- Proliferation Treaty (NPT) was opened for signature and entered into force in 1970. The NPT is ‘the’ fundamental treaty on non-proliferation and provides for safeguards measures to prevent diversion of nuclear material from peaceful purposes. In this regard, it imposes obligations on Non-Nuclear Weapon States (NNWS) and Nuclear Weapons States (NWS) respectively [9]. In July 2009, the African Nuclear Weapon Free Zone Treaty (the ‘Pelindaba’ Treaty) entered into force. The Treaty, *inter alia*, prohibits the research, development, manufacture, stockpiling, acquisition, testing, possession, control, or stationing of nuclear explosive devices in the territory of parties to the Treaty; requires Treaty parties to maintain the highest standards of physical protection of nuclear material, facilities, and equipment which are to be used exclusively for peaceful purposes; and requires all Treaty parties to fully apply the IAEA safeguards to all their nuclear activities [10].

The scope of the IAEA safeguards system has continued to evolve. The system has created export controls on nuclear material and technology, encouraged requirements relating to incorporation safeguards by design, and prescribed other verification safeguards systems including the obligation to establish a Safeguard System for Accounting for and Control of all nuclear materials (SSAC) within a state [11].

Despite these elaborate safeguards measures, nuclear proliferation continues to be a significant risk and is becoming increasingly complex, in view of the several NNWS which continue to construct nuclear power facilities that are capable of producing weapon grade material that can potentially be misused to produce fissionable materials. This fact results in the linkage between nuclear weapons potential and the spread of civilian nuclear power and research facilities [12].

Closely linked to the nuclear safeguards legal regime, is the nuclear security legal regime which concerns itself with ‘preventing, detecting and responding to theft, transfer or other malicious acts involving nuclear material and other radioactive material or their associated facilities’[13]. The key international legal instrument in nuclear security and the only internationally legally binding counter-terrorism instrument is the Convention on the Physical Protection of Nuclear Material (CPPNM), concluded under the auspices of the IAEA. The CPPNM entered into force on 8 February 1987. Subsequent amendments to the Convention in 2005 were triggered by the 9/11 terrorist attacks in 2001 in the U.S. and had the primary goal of introducing measures to reduce the vulnerability of states parties to nuclear terrorism.

The strong emphasis placed by the safeguards system on the infusion of surveillance and security into the nuclear regime informed the diffusion of nuclear technology to developing countries. A natural corollary of this was the requirement that state parties using nuclear technology ought to develop appropriate national nuclear policy and legislation incorporating the essential elements for safeguards, security and safety [3].

The occurrence of major nuclear accidents around the world has also had considerable impact on the strengthening of the international nuclear legal regime particularly in the areas of nuclear safety and nuclear liability. The Chernobyl nuclear plant accident which occurred on April 26 1986 in the Ukraine Republic (formerly within the Soviet Union (USSR)), had formidable influence on the development of the nuclear safety legal regime. Within six months of the Chernobyl nuclear accident, two Conventions, namely, the Convention on Early Notification of a Nuclear Accident and the

Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency respectively had been negotiated and adopted under the auspices of the IAEA. These Conventions entered into force in 1986 and 1987 respectively. Other notable Conventions that have been concluded in the area of nuclear safety include the Convention on Nuclear Safety (1994) and the Joint Convention on the Safety of Spent Fuel and Radioactive Waste Management (1997)[14].

From the perspective of nuclear liability, the Chernobyl accident acted as a major catalyst for widening the geographical scope of the international nuclear liability regime. The adoption of the 'Joint Protocol relating to the Application of the Vienna Convention and the Paris Convention' in 1988 attempted to bridge the distinctive nuclear liability regimes created by the Vienna and Paris Conventions respectively. This was done so that parties to the Paris or Vienna Conventions, as well as the Joint Protocol, could receive the benefits of either liability regime, without being impeded by geographical constraints as the Vienna Convention was primarily followed by Eastern European countries, whereas the Paris Convention was followed by countries in Western Europe. [1]The Joint Protocol therefore created a global regime on nuclear liability.

