THE ROLE OF NUCLEAR ENERGY FOR POWER GENERATION IN KENYA'S ENERGY MIX

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Abstract: Kenya's Vision 2030 aspires to have double digit growth rates and attain middle income country status by 2030. On 30 September 2014, however, Kenya effectively joined the ranks of middle income countries, sixteen years ahead of schedule. As the country achieves the middle income status, it faces an enormous task of meeting her energy needs due to high expectations in economic and social growth.

Lack of adequate and reliable supply of energy reduces the potential for achieving major structural changes in rural and urban economies. Energy plays a critical role in the socioeconomic development of a country and there is a close correlation between economic growth and quality of life, on one hand and demand for energy, on the other.

Kenya has shown commitment in including nuclear power in the electricity generation mix as advised by the National Economic and Social Council. According to International Atomic Energy Agency, a country embarking on nuclear power programme should follow specific laid down guidelines which Kenya is keenly following.

In this paper, the role of nuclear energy for power generation in Kenya's energy mix based on Kenya's vision 2030, Least Cost Power Development Plan and Green House gas emission control is presented. The status and benefits foreseen of Kenya's nuclear power programme are also discussed.

Keywords: Nuclear, Energy

I. INTRODUCTION

Access to energy is regarded as the basic requirement for economic growth. Due to global industrial, technological, economic and population growth, energy demand is increasing every day and every country is struggling to meet up with this ever-growing demand for energy. 1.6 billion People have no access to electricity whatsoever [1]. 2.4 billion People still burn wood and manure as their major source of energy [2]. In many places throughout the world, electricity only occurs for a few hours a day, even in cities of 10 million people. If we are to give these people a good life that only access to energy provides, we should first think about how we give it to ourselves. As at April 2015, Kenya had an installed electricity generation capacity of 2,250 MW comprising of; geothermal 41.9%, hydro 35.8%, thermal (Diesel) 20.1% , Imports 1%, TPP's 0.7% wind 0.3%, cogeneration 0.2% and Gas Turbine 0.1%) [2] as shown in figure 1.