Recently, the future of the nuclear industry in the global energy mix has been thrust into the limelight following the Fukushima Daiichi nuclear accident which occurred in Japan in March 2011 following a massive tsunami. The accident has resuscitated vigorous debate on the safety of nuclear technology. The widely divergent and sharp responses to the accident have resulted in major public policy opinion shifts, with countries such as Germany, Italy, and Switzerland opting to abandon nuclear power in its entirety, and others opting to continue to make use of the technology, subject to conducting rigorous stress tests and inspections of operating nuclear plants as part of immediate safety reviews [15].

The international nuclear legal regime will however continue to evolve to ensure comprehensive regulations are developed, including compliance with stringent safety standards, by all persons engaged in activities related to fissionable materials and ionizing radiation. This will serve to ensure that individuals, property and the environment are adequately protected from the adverse effects of nuclear technology use.

III. THE STATUS OF LAW AND POLICY ON THE USE OF NUCLEAR ENERGY IN KENYA

A. *Status of Energy Policy*

Sessional Paper No.4 of 2004 currently governs Kenya's energy sector and sets out the country's national policies and strategies for the energy sector in the short to long term. The vision of the energy sector, as stated in this policy, is to promote equitable access to quality energy services at least cost, while protecting the environment [16].

The objective of Sessional Paper No.4 on Energy is therefore to lay out the policy framework upon which cost-effective, affordable, and quality energy services will be provided. The paper recognizes in express terms, that the achievement of socio-economic and environmental transformation goals in the present and in the future is contingent, to a large extent, on the strong performance of the energy sector [16]. Integrated energy planning, which considers relevant energy sources against the consuming sectors, and which further projects future energy demand, and attendant supply, based on least-cost options, is an integral determinant of strong performance.

The overall development objectives of the Government of Kenya are stated as, *inter alia*, accelerated economic growth and rising productivity of all sectors, alleviation of poverty through provision of basic needs, enhanced agricultural production, industrialization, accelerated employment creation and improved rural-urban balance [16]. Moreover, the policy identifies the following challenges that must be constructively addressed in order to meet these development objectives: (i) ensuring security of supply through diversification of sources and mixes in a cost-effective manner; (ii) increasing access to all segments of the population; (iii) promotion of energy efficiency and conservation; and (iv)protecting the environment [16].

The Sessional Paper recognizes nuclear as a potential energy source, but highlights that the challenges associated with its use, including the technical and economic constraints associated with embarking on nuclear power, long lead times for construction of nuclear power plants, and the need to effectively address the environmental, health, and safety issues that are specifically posed by nuclear use [16].

The current Fifth Draft National Energy Policy dated August 17, 2012, which forms the basis of the final national energy policy (that is yet to be released), is based on underlying principles that are similar to those contained in the Sessional Paper. The draft policy similarly aims to provide affordable energy for all Kenyans, and to facilitate the provision of clean, sustainable, reliable and secure energy services at least cost while protecting the environment [17].[2] Moreover, the overall national development objectives of the government remain unchanged. It is noteworthy, that electricity access has shown improvement, up from 15% as at June 2004, to 28.9% as at June 2012 [17], [18][3].

In Kenya, petroleum and electricity sources of energy are the main drivers of the economy. Biomass is used primarily by the rural community. Electricity generation in Kenya has been liberalized with several licensed electric power producers participating in the industry [17]. Currently, the energy sector relies entirely on the importation of all petroleum requirements while electricity generation is predominantly hydro, and supplemented by geothermal and thermal sources [17]. According to the Least Cost Power Development Plan (LCPDP) (2011 – 2031) [19], hydropower

[1] See: http://www.oecd-nea.org/law/joint-protocol.html for a discussion of the impact of the Joint Protocol on the international nuclear liability regime.

[2] *Fifth Draft, National Energy Policy*, 17 August 2012, Ministry of Energy.

[3] O. Ayacko "Kenya's Energy Status: Challenges and Solutions," presented at the IAEA Stakeholder Engagement Workshop, Nairobi, November 5 – 8, 2012.

accounts for 49.7% of current installed capacity. Hydropower has however become increasingly unreliable over time, as a result of erratic rainfall patterns. This undependability has strengthened the government's impetus to diversify Kenya's existing energy sources.

Importantly, however, the draft national energy policy sets out the policies and strategies for the energy sector that are aligned to the Constitution of Kenya (promulgated on 27 August 2010) [20], and are also in congruity with the Kenya Vision 2030 development blueprint, which aims to transform Kenya into a globally competitive, newly industrialized, middle income country.

The realignment of the draft policy with the Constitution of Kenya [20] is significant, as fundamental structural changes were introduced to government operation with particular regard to administrative, resource allocation and service delivery functions [17]. The 'devolved system' of government necessitates a dichotomy of functional operations between the 'national' government on the one hand, and 'county' governments on the other.[4]

In the context of the energy sector, the Constitution of Kenya in part 1 of the Fourth Schedule stipulates that the *National Government* will be responsible for energy policy formulation including electricity and gas reticulation and energy regulation, whereas the *County Governments* will be responsible for planning and development within their jurisdictions [20].

In the context of nuclear energy use, the draft national energy policy (2012) has gone a step further than its soon to be predecessor, unambiguously endorsing the adoption of nuclear energy and proposing short, medium, and long-term plans for the inclusion of nuclear into Kenya's energy mix. These plans include the development of a legal and regulatory framework to govern the safe and peaceful use of nuclear. The first nuclear power plant is expected to be commissioned in 2022 [17]. Nuclear energy is expected to generate 19% of the total installed capacity by 2030, while hydropower is expected to decline to 5% [19].

Insofar as *research and development (R&D) activities* are concerned, the draft national energy policy (2012) proposes to establish a Nuclear Energy Research Centre which shall be responsible for research, development, and demonstration (R D&D) of nuclear technology and applications [17]. Consistent and ongoing programmes for nuclear research are an essential prerequisite for maintaining the safe and efficient operation of nuclear power plants and fuel cycle facilities. These programmes also ensure the creation/development of new, advanced, and innovative nuclear energy systems that continue to improve nuclear safety and security, as well as increase proliferation resistance. [21].[5]

While Kenya has captured nuclear energy in both of its *national* energy policies, the development of a basic *nuclear* energy policy remains critical as the development of national nuclear legislation, as well as the establishment of relevant institutions, is contingent upon it.

B. Status of Kenya's Legislative and Regulatory framework

The development of a national nuclear legal system comprising of legislation establishing an independent regulatory body, supporting regulations, and standards and measures for nuclear safety, is the responsibility of the government and forms the basis of effective protection of people, property and the environment [22].

Kenya has ratified a considerable number of international instruments within the international nuclear regime in the areas of nuclear safety, security, and safeguards. That being said, there remains an urgent need to prioritize the ratification of the following fundamental instruments: The Convention on Early Notification of a Nuclear Accident ('the Early Notification Convention'), the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency ('the Assistance Convention'), the Convention on Nuclear Safety ('the CNS') and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management as recommended by the IAEA's Milestones Approach on the legislative and regulatory framework infrastructure issues respectively [23]. The Milestones Approach sets out certain guidelines that a country may adopt to holistically evaluate its status (level of development) concerning 19 infrastructure issues as it embarks on the development of its nuclear power programme.

Currently, there is no basic national legislation governing the use of nuclear energy. However, the Draft Energy Bill (2012) has made provision for the use of nuclear energy as a source of electricity generation in Kenya. The draft Bill contemplates a separation of the 'promotional role' of government by establishing the Kenya Nuclear Electricity Board (through Legal Notice No.131, contained in a special issue of the Kenya Gazette dated 23 November 2012) as the 'Nuclear Energy Programme Implementing Organization' (NEPIO), from the 'regulatory function' of nuclear energy by proposing to establish an independent regulatory body known as the Kenya Atomic Energy Commission [24].

Kenya's radiation protection framework for conventional radiation sources is contained in the Radiation Protection Act Chapter 243, Laws of Kenya. The Radiation Protection Act establishes the Radiation Protection Board (RPB) which has the mandate to oversee and supervise the use of conventional radiation sources. As part of the fulfilment of its mandate, the RPB has developed the Radiation Protection (Safety) Regulations, 2010 which prescribe use of radiation sources, classify radiation areas, require approval of plans and licensing of radiation facilities, as well as the display of radiation warning signs. According to the Radiation Protection Act, standards of radiation protection include the guidelines established and published by the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), and the World Health Organization (WHO). The RPB however presently lacks sufficient workforce capacity and resources to effectively and efficiently

[4] The distribution of functions between the 2 levels of government is contained in Articles 185(2), 186(1) and 187(2) of the Constitution of Kenya.