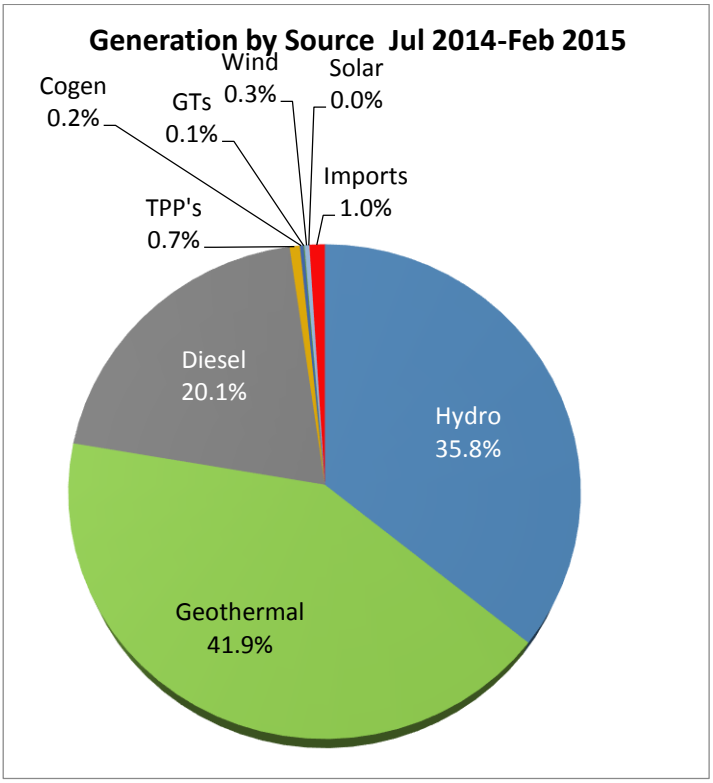

Figure 1. Electricity Installed capacity in Kenya as at April 2015

Kenya generates electricity from 3 major sources – Geothermal hydroelectric and Thermal (diesel). Thermal power stations uses fossil sources, which will be used up in the future and the complexities with carbon emission even though Kenya have discovered oil. With energy demand rapidly increasing, the Government have to find alternative means and consider diversification of the national grid to support current and future sources of energy. Provision of clean, affordable and reliable power is a requirement for the realization of Kenya's Vision 2030 Development Blueprint. In this regard, the Least Cost Power Development Plan ('LCPDP') factored nuclear power as a component in Kenya's energy mix in the future. The LCPDP 2013 – 2033 envisions that Kenya's electricity peak demand will increase from the current 1,520 MW (Dec 2014) to 21, 075 MW by 2033 [3] as shown in figure 2; where nuclear power will

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generate 4,000MW [3].

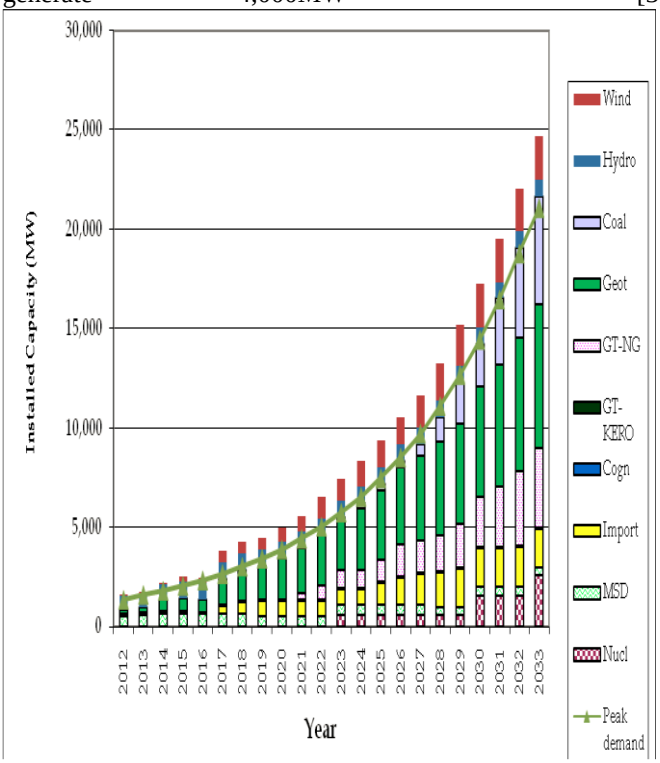

Figure 2. Forecast Kenya's electricity peak demand

In December 2010, The Government of Kenya (GoK) established The Nuclear Electricity Project Committee ('NEPC'), comprising of 13 members vide number Gazette No. 14188 of November 2010. Its core mandate is to fast track development of nuclear electricity in order to enhance the production of affordable and reliable electricity generation. The membership is drawn from nuclear stakeholder institutions. NEPC has since been transformed into the Kenya Nuclear Electricity Board vide gazette No. 131, supplement 156 of 23rd November, 2012.

In addition, Kenya's Ministry of Energy and Petroleum has proposed the use of nuclear energy for electricity generation in the Draft National Energy Policy 2015 and National Energy Bill 2015.

II. KENYAS' ENERGY STRATEGY.

National energy strategy is needed to maintain competitiveness in the national energy sector. The strategy aims at ensuring energy security and independence from exterior factors that may affect or influence the energy production in Kenya. Energy security is an important aspect of ensuring stable electricity supply.

To ensure energy security, Kenya must strive towards energy independence and take control of national power supply. Efficient, reliable and low-prices energy sources that have less dependence on other countries need to be found, as energy independence will provide competitive and affordable electricity prices that can enhance the nation's economy[4].

Kenya is also committed to finding the solution to the global warming issues. The Kenya's energy sector accounts for 38% of its CO2 emission [5]; serious consideration must be taken in the choice of future energy option in order to meet the above target.