[5] OECD-NEA "*Research and Development Needs for Current and Future Energy Systems"* No. 4453 (2003) Organisation for Economic Co-operation and Development- Nuclear Energy Agency.

handle the regulation of nuclear energy for electricity generation.

The Environment Management and Coordination Act No. 8 of 1999 (EMCA) provides for the establishment of the National Environmental Management Authority (NEMA) as the principal agency of government in the implementation of all policies relating to environmental management. The Authority is also tasked with the duty to carry out inspections where there are radioactive materials or any source of ionizing radiation. The EMCA criminalizes importation, processing, mining, exportation, possession, transport, use, or disposal of radioactive materials or other source of dangerous ionizing radiation without a licence that has been validly issued by the Authority.

IV. DEVELOPMENT OF EFFECTIVE REGULATION OF NUCLEAR ENERGY TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

A. What is meant by 'effective regulation'?

It is apt to begin this discussion by an exposition of what is meant by an 'effective (nuclear) regulator' before discussing the relationship between effective regulation and sustainable development.

At the outset, it must be remembered that the epicenter of nuclear regulation is ensuring that nuclear installations (nuclear power plants and associated nuclear facilities) are operated and maintained in a way that (significantly) minimizes any actual and perceived adverse effects on public health and safety to levels that are as low as reasonably practicable [25].[6] Possession of requisite authority and resources are indispensible prerequisites for the achievement of this mandate.

In order to achieve the broad regulatory objective highlighted in the preceding paragraph, a nuclear regulator must operate both *'efficiently'* and *'effectively.'* The Organization for Economic Co-operation and Development's Nuclear Energy Agency (OECD-NEA), while taking into account the definition of 'regulatory effectiveness' postulated by the IAEA, has developed a slightly expanded generic conception of what constitutes an 'effective' regulator. A nuclear regulator is considered effective when it satisfies the following conditions [25]:

- (i) Ensures that an acceptable level of safety is being maintained by the regulated operating organizations (that is, the organizations running the nuclear power plants);
- (ii) *Develops and maintains an adequate level of competence*;
- (iii) Takes appropriate actions to prevent degradation of safety and to promote safety improvements;
- (iv) Performs its regulatory functions in a timely and cost-effective manner as well as in a manner that ensures the confidence of operating organizations, the general public, and the government; and
- (v) Strives for continuous improvement in its performance.

At the same time, a distinction has to been drawn between 'regulatory effectiveness' which means doing the *right work*, and 'regulatory efficiency', which means doing the *work right* [25]. By necessary implication, this distinction results in separate but interrelated functional bases for a nuclear regulator. Regulatory effectiveness is based on the 'mission objectives' of the regulatory body which have to be analyzed in the first instance, before measures can actually be taken to ascertain that the regulatory functions are being performed in the right way.

Having determined that regulatory functions should be executed effectively and efficiently, an appropriate *'regulatory model'* must be developed in order to provide a mechanism through which regulatory effectiveness and efficiency can be measured [25]. It has been suggested that instructive 'performance indicators' for regulatory effectiveness are two tiered: *'direct performance indicators'*, which attempt to measure the *regulator's own activities and tend to use data that is generated within the regulatory body itself; and 'indirect performance indicators', which principally rely on the performance indicators of other stakeholders, mainly the licensees (operators of nuclear power plants) to determine the performance of the regulator.*

This model would consider the mission objectives of the regulator, as well as identify all the core (and support) processes, resources, and competencies that may be required in order to achieve the mission objectives; and the means of assessing the outcomes in relation to the accomplishment of the mission objectives (such as audit, self-assessments, external assessments and relevant indicators) [25]. The regulatory functions therefore provide a means of 'quality assurance' for the regulator, assisting it to identify the necessary improvements to procedures, and monitor compliance by members of staff [25].