Looking at the current energy situation, there are a number of challenges and weaknesses that affect energy supply in Kenya. These challenges are: low access to modern energy leading to high pressure on biomass resources, high cost of energy, demand of electricity is increasing faster than ability to install additional generation capacity, inability by Kenya Power and Lighting Company (KPLC) to connect all customers who are willing to take supply, high cost of rural electrification through grid extension due to the scattered nature of settlements; frequent power outages and high system losses, high dependence on imported petroleum fuels, the reserve capacity can't last for a considerable days for other measures to be taken, among others. This, therefore, calls for concerted efforts by the government and all stakeholders to address these challenges to ensure an adequate and cost effective supply of energy for economic growth and improvement of quality of life of the citizens, while taking cognizance of the need to protect and conserve the environment.

It is estimated that in Kenya 77% people do not have electricity connections [4]. Over 85 % of the population relies on traditional fuels such as wood, charcoal, dung, and agricultural residues for cooking and heating. Many urban and rural poor are not reached by grid-based electrical power nor is there adequate distribution of gas or other cooking and heating fuels. To address the above factors, the Ministry of Energy and Petroleum in September 2013 launched the road map for the 5000+ MW program for transforming Kenya. Through this initiative, in addition to scaling up power generation, focus will be on reducing the cost of power by over 40% in electricity for industrial and domestic customers, translating to the increased competitiveness for our economy.

III. KENYA'S ENERGY OUTLOOK AND RESOURCES

Kenya is endowed with vast natural energy resources. The following gives brief descriptions of the current and future sources of energy in Kenya as outlined by the LCPDP 2013-2033 report (MoE&P, 2013):

a) Hydro potential

Kenya has a considerable hydropower potential estimated in the range of 3000-6000 MW. Currently over 750MW is exploited, mainly in large installations owned by the national power generation utility, Kenya Electricity Generating Company (KenGen). The existing hydropower plants contribute about 38.5% of national annual electricity generation. Power generated from hydroelectric is vulnerable to large variations in rainfall and climate change which has proved to be a big challenge in the recent past with the failure of long rains that resulted in power and energy shortfalls.

b) Geothermal resources

Geothermal activities in Kenya are concentrated in the East African Rift which is associated with the worldwide rift system and is still active. Over fourteen geothermal prospects have been identified in Kenya. The Government through the Ministry of Energy and Petroleum, Geothermal Development Company (GDC), KenGen and other partners has undertaken detailed surface studies of some of the most promising geothermal

prospects in the country. Evaluation of these data sets suggest that 7,000MWe to 10,000MWe can be generated from the high temperature resource areas in Kenya in over fourteen sites.

c) Biomass

Wood fuel and other biomass account for about 68% of the total primary energy consumption. The potential for biomass power production from more decentralized resources (e.g. maize, rice husks, and coffee residues) is enormous. One study from 2004 assessed available volumes of biomass residues for charcoal production in Kenya and analyzed the attractiveness of the resource potential from the standpoint of quantity, degree of centralization, clarity of ownership, seasonal variations and competing uses. Saw dust and coffee husks were two of the more interesting resources that scored highly in the assessment.

d) Cogeneration

Biomass potential from co-generation projects is variously estimated at 159.2 MW, 193 MWe, 300 MW and 360 MWe, The potential in the sugar sector alone is estimated to be 192.8 Mwe. One major constraint may be a lack of available biomass and security of supply.

e) Biogas

Biogas potential in Kenya has been identified in Municipal waste, sisal and coffee production and in flower and horticultural farms. The total installed electric capacity potential of all sources range from 29-131MW.

f) Solar Energy Resources

Kenya has great potential of solar energy throughout the year because of its strategic location near the equator with 4-6 kWh/m^2/day levels of insolation. This can be harnessed for water heating, and electricity generation and telecommunications facilities in isolated locations.

g) Wind Resources

Of all renewable energy sources, wind power is the most mature in terms of commercial development. The development costs have decreased dramatically in recent years. Potential for development is huge, and the world's capacity is far larger than the world's total energy consumption. Worldwide, total capacities of about 60,000MW have been installed, with a yearly production of about 100 TWh.

The best wind sites in Kenya are Marsabit District, Samburu, parts of Laikipia, Meru north, Nyeri and Nyandarua and Ngong hills. Other areas of interest are Lamu, off shore Malindi, Loitokitok at the foot of Kilimanjaro and Narok plateau. On average the country has an area of close to 90,000 square kilometers with very excellent wind speeds of 6m/s and above.

(h) Power Imports and Exports

This will be made possible by way of Regional Interconnections. The regional interconnections are progressively evolving with the expected planned transmissions lines linking regional countries likely to be implemented under the Eastern Africa Power Pool (EAPP) the Nile Basin Initiative and the Nile Equatorial Lakes Subsidiary Action Programme. These lines include Kenya- Isinya-Tanzania (Arusha) 400kV line, second Kenya (Lessos)-Uganda (Jinja) 220kV line, Kenya-Ethiopia 500kV DC line and a 132kV cross-border electrification line to Moyale town from Ethiopia.

With the regional interconnections, export of electricity generated from Nuclear Power in Kenya is a possibility which will result in economic benefits for both Kenya and the Eastern African Region.

(i) Fossil fuels

1. Local coal reserves

The Government is currently undertaking coal exploration activities in Mui basin that traverses Kitui and Mwingi districts, about 200km from Nairobi to the Eastern side of the country. The basin is about 500 square kilometers in size divided into Zombe, Kabati, Itiko, Mutitu, Yoonye, Kateiko, Isekele and Karunga sub-basins. The MOE&P has so far drilled 40 appraisal wells in the basin intercepting coal seams of up to 16 meters in 27 of the wells. Plans to generate electricity from coal is at an advanced stage. 960Mw of power generated from coal will be injected in the grid by 2017. By 2030 3,000MW of electricity will be generated from coal [6]

2. Imports of coal

Kenya imports an average of 3.6 million tonnes of coal annually for use mainly in manufacturing industries [7]. Coal can also be used as a substitute for more expensive oil in generation of electric power and also supplement hydro-generated electricity shortfalls whenever there is a prolonged drought.

3. Imports of petroleum products

Currently about 20.9% of the country's electricity installed capacity is petro-thermal based which requires a lot of imported petroleum products since Kenya doesn't have any oil of its own. In the recent past the value of imported petroleum products has been on the decline due to reduced prices as a result of reduced international demand.

4. Local Oil Reserves

Kenya has been carrying out various oil exploration activities in the recent past and made a breakthrough in the year 2012, when the exploration firm, Tullow oil made a discovery in Ngamia-1, Turkana County. The exploration firm stated that the tests carried out on the first flow proved that there is huge potential of commercial oil production. It is however expected that commercial exploitation of oil will take time before benefits are reaped. Moreover, environmental issues as regards the use of oil for electricity production is a subject of discussion. Even with 100% exploitation of the domestic energy resources, especially geothermal, which is estimated at between 7,000 and 10,000MW, the country will still need alternative sources to realize Vision 2030.

IV. NUCLEAR TECHNOLOGY FOR POWER GENERATION IN THE ENERGY MIX.

Nuclear technology development is not just a driving force to economic growth. It is also a means to economic development. Nuclear energy is the most reliable and clean source of energy for any emerging economy under current scenario [6], Kenya being one of them. Although there are other safer and cleaner options like wind and solar but the capacity factor and availability challenges makes the later options less practical on a large scale. Nuclear reactors can provide safe baseload power on a large scale while taking the dependence away from oil and gas. It also does not have the intermittency problem that plagues most of the frontline renewable energy technologies we know of.

As Kenya is introducing nuclear technology for power generation it will follow an International Atomic Energy Agency guideline known as the Milestone approach [7] as

shown in figure 3. The Milestones approach breaks the planning process into three phases, and at the end of each phase is a milestone to be achieved.