A critical function of a nuclear regulator is to engage and communicate in an open and transparent manner with stakeholders – that is those with a *legitimate* stake or interest in the activities of the nuclear regulator. Examples of these stakeholders would include the general public (and its elected representatives) who require constant reassurance that nuclear activities will be handled with the utmost care to ensure that the probability of a severe accident is very small; nuclear licensees (operating organizations); government departments which have to be provided with unbiased, independent, and technically sound advice about the safety of licensed nuclear installations; and other national agencies and bodies involved with nuclear power [25].

As different expectations emanate from each stakeholder in relation to the perceived roles of the regulator, it is imperative for a nuclear regulator to carefully analyze its position in relation the each type of stakeholder above. Mismanaged expectations have the potential to severely diminish a regulator's effectiveness and efficiency.

In summary therefore, in order to guarantee nuclear safety to the highest extent possible, a nuclear regulator must operate both effectively and efficiently. In parallel to this, the regulator must operate on the basis of a well -planned

[6] OECD-NEA, "*Improving Nuclear Regulatory Effectiveness"*, (2001) Organisation for Economic Co-operation and Development-Nuclear Energy Agency.

regulatory model that considers mission objectives, core and support processes, and incorporates appropriate performance indicators to measure effectiveness and efficiency. Such a regulatory model ought to be adequately anchored on a strong legislative and policy framework not prone to political interference.

B. *What does sustainable development mean, and how is it affected by effective regulation of nuclear technology?*

The World Commission on Environment and Development was tasked by the United Nations General Assembly with a number of goals, including proposing long-term environmental strategies for achieving sustainable development by the year 2000 and beyond, while taking into account the interrelationships between people, resources, environment and development [26].

The deliberations of the Commission resulted in what is commonly known as the 'Brundtland Report' which classically defined sustainable development in the following terms: 'humanity has the ability to make development sustainable to *ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*.' [26].

One of the distinguishing characteristics of sustainable development is its versatility – that is its ability to change, according to prevailing social, environmental, and technological conditions. Social conditions would include regulatory systems, and from an energy perspective, incorporate effective and efficient nuclear regulatory systems as they have been described above. Sustainable development cannot, therefore, be fully implemented in the absence of communication and co-ordination among all relevant policy areas spanning all government levels. In the Kenyan context, these government levels are the national and county government levels.

Current technologies for supplying energy have increasingly been viewed as being *unsustainable* either because supplies may be exhausted, or technologies in use produce greenhouse gases, which result in global warming, and attendant climate change, which is harmful to the environment [27]. Nuclear technology is therefore a sustainable energy source, to the extent that it is able to produce vast amounts of heat and electricity without emitting virtually any carbon-dioxide into the atmosphere.

There are 'three pillars' of sustainable development that have commonly been identified [27]:

(i) *Economic pillar*: the ability to provide reliable, low-cost electricity is an important aspect of sustainable development. Once a nuclear power plant is built, the electricity generated is often cheaper than many other generating methods because the plants have a long life, and the ongoing operating and maintenance costs are low [27].

(ii) *Environmental pillar*: nuclear power emits virtually no greenhouse gases. This means that rapid expansion of nuclear power has the potential to significantly reduce the quantities of carbon dioxide that are emitted into the atmosphere, which in turn has a positive effect on the environment as global warming is greatly reduced [27]. At the same time, rapid expansion of nuclear power would result in an increase of nuclear waste generation (spent fuel from the nuclear reactors). From an environmental sustainability viewpoint, it would therefore be necessary to ensure that radioactive waste is properly and safely disposed of [27].

(iii) *Social pillar*: making a concerted effort to increase technical and intellectual initiatives in nuclear technology provides several ancillary benefits in sectors such as medicine, manufacturing, public health, and agriculture, which in turn results in positive economic benefits for society at large [27].

Against this background, can nuclear energy help make development sustainable?

The answer to this question is that nuclear energy, through effective regulation that takes into account the economic, environmental, and social pillars of sustainability, can result in sustainable development. The overriding, incontrovertible benefit of an effective and efficient regulatory system is its ability to support the development of technologies that ensure energy security (such as nuclear technology that is able to supply base load power) which promotes human development, while remaining ecologically friendly (nuclear power emits no greenhouse gases) – the very essence of sustainable development as it is defined in the Brundtland Report.