Essentially, the first phase is about the decision to commit a country to a nuclear power programme. It's about assessing all the nuances, obligations, constraints and opportunities that a country should take into account prior to making such a decision.

In the 2nd Phase, that decision has now been made, and this phase is about all the things that need to be done to prepare for building a nuclear power plant. Actually, Phase 2 is defined to end a bit before that point; specifically its Milestone is to have prepared everything to the point of being ready to invite bids to build the first nuclear power plant.

In Phase 3, you evaluate the bids, choose one and build the plant. Its end, its Milestone, is when you're ready to actually start commissioning and operation.

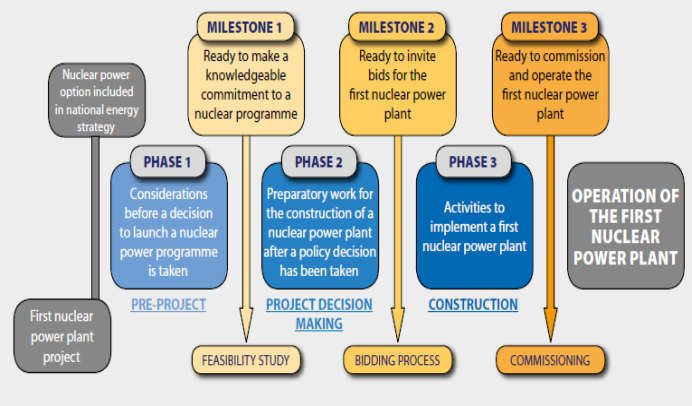

Figure 3 Milestone Approach in Introducing Nuclear power Programme.

Besides the technological aspect, nuclear energy will also offer Kenya the independence and the energy security that is essential for the economic and political stability of the country. The recent protest in Nigeria is an unfortunate example of how volatility of fuel price could lead to a major political breakdown and subsequently affect the economic growth of the country. Nuclear power could alleviate that volatility.

Energy security would also allow Kenya to be more sovereign in its decision making. Developing countries like Bangladesh quiet often has to make the very unpopular decision to raise fuel price (by cutting down subsidy) at the request of IMF who holds the key to most forms of aid provided to developing countries. Removing dependence on fossil fuel would remove Bangladesh from such obligations set by IMF.

Since the first industrialization process started in the 1960s, the Korean economy had been transforming at a more rapid rate than any other country in the world had ever experienced. The Republic of Korea embarked on a series of 5-year economic development plans pursuing what amounts to a classic pattern of economic development. Industrialization initially focused on light industries such as food, beverage and textiles, moving next to chemicals and metal products, and then to intermediate goods such as equipment and machinery. The focus was first on export-oriented mass production, taking advantage of Korea's abundant cheap labor and taking into account the scarcity of capital and of resources.

By the early 1970's, the trend of industrialization had shifted to heavy industries. Imports of capital and technology were especially crucial for the development of the heavy and chemical industries, notably metallurgy (iron and steel especially), shipbuilding (and later automobiles), and construction. In contrast to the early years, the Government had increasing access to private capital markets, facilitating both technology imports and investment, and a highly skilled labour force. The heavy industries were a driving force for national economic development, which helped in broadening the industrial base and essentially restructuring the economy. By 1973, the real per capita income had more than doubled the levels of that in the mid-1960s as the result of the increasing share of manufacturing to around 25% of the country's GDP.

The 1980s saw a period of adjustment in government policies and an industrial shift to more service and high-tech industries. By 1995 exports had risen to about one third of the GDP. The Korean economy grew by more than 8.7% per annum in real terms in this period. The Korean economy suffered from the Asian economic crisis in 1997 but resumed growth in 1999. In the 2000's, the Korean economy grew at the average rate of 5.2%. During the economic development period, the demand for energy grew rapidly. It is noteworthy that throughout this period, electricity demand always grew faster than economic growth.