Finally, effective and efficient regulation of energy technology (including nuclear technology) has the ability to *link* sustainable development with the achievement of the Millennium Development Goals (MDGs). The *Millennium Declaration* was adopted by the United Nations in 2000 and sets out shared targets for, *inter alia*, drastically reducing poverty (which is partly achieved through energy security), and engendering environmental sustainability by 2015 [28].[7]

C. *What is the role of engineers in the development of nuclear regulation for sustainable use of nuclear technology?*

Engineers play a vital role in ensuring nuclear safety. First, engineering codes and standards developed by various national and international engineering and scientific societies represent consensus in design, construction, operation, and quality assurance practices and often become part of regulatory requirements if endorsed by the national regulatory authority. These codes and standards include Nuclear Quality Assurance Standards and may relate to materials, design and construction, in-service testing and in-service inspection of nuclear facilities among others and have the benefits of improved efficiency, transparency, high quality requirements, credibility, improved standardization, predictability and the benefit of regulatory certainty. Standards and codes, unlike legislation, have greater ability to evolve with time, experience and technological development, as well as adapt to

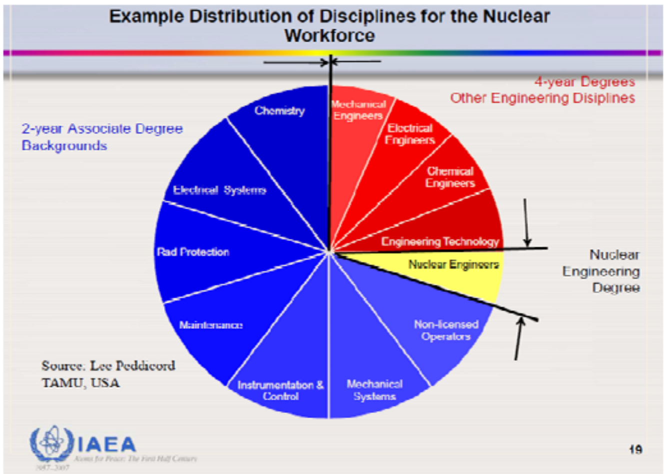
[7] *"OECD Contribution to the United Nations Commission on Sustainable Development 15: Energy for Sustainable Development"* (2007) Organisation for Economic Cooperation and Development. Available at: http://www.oecd.org/redirect/dataoecd/6/8/38509686.pdf.

include lessons learnt from nuclear incidents. Observation of set standards and specifications contribute to the overall safety of a nuclear power facility. It should be noted that engineers form the majority of the required workforce for nuclear energy development as indicated in Table 1 and Figure 1. Therefore, their participation in the development of safety regulations (including regulations concerning reactor and technology design), as well as research and development (R&D) activities must be unwaveringly encouraged [29].

TABLE 1
ESTIMATED MANPOWER REQUIREMENTS AT THE PEAK DURING NPP PROJECT CONSTRUCTION AND COMMISSIONING [30]

	Scientists	Engineers	Technologists	Technic	Total
Pre-Project Activities	1	27	2		30
Project Management	16	69	15		100
Manpower Classification activity	25	185	160		370
procurement	8	12	10		30
Quality Assurance/control	8	32	60		100
Manufacturing (Equipment & components)	90	210	600	2100	3000
Plant Construction	10	210	600	2270	2700
Plant commissioning	10	40	50	100	200
Operation & Maintenance	25	25	140	30	220
Nuclear Fuel Cycle	5	35	70	30	140
Nuclear Licensing	45	5			50
Total	**243**	**720**	**1447**	**4530**	**6940**

Source: Akira Omoto (2008)



Source: Lee Peddicord, TAMU, USA
Fig. 1 Distribution of disciplines for nuclear workforce [29]

V. RECOMMENDATIONS

It is clear from the foregoing, that law and policy provide the 'enabling framework', akin to an operational manual, for the energy sector in broad terms. Narrowing this general proposition down to nuclear energy use, the policies provide guidelines that provide guidance for those institutions mandated to implement prescribed measures for the development of nuclear power. These guidelines are accompanied by timeframes which take into account the protractile (long-term) nature of nuclear power programmes and provide a basis of performance evaluation with regard to achieving short, medium, and long-term plans.