Korean energy policy has quite consistently focused on supplying energy in order to fuel rapid industrialization and strong economic growth. This growth was driven by the expansion of energy-intensive industries in the 1980s and 1990s, which were fostered by concentrated development policies and resulting in a very higher national average standard of living.

All of this was done with limited indigenous coal and hydro energy resources, and hence before the advent of the nuclear power industry, Korea needed to import 97% of its energy. 80% of electricity generation was dominated by imported crude oil, creating severe economic problems as oil and energy prices rose in the 1970s. Faced with the need for further increases of increasingly expensive fuel imports to supply its rapidly growing industrial, transportation, and electricity sectors, the government opted to diversify its energy sources by focusing on nuclear power as a more technology-oriented, rather than a resource-oriented way, to reduce reliance on imported energy. The energy and electricity intensive intermediate and heavy industries provided a ready market and a rationale for domestic nuclear power that would permit their continued competitive output and growth without dramatically increasing energy imports. In reality, the development of the nuclear industry created domestic markets for equipment, the metallurgical and construction industries, electronics, and the business service sectors including finance and insurance, which in effect created a significant inter-sectoral symbiosis.

The electricity sector thus provided more than just electricity to the fledgling industrial sector. "The earliest and largest modernization projects in post-war South Korea were power plants. Large domestic conglomerates were selected to construct, engineer and manage huge coal, oil and nuclear power plants"

Between 1960 and 1987, Korea built 20.6 GW of new generation capacity (14.8 GW of fossil-fuelled plants and 5.8

GW of nuclear plants). Construction of these plants and the gradual increase in domestic contribution helped in establishing and expanding the industrial base of the economy. Conversely, "South Korea's spectacular economic growth was, in part, based on a formula of doubling electricity capacity every ten years"

Nuclear technology in the Republic of Korea has been an integral part of the country's socio-economic development over the past decades, and its evolution from an importer to an exporter of nuclear plants and nuclear technologies provides spin-offs to technological innovation as well as to the environmental benefits in terms of avoiding Green House Gases GHG and other pollution in the context of achieving sustainable development.

Nuclear technology was chosen to diversify the energy supply in response to the economic development setbacks resulting from the oil crises of the 1970's and 1980's. A strong commitment by the government to develop a nuclear power programme received impetus from three main factors: lack of domestic energy resources, favourable world nuclear markets in the 1980's, and having an active and concerted government cooperating with a dedicated nuclear work force.

Korea's commitment to nuclear power and its need for initial imports of nuclear technology were greatly aided by the depression of the world nuclear industry in the 1980's, which was the result of the collapse in international oil prices in the mid 1980's and the growing excess generating capacity of the Organisation for Economic Co-operation and Development (OECD) countries due to the delayed impact of efficiency improvements and economic restructuring prompted by the oil price hikes of the 1970s. These changes were also based on the public's reaction to the Three Mile Island and Chernobyl accidents which occurred on March 28, 1979 and April 26, 1986 respectively and the resulting growth of the anti-nuclear-movement. And the most recently nuclear accident at Fukushima Japan on March 11, 2011

Strong government commitment was essential first to foster and then to marshal Korea's well- educated human resources to successfully implement the national nuclear technology self-reliance programme. The Korean nuclear scientists and engineers that were engaged in overseas nuclear power programmes were attracted back to Korea to play key roles in the localization of nuclear power technology development and the enhancement of direct national participation into nuclear power projects.

National participation in a project generally means the use of locally produced material and domestic manpower resources without downgrading the quality and safety aspects of the project nor jeopardizing the schedule of project execution. Meaningful national participation in a nuclear power and plant construction industry requires the existence of a capable construction industry, and medium and heavy manufacturing, including cement, steel, machinery and equipment and chemicals. This also requires competency in other services such as civil engineering, quality assurance and control and testing, and specialized manpower training including managerial skills. The active production history of nuclear energy development started in 1978 when the Kori-1 nuclear power plant, built on a turn-key basis, first began commercial operation. It was an imported reactor with imported service and support, with little participation from the domestic industries and limited use of local labour or construction materials (for on-site non-specialized purposes). In 1985, the government started implementing an incremental national self-reliance policy and began allocating some responsibilities to local organizations. At first these responsibilities were limited to civil engineering and design, construction, and plant engineering, manufacturing some equipment and non-critical components for plant balance, and managing projects. With the construction of the Yonggwang 3 and 4 NPPs in 1989, domestic nuclear industries became the prime project contractors with only limited technological support and technology transfer from foreign subcontractors. Equally important, local manufacturers extended their normal product lines to incorporate nuclear designs and standards, and special factories were set up locally to manufacture heavy and specialized nuclear components.

Korea has rapidly accumulated extensive experience in nuclear sector development and planning and nuclear power plant construction and operation. Over the past three decades, Korea has become one of the world's leading nuclear power countries, with 20 Nuclear Power Plants (NPPs) in commercial operation in 2005, with a total net generating capacity of nearly 17.5 GW, supplying approximately 18% of Korea's total primary energy and more than 40% of the nation's electricity.

Korea is already exporting reactor components, and is now also in a position to supply plants for export. Korea has already developed the Korean Standard Nuclear Reactor (KNSP), a PWR that is being used in Ulchin-3, - 4, -5 and -6, and Yonggwang-5 and -6. They are also constructing a Korean Advanced Pressurized Reactor (APR 1 400) for Shin-kori 3 and 4, and the Optimized Power Reactor 1 000 (OPR 1 000). Korea may therefore well be a strong competitor in the vendors and plant suppliers market in the near future. Based on domestic technology and more than twenty years of experience in the construction and operation of nuclear power plants, the Korean nuclear industry is in fact actively developing an overseas nuclear power business aimed at supplying engineering and technical services, components, construction services, or even the complete building of a KSNP. The overseas engineering and technical services will cover the plant life cycle including project planning, project management, equipment procurement, commissioning and start-up, operation and maintenance, as well as replacing major equipment, such as steam generators.

IV. Conclusion

The need for alternative source energy in Kenya is prudent. The need to secure Kenya's future energy security is real considering the projected electricity demand by 2030 Vis a Vis the energy resources available. Considering nuclear will be one of the best ways of curtailing any future challenges that might threaten the country's developing economy. Nuclear as a source of energy has its own advantages, so it should be judge with open minds not autocratically.

Kenya has recognized the potential benefits of adopting nuclear power and has taken the policy decision to include it as a technology 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.

This paper has shown that considering nuclear option not only assures future energy security, but also helps Kenya in various ways such as economy, production and social development. The nuclear fuel cost is stable and the production cost is comparable to the present rate, so electricity will remain affordable for Kenyan citizens.

Steady, reliable, and cheaper nuclear energy will help to improve the various sectors. For example, improved production and industrial sector from adequate electricity will provide more job opportunity, upgrade product quality, and hence boosts the economy to a higher level.

Nuclear power also contributes in preserving environment and biodiversity since its land requirement is smaller area compared to solar and wind energy. Thus, preserving land for future development and the valuable natural resources in the area are protected.

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REFERENCES

[1] BP p.l.c., BP Statistical Review of World Energy, London, United Kingdom, June 2011

[2] Power to the People – an ITDG position paper on sustainable energy solutions for the world's poor, available from www.itdg.org

[3] "Least Cost Power Development Plan" (LCPDP), 2011 – 2031, Ministry of Energy.

[4] "Study on Kenya's energy demand, supply and policy strategy for households, small scale industries, and service establishments. Final Report." Nairobi: Ministry of Energy Kamfor (2002),

[5] Developing countries, monitoring and reporting on greenhouse gas emissions,policies and measures, EU 2010

[6] Nuclear Power Plant for sustainable Energy Development for Bangladesh, Int. J. Solar Energy, pp. 56-65 Akram, S. (2006).

[7] Milestones in the development of a national infrastructure for nuclear power. — Vienna : International Atomic Energy Agency, 2007.