Regarding R&D activities, it is recommended that the following considerations ought to be taken cognizance of:

(i) Kenya should seek to develop a research policy dealing specifically with nuclear energy technology. This policy would derive its legitimacy from the primary and overarching draft national energy policy (2012), and reflect the values that underpin it.

(ii) In order to enable nuclear power to play a concrete role in meeting Kenya's future energy requirements in a sustainable manner, it is imperative to identify R&D needs and to ensure that there is *adequate expertise and resources (financial and human)* to meet them. This has been explicitly recognized in the 'short-term agenda (2013-2017)' Action Plan in the draft national energy policy, 2012, which affirms that the government is committed to undertaking comprehensive human resource/human capacity building programmes in nuclear energy. These capacity building programmes ought to be structured in a manner that meets the short-term (immediate), intermediate, and long-term needs for the nuclear industry, so that a consistent flow of competent labour is available to the greatest extent possible.

(iii) From a *financial* perspective, it is clear that the effectiveness of any R&D activities is heavily contingent upon the availability of adequate funding. The nuclear national research policy should be flexible and include a number of funding options/structures that encourage partnerships between players in both *public* and *private sectors* at local and international levels respectively.

(iv) The possibility of *decentralizing* R&D activities from the national level (in the Kenyan context, the proposed Nuclear Energy Research Centre in the draft national energy policy, 2012) should be considered. Such a measure would entail for example, permitting certain types of R&D activities to be performed by or supported by companies in the nuclear industry, including electricity utilities.

(v) The national nuclear research policy should emphasize the importance of, and create opportunities for *international technology collaboration* initiatives between Kenya and countries with nuclear power programmes (ranging from newly embarking countries, to those with established and rapidly expanding nuclear power programmes). These technology collaboration initiatives would provide several benefits such as promoting information exchange and deliberation on common areas of interest (including creating greater exposure to new, emerging ideas); provide a platform for harnessing necessary financial support; and build technical capacity.

In conclusion, R&D activities in the national nuclear research policy should be carefully prioritized in order to avoid duplication of effort [16], and leverage whatever resources that are available in the most optimal manner.

VI. Conclusion

Kenya has recognized the potential benefits of adopting nuclear power and has taken the policy decision to include it as an energy option in its national energy policy. This decision has been taken against a background of exponentially increasing energy demand arising from accelerated socio-economic growth on the one hand, and concomitant dwindling supplies of energy on the other. The combined effect of this mismatch in demand versus supply has resulted in high costs of energy domestically and industrially.

The national energy policy serves the core function of providing the enabling framework for the optimal exploitation of nuclear energy, setting out goals and action points over the short, medium, and long-term. Commendably, the policy has recognized the important role that research and development (R&D) activities play in promoting the emergence of innovative technologies across the energy sector as a whole, including renewable energy sources.

This paper has proposed, *inter alia*, that a research policy focusing exclusively on R&D activities in the nuclear field should be established. This policy would focus on nuclear energy, but ultimately take into account the overriding public policy objectives that drive the primary national energy policy, namely, energy security and energy efficiency. In addition, the research policy ought to create a framework that provides for flexible financing options that involve public and private sector players, as well as utility companies that are involved in the nuclear industry. The resultant nuclear research programme must comprise of a technically competent team of scientists and engineers in the nuclear field, with knowledge in the three cardinal areas of nuclear safety, security, and safeguards (non-proliferation).

This paper has affirmed that nuclear energy can indeed make development sustainable from an energy perspective. This sustainability can be achieved through the establishment of robust regulatory (nuclear) energy models, which possess the hybrid character of 'regulatory effectiveness' and 'regulatory efficiency', coupled with suitable performance indicators that allow regulatory effectiveness to be measured as accurately as possible. Active government involvement and co-ordination between national and county levels of government, including relevant institutions at both levels, and with all stakeholders is mandatory if an integrated sustainable development approach towards energy is to be achieved.

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